New Frontiers in Historical Ecology

CLIMATIC AND ECOLOGICAL CHANGE IN THE AMERICAS

A PERSPECTIVE FROM HISTORICAL ECOLOGY

Edited by
James Andrew Whitaker,
Chelsey Geralda Armstrong, and
Guillaume Odonne

ROUTLEDGE

Climatic and Ecological Change in the Americas

This book offers a comparative analysis of the experiences, responses, and adaptations of people to climate variability and environmental change across the Americas. It foregrounds historical ecology as a structural framework for understanding the climate change crisis throughout the region and throughout time. In recent years, Indigenous and local populations in particular have experienced climate change effects such as altered weather patterns, seasonal irregularities, flooding and drought, and difficulties relating to subsistence practices. Understanding and dealing with these challenges has drawn on peoples' longstanding experience with climate variability and in some cases includes models of mitigation and responses that are millennia old. With contributions from specialists across the Americas, this volume will be of interest to scholars from fields including anthropology, archaeology, geography, environmental studies, and Indigenous studies.

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New Frontiers in Historical Ecology
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Dynamic new research in the genuinely interdisciplinary field of historical ecology is flourishing in restoration and landscape ecology, geography, forestry and range management, park design, biology, cultural anthropology, and anthropological archaeology. Historical ecology corrects the flaws of previous ecosystems and disequilibrium paradigms by constructing transdisciplinary histories of landscapes and regions that recognize the significance of human activity and the power of all forms of knowledge. The preferred theoretical approach of younger scholars in many social and natural science disciplines, historical ecology is also being put into practice around the world by such organizations as UNESCO. This series fosters the next generation of scholars offering a sophisticated grasp of human-environmental interrelationships. The series editors invite proposals for cutting-edge books that break new ground in theory or in the practical application of the historical ecology paradigm to contemporary problems.

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Contents

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Foreword

Now and then a book of contributed chapters appears that genuinely proffers new data as well as novel theoretical constructs that are cross-referenced under a single research umbrella or program. This is one of those books. It represents a clarion call to a new generation of environmental anthropologists, wildlife ecologists, conservation biologists, and – what many of the writers herein self-identify as – historical ecologists. The diverse background, training, and specialization of the three editors (social anthropology, anthropological archaeology, and ethnopharmacology) bespeak to me the very interdisciplinary roots of the research program known as historical ecology. My coeditor of this book series, Carole Crumley, and I have identified numerous new applications of historical ecology on almost every possible landscape on earth based on a literature review not yet published. The research program has expanded hugely since about the beginning of this century, and it is a daunting task for any one scholar to keep up with everything that is coming out, and in a broad array of publication venues and languages at that.

The volume here is clearly focused on a little known yet tremendously significant applied subject matter, namely traditional ecological knowledge and its perspective and analysis of climate change, both of local and global sorts. I am honored to be able to contribute a few words at the beginning and to endorse, in light of its importance, this work, for – to my way of thinking – it potentiates moving the sciences of the environment (and of humans) forward, more deeply into the 21st century, with its currently attendant, increasingly obvious, anthropogenic climate crisis. I am impressed with several new terms and concepts associated with these sciences – all useful to historical ecology – in the various chapters of this volume (creative landscape, relational models, replacement theory, coercive conservation, domesticated landscape, and food sovereignty – particularly of traditional societies in environments not yet completely altered by primary landscape transformation of the ruinous kind). A few points seem central to this volume and fuse it together in terms of historical ecology and its potential applications. First, the volume abandons certain shibboleths about humans and the environment that have persisted in *coercive* *conservation* (as noted above, a term aptly coined in the Introduction). There are at least two of these: (1) people are always adverse in some way both to local and global environments and their biota (à la the Gaia hypothesis, for example) and (2) the only way to promote environmental diversity, stability, and health is to disentangle humans from their environments, if these environments are speciose or in some other way deemed valuable, or to proscribe and prevent people – even those from traditional societies not associated with environmental destruction – from occupying such environments if found to be unoccupied. The writers show that human agency can be constructive of environments – the matter is clearly contingent on socioeconomic, cultural, and historical conditions, well presented in these chapters. Second, there is an ancillary canard that needs to be noted: that only Western science can solve, if ever, the crises being unleashed by anthropogenic climate change on every conceivable landscape. This book shows in splendid fashion the diversity of traditional local and global knowledge systems concerning climate and the environment in all the Americas, an original and herein well-justified juxtaposition of a geographic and regional sort. The volume before us marks an advance in knowledge because the authors and editors instantiate in their well-researched chapters a historical–ecological conjuncture between what is local and what is global, and how to navigate the similarities and differences of climate change between them.

William Balée
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Introduction

James Andrew Whitaker, Chelsey Geralda Armstrong, and Guillaume Odonne

Climate change and related anthropogenic influences are increasingly apparent worldwide, as reflected by mounting scientific evidence and peoples' local experiences. The effects of Earth's changing climate are being experienced at unprecedented scales and across varying landscapes and bioregions. These impacts include acute shifts and changes in local food production and global supply chains, escalating disaster and mitigation efforts, and increased emergency health concerns. While climate change is a global phenomenon, the 2022 IPCC assessment report has underscored the importance of understanding and mitigating regional impacts, adaptations, and vulnerabilities. Included in the report, and noted elsewhere, are the rippling impacts of climate change on peoples' lived experiences, livelihoods, and homelands, which are most apparent at local scales (Batterbury 2008; Wolverton et al. 2014).

In the last two decades, there has been increased attention on Indigenous and local populations whose livelihoods and subsistence practices are closely tied to their landscapes. People are often keenly aware of local effects from climate change, such as altered weather patterns, seasonal irregularities, melting glaciers, flooding and drought, and other challenges that impact their communities and livelihoods. Climate change impacts are also exacerbated in communities where excessive resource extraction and colonial legacies have increased vulnerability to punctuated changes (Douglass and Cooper 2020). Despite this, Indigenous and local peoples disproportionately manage some of the most biologically diverse and intact landscapes on earth (Garnett et al. 2018; Fa et al. 2020). Responses to climate change challenges have drawn on longstanding (e.g., centennial and millennial) experiences with climatic variability, shifts in fluctuating social–ecological relations, and responses to ecological imperialism and colonization (Adamson et al. 2018; Kaptijn 2018). Such strategies include intensive land-based monitoring (Salick and Ross 2009), continued implementation of traditional ecological knowledge and management systems (Gómez-Baggethun et al. 2013; Pearce et al. 2015), carbon-negative livelihoods (Walker et al. 2020), and the co-production of knowledge with climate scientists (Riseth et al. 2011; Reyes-Garcia et al. 2019).

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The relationships between people and their inhabited landscapes are formative and ripe for interdisciplinary research in relation to climatic and ecological changes through time. Historical ecology is especially well-positioned to provide a practical and theoretical framework for understanding long-term social–ecological patterns and processes in the context of our current climate crises (Balée 1998, 2006, 2013; Balée and Erickson 2006; Crumley 1994, 2017, 2018, 2021; Crumley et al. 2017; Odonne and Molino 2021). For example, across South, Central, and North America, historical ecologists have shown how societies have altered local environments to produce "cultural forests" (Armstrong 2021; Armstrong et al. 2021; Balée 2013; see Crumley 2017, 2021) and "domesticated landscapes" (Erickson 2006). Through applied practices of landscape transformation, (e.g., raised fields, earthworks, midden engineering, plant translocations, and Amazonian Dark Earths), environmental challenges have been addressed over centuries and even millennia (Balée 2010; Crumley et al. 2017; Graham 2006; Rostain 2008a, 2010).

Anthropologists and archaeologists, working within a historical–ecological framework have assessed climate variability, climate change, and related impacts by centering their research on human–landscape interactions over explicit and controlled timespans (Rick and Sandweiss 2020; Stephens et al. 2019). Concepts of resilience and sustainability are inherently temporal in their application and assessment. However, temporal scales, which affect observations and analyses, are sometimes insufficiently considered or poorly implemented in climate change research (Lane 2015). As such, we seek to demonstrate the generative intersection of localized and Indigenous knowledge and historical–ecological timescales as a means to better understanding and working towards climate change mitigation efforts. With contributions from specialists throughout the Americas, this edited volume will comparatively examine experiences and responses to climate change and related environmental changes across South, Central, and North America. We foreground historical ecology as a primary framework for understanding human engagements with climate change through time and analyze how the global crisis is experienced and dealt with in localized contexts.

Historical Ecology, Climate Change, and Indigenous Knowledge

Over forty percent of the globe is considered vulnerable to climate change impacts and the sixth IPCC assessment report suggests that global-scale technological and bioengineering solutions will not be sufficient to address the climate crisis. Thus, strategies that include culturally-relevant mitigation to reduce vulnerability will be increasingly important in coming years. Anthropologists and archaeologists are uniquely situated to this task (Crumley 2021). Although not initially forthcoming, leading to the criticism that anthropologists were "*fiddling while the globe warms*" (Rayner 1989), anthropological engagements with climate change have increased in pace and volume during the last two decades. Anthropologists have now produced numerous books and edited volumes (Baer and Singer 2018; Barnes and Dove 2015; Crate and Nuttall 2009; Crate and Nuttall 2016; Strauss and Orlove 2003; Welch-Devine et al. 2020), special issues in peer reviewed journals (Lahsen 2010; McCarthy et al. 2014; Magistro and Roncoli 2001; Salick and Ross 2009; Pisor and Jones 2021), and broad literature reviews (Brown 1999; Crate 2011; Jorgenson et al. 2019) concerning climate change. Archaeologists have also contributed important volumes on ancient human land-use and impacts to changing environments (Braje et al. 2021; Chambers 2012; Dawson et al. 2017; Isendahl and Stump 2019; Redman 1999; Stump 2010). These contributions have come from around the world and have zeroed in on integral connections between long-term changes in weather patterns and ecological events, like flooding and drought, as they relate to more traditional anthropological concerns, such as social and cultural practices and Indigenous and local knowledge (Batterbury 2008).

Previous contributions have been geographically and topically wide-ranging. For example, in two groundbreaking edited volumes which remain foundational to the anthropology of climate change, Crate and Nuttall (2009, 2016) present chapter-length ethnographic engagements with climate change topics ranging from the Andes (Bolin 2009; Paerregaard 2016), to the Arctic (Henshaw 2009, 2016), to South Asia (Finan 2009; Finan and Rahman 2016), to Oceania (Jacka 2009, 2016). More recently, research has focused on how local perceptions and knowledge of climatic and ecological changes emerge and become embedded within peoples' everyday lives (Sillitoe 2021; Welch-Devine et al. 2020). Despite a growing literature on climate change, anthropological interventions into the climate crisis have struggled to link the global with the local and have had difficulty articulating a theoretical framework capable of providing a broad comparative scope. As a result, some researchers have called for a more integrative approach with the goal of coordinating scalability between place-based and localized climate change research, on the one hand, with globally-focused climate change research and policy agendas, on the other (Reyes-Garcia et al. 2019).

Although anthropology is critically situated to connect local experiences of climate change with larger-scale processes and changes (Crumley 1994; Whitaker 2020a; Wolverton et al. 2014), many edited compilations on climate change have perhaps – at least until recently (see Crumley 2017) – prematurely reached for a global scale of comparison at the expense of mid-level regional accounts. As Crumley et al. (2017: 1) write, climate change and related contemporary crises *"require attention, both locally, where global changes impact communities, and globally, where local practices influence global change."* Without the latter, fine-grained climate ethnographies often become disjointed from their globally oriented theoretical frameworks. However, the global emphasis has come at a cost to the local "on the ground" perspectives that constitute anthropology's primary and best contribution to climate change research. In other words, there is often a disconnection between the high-resolution localized documentation of experiences, perspectives, and challenges of people concerning contemporary climatic and ecological change, and the global comparative scale within which they are theoretically positioned. For example, in these contexts, Indigenous knowledge and practices, for example, traditional ecological knowledge and traditional environmental and resource management, are sometimes extracted for outsiders' goals without benefiting the communities sharing that knowledge (McAlvay et al. 2021). Uncritically scaled-up research often results in Indigenous and local peoples' knowledge being removed from the contexts within which it successfully operates, e.g., at a landscape-scale. Johnson (2010) calls these rudimentary studies "TEK bites": the fragmentary pieces of knowledge removed from peoples' lived realities, governance structures, and other social institutions in which such knowledge is both situated and successful (see also Berkes 2012).

While calls to include "people" as important agents of climatic and environmental change and mitigation have raised the profile of research in the field of evolutionary and biological anthropology (Pisor and Jones 2021), as well as human behavioral ecology, these tend to deemphasize local scale understandings and ontologies of the landscape in favor of adaptationist models. Throughout this volume, we acknowledge peoples' ability to adapt to environmental change, but we focus on human understandings, ontologies, and practices as important mediating and transformative factors that influence sustainability and resilience. We critically interrogate the adaptationist approach for understanding human–environment interactions, while focusing on ongoing relationships between people, biota, and biophysical processes, where human agency and action are essential to the structure of the landscape (Balée 2006; Armstrong et al. 2019). Both biophysical and anthropogenic processes are necessary to our understandings of the landscape (see Szabó 2015). While past forms of cultural ecology emphasized peoples' adaptation to the environment in a fixed context, historical ecology emphasizes diachronic interpretations of landscape change and the ways that landscapes have been transformed and modified by humans (Crumley et al. 2017; Rostain 2008a, 2008b, 2010).

The chapters in this volume bridge the theoretical and cross-cultural challenges faced by many research engagements with climate change by focusing on historical ecology as a research programme capable of articulating diverse ecological and ontological domains through the central concept and scale of the *landscape*. Although archaeologists and ethnographers have made recent progress in this area (see Oba 2016), localized understandings of climate change (as the 2022 IPCC assessment report outlines) and localized scales of study seems to have had limited engagement with historical ecology as a central framework (but see McIntosh et al. 2000). This volume aims to address this lack of engagement.

Although the challenge of climate change is global, regional comparisons provide a productive scale and avoid the seeming incommensurability of cultural and ecological variables at a global scale. A geographical focus on "regions" has also been comparatively emphasized by historical ecologists (Crumley et al. 2017). By emphasizing a nested regional scale within settler states in the Americas, rather than a global one, we aim to balance the local and global scales for comparative and applied analyses.

Despite the growing literature on climate change, ethnographic engagements with local experiences remains geographically uneven. For example, Kawa (2016: 23) has written of an "*overlooked anthropos*" in relation to climate change and the broader Anthropocene in Amazonia, which has received less attention from climate change ethnographers than might be expected considering the critical role of the Amazon rainforest in absorbing and sequestering atmospheric greenhouse gasses (Baer and Singer 2014; Brondizio and Moran 2008; Whitaker 2020a). Similarly, temperate rain forests in western North America are under severe threats from logging, catastrophic wildfires, and other climate change impacts (Price et al. 2020), but there is limited research on the role of Indigenous peoples in shaping the structure and productivity of biologically diverse forested landscapes (Deur and Turner 2005; Turner 2014; Armstrong et al. 2021). Historical–ecological research that highlights Indigenous land-use and landscape management as a cornerstone of climate change mitigation has not previously overlapped in the literature spanning North, Central, and South America. This volume addresses the gap and provides a broad comparative scope of applicable research across these regions.

Historical ecology's emphasis on human–landscape dynamics ameliorates one of the main comparative challenges of anthropological research on climate change. The challenge is that different societies have diverse ideas and ontologies concerning concepts such as "weather," "climate," "stewardship," and "change," which do not always fit into Western languages and conceptual frameworks (Rosengren 2018, 2021; Whitaker 2020a; see Byg and Salick 2009: 163; Rudiak-Gould 2014; Schnegg et al. 2021), making geographically wide-ranging accounts difficult to compare (see also Reyes-Garcia 2019). With historical ecology, such differences are highlighted using a landscape-scale approach which is then featured in the broader contexts of peoples' social–ecological interactions, practices, and knowledge. The comparative framework and scalar approach of historical ecology facilitates an enhanced understanding of peoples' unique responses to real-life threats and challenges stemming from climate change (Armstrong et al. 2017; Crumley et al. 2017). By focusing on people's historical relationships with their local landscapes, historical ecology does more than broaden research engagements with peoples' responses to climatic and ecological vulnerabilities. It also engages with changing landscapes, applications of Indigenous and local knowledge (Crumley 2017), and questions about the continuity or discontinuity of "nature" and "culture" that perdure at the very heart of interdisciplinary research enquiries (Balée 1998, 2006).

Chapter Themes

This edited volume brings together anthropological and archaeological perspectives that broaden our understanding of change across both recent and deep-time cultural landscapes. In the first three chapters, archaeology and paleoecology are mobilized to understand sociocultural and demographic shifts at a broad scale over millennia. Stéphen Rostain and Jonas Gregorio da Souza examine the influence of pre-Columbian climate change in Lowland South America through a historical–ecological lens. They reposition the relationship between climate and people, focusing on sociocultural variables, such as demography, mobility, and settlement patterns, spanning thousands of years and across continental-scales. The second chapter by Anabel Ford investigates Maya forest gardens using novel methodological approaches to critically scrutinize the consilience of ethnographic, archaeological, and paleoecological records in Central America. In the third chapter, Torben Rick, Gabriel Sanchez, and Shannon Tushingham highlight the value of a historical–ecological framework for evaluating thousands of years of human–environment interactions across coastal California. With an emphasis on environmental change and the increasing need to meet the challenges of severe drought and wildfires faced by Californians today, the authors offer an enlightened perspective on preparing for future climate instability while promoting equity and social justice.

The following chapters examine long-term human–environment interactions that have resulted in complex biocultural landscapes, and which are currently targeted as pathways toward mitigating climate change. Chapters 4 and 5 engage with smaller scale human–landscape interactions while examining landscape management by Indigenous peoples in the Americas over thousands of years of documented climate variability and environmental change. Natalie Mueller examines paleoecological data and shows how Indigenous peoples in eastern North America have resisted ecological changes in prairies and pyrophytic forests, which include many of the valuable resources that underpin longstanding cultural traditions. The fifth chapter, by Christopher Roos, Thomas Swetnam, and Christopher Guiterman, shows how generations of Ancestral Pueblo and Apache peoples have managed conifer forests throughout the American Southwest, improving fire resilience in their lived landscape. The result of these millennial-scale interactions, particularly in local pine forests, has been shown to reduce severe risks from wildfires under current climatic changes.

In the sixth chapter, Ana Ladio and Mauricio Sedrez dos Reis use relational models (RMs) within the context of conserving pewen forests (*Araucaria araucana*), a cultural keystone species for Mapuche people in Argentina and Chile. The authors focus on the cultural and environmental significance of human-pewen forests through time, and their role in promoting food system resilience and conservation. The seventh chapter, by Chelsey Geralda Armstrong, Sara Wickham, and Kalina Hunter, considers the role of Ts'msyen, Haíłzaqv, and Wuikinuxv people in shaping the structure and function of forests across the Pacific Northwest. Specifically, peoples' traditional management of forest garden systems has resulted in an increase in local biodiversity and functional diversity, as well as improvement of overall soil quality in various regions. The authors contemplate the scientific, legal, and applied outcomes of this research, focusing on restoration and reclamation in an uncertain future. Moving from forests into the intertidal, in Chapter 8, Dana Lepofsky and Anne Salomon describe how Indigenous peoples throughout the Pacific Northwest Coast constructed intertidal rock-walled terraces called clam gardens and managed them amidst climatic and ecological changes over millennia. These unique cultural landscapes have been the cornerstone of food sovereignty initiatives for many coastal First Nations, and the authors highlight key aspects of this long-term research program that braids together a novel intersection of scientific and Indigenous knowledge. Isabel Rivera-Collazo focuses on Central America in Chapter 9, where she examines the importance of centering local peoples' perspectives in understanding past climatic crises on islands in the Caribbean. With a focus on palaeoecological, climatic, and archaeological data, she brings forth invaluable lessons for researchers seeking to contribute more critically to climate change research, centering issues of food and habitat security.

The last three chapters emphasize local perspectives and ontologies concerning climate change and responses to environmental change over time in Lowland South America. Chapter 10, by Marquisar Jean-Jacques, Marianne Palisse, Martijn M. van den Bel, Antoine Gardel, and Edward Anthony, provocatively asks, whose "climate change" are we are really talking about anyway? They examine Kali'na understandings of long-term climatic, ecological, and historical changes in the Maroni River to broaden discourses of both "climate" and "change." In Chapter 11, Pirjo Kristiina Virtanen, Álvaro Férnandez-Llamazares, and Francisco Apurinã examine relationships between oral histories and memories in relation to changing landscapes among the Apurinã and Tsimane' peoples of Amazonia. In the twelfth and final chapter, James Andrew Whitaker compares Makushi and Akawaio perceptions and encounters involving weather and climate change in Guyana. He shows how Makushi and Akawaio people today often interpret changing weather and climate variation using recently introduced discourses of "climate change" and how they position these observations within ontologies centered around the historical–ecological landscape.

The Nexus of Global Change And Historical Ecology

The themes, observations, and data examined throughout this volume lie at the cutting edge of historical–ecological research and hold continuing relevance within both academic and applied contexts. Although often without sufficient engagement in existing scholarship, collisions between conservationists, policy makers, and local and Indigenous peoples continue to play out in dramatic and often tragic ways across the Americas. The urgency of climate change can exacerbate these conflicts when perceived through a lens which continues to separate "nature" and people. Historical ecology can help to clarify issues of legal, ethical, and scientific inquiry by making relevant Indigenous and local land-use histories and ecologies.

Our collective studies in North, Central, and South America illustrate the significance of historical ecology for probing and better understanding how people transform their landscapes through local knowledge, ontological frameworks, and practices. As demonstrated throughout this volume, these aspects of historical ecology often bely modern conservation approaches and neo-colonial practices, which continue to reproduce outdated views on ecological and technological supremacy in the face of climate change.

Current conservation projects in Lowland South America often aim to separate Indigenous peoples from their local territories based on the demonstrably false premise that peoples' environmental impacts are inherently detrimental to terrestrial, marine, and riverine landscapes (see Balée 1998, 2006). Such "coercive conservation" measures sometimes involve removing local people from their land base or restricting local use and subsistence practices (Peluso 1993). For example, the Iwokrama International Centre in Guyana reportedly restricts hunting, fishing, and farming in traditional Makushi territories (Whitaker 2020a, 2020b). In yet other regional scenarios, hydroelectric and similar large-scale projects aim or result in the dislocation of local peoples from their landscapes. Some governmental policies have led to a radical shift in Indigenous peoples' practices. For example, in French Guiana, Indigenous peoples have been encouraged to settle into perennial villages, but are now restricted from following their traditionally mobile and semi-sedentary way of life, leading to egregious conflicts over land rights. In the Pacific Northwest, where Indigenous peoples have never ceded rights and title to their territories, conflicts over intensive resource extraction continue to operate under the assumption that people simply do not "use" their lands sufficiently (Daly 2005; Martindale and Armstrong 2019). This has led to concerted research efforts involving clam gardens, forest gardens, orchards, and other traditional land-use practices, which may help communities assert sovereignty to their lands and waterways, resulting in more locally-relevant climate change mitigation strategies.

Despite scholarly research and the assertion of local and Indigenous peoples, the separation of "nature" and people persists in legal, commercial, and nonprofit contexts. Historical–ecological scholarship has provided scholarly and legal language that shows what Indigenous peoples have always known: that the management of local landscapes – intentionally, sustainably, and flexibly – has mitigated, buffered, and imparted valuable lessons in relation to long-term and short-term ecological variability and climate change. Although recognition of local and Indigenous peoples has been more apparent in matters of conservation and biodiversity, they are often tokenized or only valued when tested against Western science (Tormos-Aponte 2021). As a result, many peoples' longstanding sustainable and resilient practices, in relation to climatic, ecological, geomorphological, and broader global changes, have yet to be fully integrated into the design and implementation of climate change action and research. With a view to local Indigenous knowledge, ontologies, and practices over explicit temporal scales, this volume shows that understanding the past is an important and just strategy to building a better future.

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1 “Open the Floodgates of Heaven”

Amazonian Climate Change in Pre-Columbian Times

Stéphen Rostain and Jonas Gregorio da Souza

“After The Rain Has Fallen”

Climate change has fundamental consequences for societies that are sometimes beneficial and in other cases detrimental. For instance, it is likely that regional and continental scale climate variability has caused huge migratory movements resulting in profound transformations within Amazonian societies around 1100 AD (Iriarte et al. 2017). Similarly, some researchers assert the increases in temperature in the Andes could have favored the emergence of the Inca Empire (Chepstow-Lusty et al. 2009). More to the north, increasing evidence suggests repetitive droughts played a role in the Classic Maya collapse between 660 and 1000 AD (Kennett et al. 2012). Whether through adaptation, expatriation, or disappearance, societies have reacted and modified their behaviors according to shifts in climate and other natural phenomena.

In Amazonia, evidence of various instances of climate change and variability during the second millennium (700–1300 AD, depending on the region) evinces a period of widespread reorganization and population movements, for which climate may have played a prominent role. Recently, scholars have proposed that some Amazonian societies prospered during these periods of climatic variation while others were more negatively impacted (Souza et al. 2019). Moving beyond explanations of change and towards a more nuanced understanding of vulnerability and management, we explore in this chapter to what extent different types of pre-Columbian societies confronted environmental stress and evaluate the archaeological record to better assess societies’ resilience.

“Come Rain or Come Shine”

Climatic conditions have been relatively stable in the Amazonian lowlands since the end of the last glacial maximum, with minor increases in temperature and precipitation (Whitney & Mayle 2012; Flantua et al. 2016). The Amazon River extends approximately 6,800 km, with 17 tributaries longer than 1,500 km each and three rivers more than 3,000 km long. Across diverse

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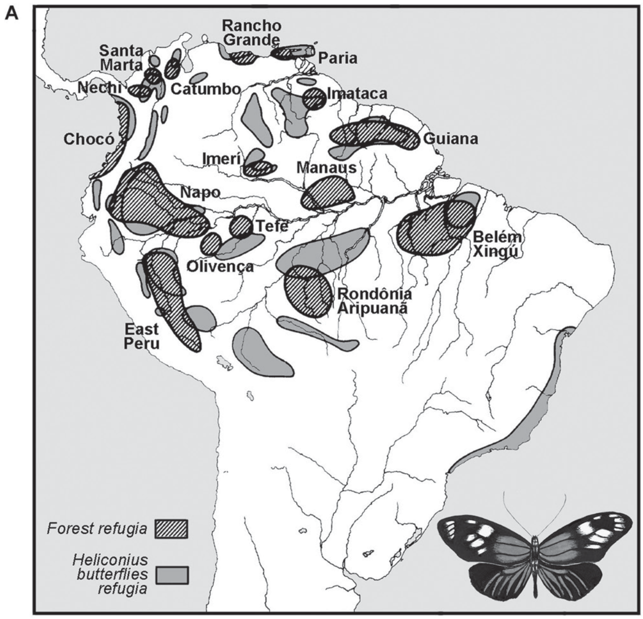
environments and microclimates, there is a tremendous amount of rainfall and temperature variability throughout the Amazon basin. While most of the Amazon Basin receives an average of 1,500–3,000 mm/y, with a maximum of 12,000 mm, the equatorial northwestern and the Amazon River estuary receives even higher rainfall. The most rainfall occurs along the Andean foothill region up to c. 1,500 m altitude. Conversely, the driest conditions found farther south of the Amazon Basin receive 1,500 mm/y (Goulding et al. 2003). Annual and daily temperature variability is relatively similar throughout Amazonia. Mean annual temperatures range from 18 to 23°C. Although Amazonia regularly suffers from excess water with spectacular floods, the droughts have the most calamitous and lasting consequences on inhabitants. Since the 1970s, archaeologists and other scientists have considered ancient climatic oscillations as a factor in cultural changes during the prehistory of Amazonia (Meggers 1979).

For example, Meggers outlined a significant turnover in naturally occurring vegetation in South America lowlands between about 18000 and 13000 years BP. The detection of broad climatic variations in the Quaternary Period is typically based on the distribution and diversity of flora and fauna, which is often considered a proxy for periods of aridity. The theory of forest refugia and fauna suggests that such proxies correlate to dry transition episodes, which have been subsequently applied to archaeological and anthropological research (see Figure 1.1A–B).

For example, attempts have been made to correlate these Amazonian refugia with the distribution of two linguistic families: speakers of Tupi-Guaranian and Arawakan (Meggers 1979).

Fifteen years later, Meggers (1994) extended her study by analyzing cultural and historical chronologies throughout Amazonia. Many of these sequences indicated discontinuities corresponding to climate-shifting events like mega-Niño, as further highlighted by archaeological data from the northern coast of Peru. Changes in cultural historical models were tested against pollen data, charcoal and soil analyses, and changes in water levels, indicating intermittent episodes of aridity in the neotropical lowlands since 2000 years BP. Similarly, episodes of aridity have been documented using regional pollen data where forests were replaced by savannahs from eastern Colombia (van der Hammen 1974, 1991) to the Lower Magdalena valley in western Colombia (Wijmstra 1967) and in central Marajo Island in Brazil (Absy 1985). Cultural changes (as evidenced by settlement patterns and marked linguistic fragmentations) appear to correlate with these episodic shifts, dating to 1500, 1000, 700, and 400 years BP (Meggers 1994).

The El Niño–Southern Oscillation (ENSO) is a climatic phenomenon that influences much of the climatic variability in South America. Although ENSO events are a natural occurrence, they are a driver of regional weather patterns (e.g., spurring dry conditions). Given the evidence that climate variability associated with ENSO had recognizable impacts on local communities



B Location	Evidences	Chronology BP	Reference
Middle Caquetá (Western Amazon)	Drought	11500-4700	Behling *et al*. 1999
Middle Caquetá (Western Amazon)	Increase in precipitations	3000	Berrío 2002
Loma Linda (Eastern Colombia)	Increase in precipitations	3600	Behling & Hooghiemstra 2000
Porto Velho–Humaitá transect (Southwest Amazon)	Drought	9000-3000	Freitas *et al*. 2001
Beni River, Bolivia (Southwest Amazon)	Expansion of the forest	2000	Burbridge *et al*. 2004
Titicaca Lake	Increase in humidity	2000	Baker *et al*. 2001
BR 174 Road, Manaos (Central Amazon)	Drought	7700-3000	Piperno & Becker 1996
Caxiuaná (Eastern Amazon)	Increase in precipitations	2700	Behling & Lima da Costa 2000
Caeté Estuary (Eastern Amazon)	No mangrove vegetation	5900-2800	Souza Filho *et al*. 2009
Estuary (Eastern Amazon)	General reduction in mangrove species	5600-3600	Behling 2002
Estuary (Eastern Amazon)	Reduced discharge of the Amazon River	8000-5000	Behling 2002
Amazonian alluvial plain	Resumption of sedimentation in the Amazonian alluvial plain	1710	Toledo & Bush 2008

Figure 1.1A–B Part A: Refugia map in Amazonia reconstructed from the modern distributions of plants and *Heliconius* butterflies suggesting biogeographical probability for fragmentation of the humid forest several times during the Quaternary Period (redrawn from Prance 1973: fig. 24; Brown et al. 1974: fig. 3; Meggers 1979: fig. 1; water painting butterfly, Rostain). Part B: Compilation of some paleoecological studies that indicate climatic changes that occurred during the Middle Holocene in the Amazon Basin (redrawn from Neves 2007: tabl. 1).

in Ecuador and Peru, we expect similar patterns to materialize in Amazonia. During El Niño, precipitation decreases significantly in the northeast of the Amazon Basin, which causes a notable decrease in the flow and discharge of water in this region, while the opposite is observed during La Niña – as the opposite climate phenomenon – during which precipitation and river flow and discharge increase.

The meteorological consequences are evident during both El Niño and La Niña, when peak rainfall and aridity are reached. The disastrous drought of 2005 left Amazonia bereft of 60% of its usual annual rainfall. Deforestation continued and led to erosional sediment deposits, which (coupled with drought) led to catastrophic impacts – thousands of fish washed up dead along the rivers and hundreds of communities were left isolated and without access to usual infrastructure. Five years later, the same 700,000 km^2 area (twice the size of France) experienced a severe drought on the unhealed ruins of the previous one. The dramatic drying up of the Amazon basin is underway and both anticipated and unanticipated impacts are expected throughout the region, which affect all manner of cultural and environmental resources. Although the current climate crises are exacerbated by human-caused drivers, it can be expected that similar or less severe disasters provoked by mega-Niño events occurred during pre-Columbian times.

"Let It Rain"

Apart from extreme climatic events, researchers have also highlighted past variations in precipitation that may have had a profound impact on the inhabitants of Amazonia. Neves & Furquim (2021) describe some effects of climatic variability during c. 13,000 years of pre-Columbian occupation. The cooling of the northern hemisphere between 8200 and 4200 years BP induced important climatic and ecological changes in South America – notably, cooling events resulted in decreased precipitation and drought in western Amazonia (Baker et al. 2001), a northward shift of the forest/savanna ecotone in the southern bangs (Pessenda et al. 2001), and wetter conditions in eastern Amazonia (Wang et al. 2017). The direct effect was an apparent decline of human populations on the continent until around 6000 BP, when the climate stabilized again (Riris & Arroyo-Kalin 2019).

Did Holocene climate events drive largescale cultural changes? When analyzing the emergence of a true "Neolithic" in the region, Neves (2007) considered the paleoclimatic record as an agent of sudden and simultaneous socio-cultural change in Amazonia (see Figure 1.1B). Specifically, he investigated whether there was a correlation between mid- and late-Holocene climatic variations and the radical shift to a marked sedentary lifestyle, with economies increasingly dependent on large-scale agriculture and intensive management of natural resources. Paleoecological data points to a gradual general increase in humidity and forest expansion beginning in 3500 BP. At the same time, archaeological evidence supports cultural transformations, such as the construction of earthen mounds in the Llanos of Venezuela, the Guiana coast, the island of Marajó, central Amazonia, and southwestern Amazonia; the concomitant development of raised fields and/or specific earthworks (causeways, reservoirs, canals, etc.); and in several cases the creation of extended road networks radiating from large settlements of annular plan in southern Amazonia. Without systematically establishing a causal relationship between climatic and social changes, Neves' objective was to judiciously identify possible correlations between the two phenomena (Neves 2007).

"I Wish It Would Rain Down"

Large-scale climatic changes appear to have influenced the cultural organization of Amazonian linguistic groups during the last millennium (Meggers 1979). These changes are observed to correlate with the drying periods associated with the Medieval Climatic Anomaly (950–700 BP), but the finer-scale data tells a more nuanced story. Recently, Souza et al. (2019) headed a large-scale study bringing together several international specialists to understand climatic and archaeological events during the first half of the second millennia (see Figure 1.2A–B).

Dates from hundreds of archaeological sites were collected and analyzed, reflecting cultural chronologies from seven scattered regions, which were then cross-referenced with paleoclimatic records sampled from six scattered regions of Amazonia. Data on variations in the hydrological cycle come from the sedimentary record at Cariaco Basin near Venezuela (Haug et al. 2001), oxygen isotope records from the Pumacocha Lake sediment core in Peru (Bird et al. 2011), Palestina Cave in the foothills of eastern Peru (Apaéstegui et al. 2014), stalagmites collected in cave systems at Paraíso south of Santarém in eastern Amazonia (Wang et al. 2017), Pau d'Alho cave in the northern portion of the La Plata Basin along the transition zone of the Brazilian Amazon Basin (Novello et al. 2016), and Torotoro caves in the eastern Bolivian Andes (Apaéstegui et al. 2018). In order to succinctly present and analyze this data, the following sections synthesize the main results of de Souza et al.'s findings (see Figure 1.2B).

The Guiana Coast

The pre-Columbian occupation of the Guianas coast has been the subject of various archaeological works that provide a coherent overview of the succession of societies in this coastal fringe (Rostain 2008, 2012; van den Bel 2015). The coastal plain experienced a marked cultural boom around the first half of the first millennium AD. The coastline, southeast of Cayenne Island, then became the territory of the Aristé groups, whose culture related to the Lower Amazon Polychrome tradition. The western coastline was occupied by completely different cultural groups, stemming from the Arauquinoid tradition of the Middle Orinoco. They spread eastward along the coastal

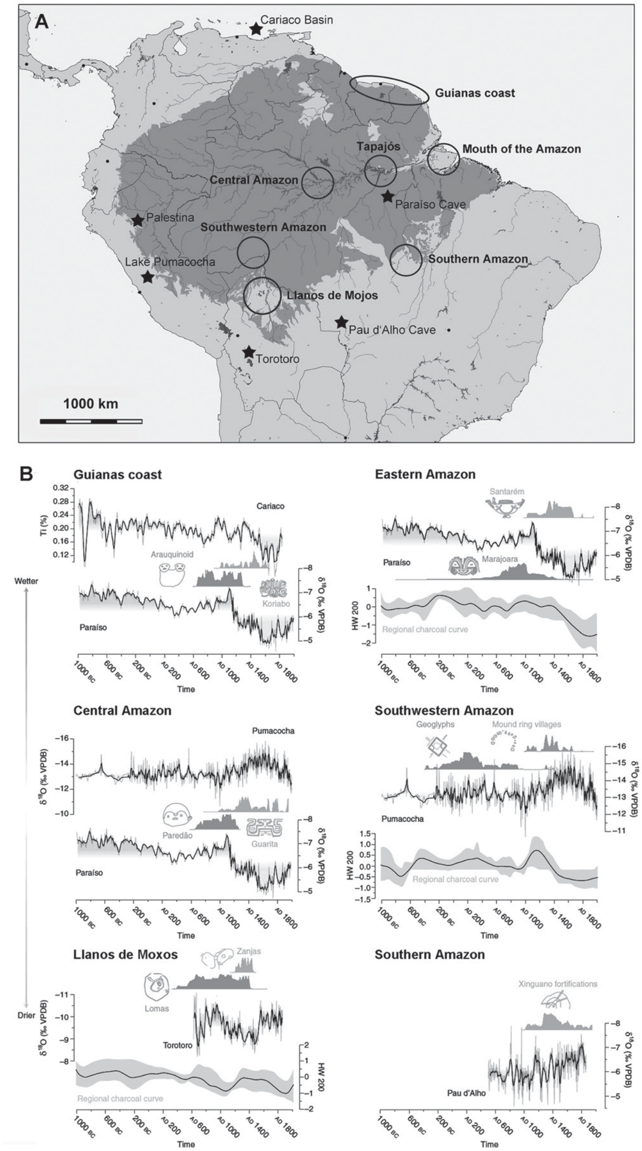


Figure 1.2A–B Part A: Map of the archaeological regions (circles) and paleoecological samples (stars) discussed in the Souza et al. (2019) study (drawing, Rostain). Part B: Periods of cultural change (graphics) and paleoclimate records (curves) for six regions of Amazonia, and regional charcoal curves from the best sampled regions. The duration of each archaeological culture is represented by summed calibrated probability distributions of the radiocarbon dates. The "wetter" and "drier" arrows refer to the interpretation of the paleoprecipitation records (Souza et al. 2019: fig. 3).

fringe of the Guianas from 650 AD. These Arauquinoid groups, which were apparently hierarchical and organized into chiefdoms, are famous for their earthwork structures and marked management of the landscape, including habitat mounds, causeways, dykes, basins, canals, and raised fields (Rostain 2012). Raised agricultural mounds, which vary in size and shape, extend over tens of square kilometers from the Berbice River in Guyana to Cayenne Island in French Guiana (see Figure 1.3A–B).

Analysis of phytoliths, pollen starch grains, and stable isotopes extracted from the raised fields and ceramic cooking plates provided evidence of maize, squash, and cassava cultivation (Iriarte et al. 2010; McKey et al. 2010).

The amalgamation of Arauquinoid groups seems to have dissolved in the 14th century AD. It has been assumed that the cause was the expansion of exogenous communities of Koriabo tradition, which spread from the interior to the coast from the 13th century AD (Rostain 2008). Several coastal archaeological sites show mixed levels of Arauquinoid and Koriabo material, while others indicate a complete replacement of the original Arauquinoid or Aristé materials by the new Koriabo arrivals.

However, beyond the replacement theory, another factor may have impacted the Arauquinoid farmers: Paleoclimatic data from the Cariaco Basin, which lies just west of the Guianas, show prolonged drought conditions around the 14th century AD (Haug et al. 2001). High field cultivation may have been relatively fragile and subject to risks from climatic variations, as water may have been in short supply. Persistent and repeated climatic crises year after year could have had a negative impact on agricultural production and even on the technique of raising fields, which became unsuitable under the new conditions. Being unable to face the circumstances of severe drought, the Arauquinoid societies may have shifted and reorganized around new subsistence strategies and material culture as a result; this was before European colonization.

Mouth of the Amazon (Eastern Amazonia)

The immense island of Marajó (c. 49,000 km^2) at the mouth of the Amazon River has been detailed with one of the first major pre-Columbian cultural chronologies (Meggers & Evans 1957). Around 400 AD, at about the same time as the coastal Guianas, stratified Marajóara culture emerged in the swampy eastern part of the island where inhabitants built large earthen mounds to inhabit and bury their dead (see Figure 1.3B). The largest mounds extended over three hectares and were seven meters high. The sites were composed of several mounds along the river and could house up to 2,000 inhabitants (Roosevelt 1991).

However, the Marajóara people did not move into the floodplain savannahs to cultivate large raised fields like the Arauquinoid groups of the Guianas coast. Maize macro-botanical remains have not been located and isotopic values from human remains found in urn burials indicate a diet based on

Figure 1.3A–B Monumental earthworks were often very sensitive to strong climatic variations, especially floods. Part A: Pre- Columbian raised fields in a flooded savannah west of Cayenne Island, French Guiana. Such agricultural mounds are very sensitive to climatic variations and flooding levels (photography, Rostain). Part B: Artificial earthen mound in the Marajó Island, mouth of the Amazon, Brazil (courtesy of Meggers).

undomesticated C3 plants and aquatic resources (Hermenegildo et al. 2017). The Marajóara diet was based largely on fish, and evidence suggests large water pools constructed at the base of habitat mounds were used to capture fish year-round (Schaan 2004). This targeted subsistence strategy, which relied on local fish populations, may have resulted in increased vulnerability and susceptibility to climatic variations.

The decline of Marajóara populations followed a trend comparable to that of the Arauquinoid. Around 1200 AD, the arrival of more mobile Aruã groups might have arisen as a result of a disorganization of Marajóara chiefdoms. This population shift may reflect impacts from climatic changes, analyzed using speleothems from Paraíso Cave, which is located further west in the lower Amazon (Wang et al. 2017). The height of Marajóara occupation of the island coincides with a time of decreased precipitation. This drought situation led to a decrease in river flow, which likely augmented salinity of the water – corresponding to Marajoara aquaculture (Lara and Cohen 2009).

Mouth of the Tapajós (Eastern Amazonia)

In contrast to the decline of Marajóara, the Santarém culture flourished from 1100 AD, in the vicinity of the present-day city of the same name, at the mouth of the Tapajós. This stratified society adopted a more diversified strategy of agroforestry polyculture and probably *várzea* agriculture. Maize phytoliths were abundant in the Tapajós alluvial plain, which indicate preponderance for maize cultivation (Maezumi et al. 2018).

In contrast to the climate-forcing impacts on the island of Marajó, the drought conditions affecting the Santarém region do not seem to have significantly affected the inhabitants. On the contrary, at the time there was an increase in fire activity concomitant with a demographic boom (Maezumi et al. 2018).

Central Amazonia

In central Amazonia, the meeting of the Negro and Solimões Rivers forms a branch of the Amazon River, whose inhabitants formed a dynamic cultural landscape during the last millennium before European colonization. Large villages of Paredão culture composed of several earthen mounds arranged in a circle around an extended central plaza appeared around 700 AD (Neves 2011), which coincides with the beginning of the great earthworks of the Guianas coast (Rostain 2008). The most remarkable feature of these settlements is the soil structure and composition reflected by *terra preta*, also named Amazonian Dark Earths (ADEs). These fertile anthropogenic soils resulted from intensive and prolonged human activities (Bozarth et al. 2009) and allowed for the development of efficient management of *várzea* (alluvial plain), agricultural fields, and cultural forests.

Despite their stability, the Paredão groups experienced a decline from 1000 AD onwards with the violent invasion of groups of the Guarita culture, which was linked to the Polychrome tradition originating in central-western Amazonia around 750 AD (Almeida and Neves 2014). By 1200 AD, the ring villages of Paredão mounds were all replaced by smaller Guarita settlements, and people re-occupied the ditch- and palisade-protected villages of the Paredão culture (Neves and Petersen 2006).

Unfortunately, paleoclimatic data are lacking in the region and the available cores are too remote to be meaningful. The Lake Pumacocha sample in the Andes, as well as the Paraíso sample in the lower Amazon, however, report a period of marked drought from 1000 AD onwards (Bird et al. 2011), which could corelate with the timing of Guarita migration to central Amazonia.

Southwestern Amazonia

Southwestern Amazonia, straddling Brazil and Bolivia, presents a dynamic cultural landscape which has recently been uncovered by deforestation, revealing hundreds of closed ditches (Pärssinen et al. 2009). Called "geoglyphs," the ditches are round, oval, or square and range from 100 to more than 300 m in diameter (Saunaluoma & Schaan 2012). Archaeological excavations have revealed that the use of these ditches began around 400 BC (Schaan et al. 2012). However, with the near-total absence of domesticated plant remains, some interpretations suggest that the area served ritual functions and thus was used more for occasional gathering places for collective ceremonies.

Archaeobotanical data has shown that the construction of the ditches was not accompanied by large-scale or long-term intensive deforestation, but by occasional spot clearing, a hallmark of agroforestry practices. Interestingly, research suggests that peoples' management of the forests in this region began at least 4,400 years ago and the succession of secondary forest was dominated by palms for millennia (Watling et al. 2017). Peoples' presence in the region appears to decline as geoglyph sites were abandoned approximately 650 BP (Schaan et al. 2012; Watling et al. 2017).

Although ancient villages associated with the geoglyphs have not been found, it is very likely that inhabitants were organized in scattered and loosely stratified groups. Peoples' use and management of palm fruit forests were likely subsidized by maize and squash (Watling et al. 2017). Shortly after 1000 AD, the geoglyph tradition declined and was eventually replaced by villages composed of small earthen mounds (Saunaluoma 2010).

Paleoclimatic data obtained in Peru at Lake Pumacocha (Bird et al. 2011) and the Palestina Cave (Apaéstegui et al. 2014) show a sharp decrease in precipitation over the Andes and western Amazonia during the time of the geoglyph decline. This is followed by a resurgence of precipitation in the following centuries, along with the spread of ringed monticular sites. As in the regions previously presented, the questions obviously arise as to the role of these climatic changes in the population movements that replaced the local groups and habits.

Llanos de Moxos

The vast region of the Llanos de Moxos, over 110,000 km² in area, has been extensively used and modified by pre-Columbian populations (Erickson 2006) through agricultural strategies and complex political organization (Walker 2008). However, the nature and form of the earthworks vary notably from region to region and form distinct clusters (Lombardo et al. 2013). For example, the northwestern llanos is characterized by platform fields near Santa Ana de Yacuma, while the northeastern cluster is composed of three overlapping complexes of ditched fields, ring ditches, and canals, causeways, and fish weirs near Baures. A huge expanse is also marked in the south by canals and causeways. However, the southwest region around San Ignacio de Moxos saw the development of ridged fields, while the southeast near Trinidad is marked by monumental mounds (Lombardo et al. 2013).

The latter sites are composed of large earthen mounds, built from 400 AD, that reach up to 21 m in height and 20 ha in area (Prümers 2017). Stratified groups cultivated and cleared the savanna ecosystems through prescribed burning; in other areas, where drainage was a limiting factor, communities built raised fields and canals (Erickson 2006; Prümers and Jaimes Betancourt 2014). In addition, some communities developed an ingenious fish catching and farming system to overcome dry season shortages (McKey et al. 2016).

These strategies were likely based on a certain climatic regularity, which was stable up to the second millennia AD. From 1200 to 1500 AD, subsistence systems were likely disrupted by excessive climatic events, which were probably responsible for the abandonment of large mounds and the decline of slash-and-burn in the savanna (Whitney et al. 2013). Interestingly, at this time, defensive perimeter ditch sites increased in the northeast (Prümers 2014). Analysis of the speleothem from the Umajalanta-Chiflonkhakha caves in Torotoro Park on the tropical slope of the eastern Bolivian Andes, when compared to various samples from the Andes, confirm climatic shifts associated with increased drought (Apaéstegui et al. 2018). In the absence of archaeological evidence of the arrival of new human groups, the climatic explanation for cultural change is most likely at this time.

Southern Amazonia

The southern Amazonian region of the Upper Xingu also experienced dynamic episodes of cultural change prior to the arrival of Europeans. As in the Llanos de Moxos, the landscape here was extensively modified by the construction of roads and ditches (Heckenberger et al. 2003). Fortified sites were distributed within a hierarchical network and connected by more or less marked paths over a territory of 20,000 km² (Heckenberger et al. 2008).

The largest villages housed up to 2,500 inhabitants on an area of more than 20 ha. Just west of the upper Xingu are ditch enclosures comparable to those in southwestern Amazonia and the Llanos de Moxos (Souza et al. 2018). Evidence suggests an exceptional distribution of peripheral ditched sites, which extends from the southwestern Amazonia through the Bolivian llanos to the southern forest, drawing a crescent moon-shaped territory.

In this latter case, the relevant paleoclimatic data come from the speleothem of the Pau d'Alho cave, which lies between the Plata Basin and the Amazon Basin in Brazil (Novello et al. 2016). However, unlike other Amazonian regions, climate data from 1100 AD in this area shows high variability on a multi-decadal to centennial scale with no marked tendency towards wet or dry. In this case, there is no proven connection between the rise of the dynamic and changing cultural landscape and climate variability and change.

"Rain Over Me"

Souza et al.'s (2019) study considers a wide variety of paired archaeological and climate data, scattered over much of Amazonia. Paralleling the sociocultural history of each case study with the impacts of past climate change convincingly illuminates the fragility or resilience of early inhabitants. This overview allows us to consider coarse-grain models of Amazonian settlement history during a period shortly before the arrival of Europeans. Far from the traditional image of the European conquest breaking a regular and peaceful evolution of the Amazonian populations, several instances reflect heterogenous and changing cultural landscapes. As elsewhere in the Americas, temporal synchronicities between climate and pre-Columbian cultural change have been demonstrated and help to explain abrupt shifts in the cultural chronology of the first half of the second millennium (Souza et al. 2019).

The arrival of the first humans at the end of the Pleistocene coincided with a climatic warming in Amazonia that may have partially impacted the disappearance of the megafauna (Ranzi 2000). Subsequently, climatic fluctuations during the Holocene sometimes had crucial repercussions on demography and human movements. For example, the drier period accompanying the Medieval Climatic Anomaly (950–700 BP) most likely had direct consequences on human settlement (Souza et al. 2019). While some Amazonian cultures flourished, others collapsed or moved.

We can tentatively conclude that populations employing a mixed agricultural strategy based on rotating polyculture agroforestry, the use of Amazonian Dark Earths, and opportunistic cultivation on *várzea* probably survived extreme climatic events relatively easily. Conversely, the pre-Columbian societies that invested in larger-scale agricultural exploitation, which required investments in earthworks, were more sensitive to climatic variability. While earthworks were likely productive in the short term, they may have been more vulnerable over longer periods. There is thus a strong coincidence between the climatic changes that crossed Amazonia from the beginning of the second millennium – dominated in many places by violent droughts – and societal unrest, even profound crises. The environmental stress had different impacts according to the interactions set up by the various socio-economic systems, as well, in part, as the more or less hierarchical political structures. However, it must be remembered that while climate and environment condition populations, they do not determine them.

"Set Fire To The Rain"

In sum, the long pre-Columbian sequence of 13,000 years was interspersed with extreme climatic changes that had dynamic impacts on peoples' settlement and subsistence patterns. Some extreme events observable at the landscape scale (i.e., through archaeological and paleoclimate data) are also observed on localized scales and through other lens, for example, flood events as detailed in Amazonian cosmovisions, oral histories, and myths. Mentions of floods and inundations are common in the origin myths of many Amazonian ethnic groups. For example, in French Guiana, the Palikur explain that human-like beings from the underworld originally lived on an island called Wakayri, opposite the hill of Montabo on the island of Cayenne. During the flood, this island broke at the base, leaving only its base in place, which became the islet La Mère. The top was washed away and drifted to Arukwa (Urukawa) in the northern state of Amapá, Brazil, where it ended up (Renoux, pers. com. 2022). More to the South, the Urubus-Kaapor of the state of Maranhão in Brazil consider that the savannahs were created by a gigantic forest fire ignited by the ancestor "Moon" (Ribeiro 1996), which could be interpreted as an anthropic origin or a natural climatic change.

Other myths seem to be even more directly linked to the extreme climatic variations of the past. The myth of the beginning of Palikur history is particularly interesting in this sense, since it describes an original drama where drought and flood follow one another (Renoux, pers. comm. 2022). After seven years without rain, the rivers began to dry up, their water became salty, and food and fish were in short supply, so the humans sent a shaman to convince "Cold" (*Kiseviye*), the master of rain, to bring back the rain. But it worked so well that it rained continuously for days, flooding all but their village. After that, the situation improved. This story shows the catastrophic effects of a violent change in climate over several years and the consequences on the population. It also suggests a level of resilience.

The current inhabitants of Amazonia are obviously experiencing climate change in its extreme manifestations, including drastic droughts and impromptu floods. Although such climate shifting events are not new, it is their accelerated frequency and attention which is cause for alarm. Many inhabitants associate climate change with human activities, especially Westerners who lack respect for more balanced ways of living and managing life (see Sultana 2022). Thus, Indigenous peoples of northwest Amazonia, especially the groups of Caquetá Putumayo, point to human society as responsible for the current climate crises, noting: "*Disorder in nature is a reflection of disorder in society*" (Echeverri 2009: 25).

A study conducted among people inhabiting the floodplains of the mid-Solimões Basin in Brazil shows that the people intensify adaptation strategies during extreme climate events (Ávila et al. 2021). Local populations detect the increasing frequency and intensity of extreme floods and droughts and adapt to the direct consequences affecting their cultivation systems and associated agrobiodiversity. Although extreme flooding is perceived as having more impact on crops than extreme droughts, both have consequences on peoples' livelihoods. Consequently, Indigenous people use a series of practices and changes in cultivation systems, especially in *várzea*, to counteract effects of such extreme events (Ávila et al. 2021).

Despite many ingenious strategies, many Indigenous are now beginning to worry about the more recent acceleration of extreme events. For example, in French Guiana, in February 2022, uninterrupted torrential rains reached in one week a level that usually takes one month, which resulted in violent floods. A study showed that in the southeast Amazon, during the dry season, the temperature increased by 2.5°C over 40 years. In the northeastern Amazon, rainfall dropped by 34% during the dry season from August to October. Environmentalists warn that this situation is downright apocalyptic (Berenguer and Armenteras 2021). For the first time, Indigenous people are questioning the resilience of their environment and their adaptation to major disturbances.

Unfortunately, the topic of climate sensitivity among Amazonian people has been little addressed by scholars in Amazonia (Simpson et al. 2022). Still, some researchers have done so. Anthropologist Cometti (2015) has devoted his research to climate change among the Q'eros of the Peruvian Andean highlands. These 3,000 descendants of Incas living near Cuzco are direct victims of climate change. They have recently witnessed the melting of nearly half the size of the glaciers and the increased variability of temperatures and rainfall patterns. All of these changes impact their agricultural and pastoral activities. Faced with these transformations, there is a marked feeling of guilt. They blame themselves for abandoning their ancestral rituals in favor of the development of their tourist activity (Cometti 2015) (see also Whitaker's chapter in this volume).

An important question has been raised by geographers Lewis and Maslin (2015) about the environmental consequences of the epidemiological impact of the European conquest. Indeed, the microbial bomb ignited by the conquerors – but also to a lesser extent wars, slavery, and famines – had a decisive impact on the Indigenous settlement. Indeed, at the time of contact in 1492, the population of the Americas as a whole was estimated at between 54 and 61 million inhabitants. Within a century and a half, by 1650, it fell to 6 million (Denevan 1992, 2014). Like the rest of the continent, Amazonia then lost 90% of its inhabitants. According to the two researchers, this demographic fall would have drastically slowed down Indigenous agriculture, and notably the use of fire. This decline in exploitation would have allowed the regeneration of 50 million hectares of forest and grassland and provoked the lowest CO_2 content ever known on earth. Based on this hypothesis of a radical change in human impact on nature, Lewis and Maslin (2015) propose to date the beginning of the Anthropocene to 1610. This is considered the era in which humans became as influential in the history of the earth as the previously selected geological epochs (Crutzen and Stoermer 2000). While the choice of this chronology may be debatable, the fact remains that an essential shift in humanity was already taking place in the 17th century; this shift would become a reality in the 19th century as a primary agent of change on the planet comparable to geological events.

In any case, the ever more virulent fires, the denser tropical rains, the terrifying floods, and the extreme droughts are inexorably affecting Amazonia without hope of recovery. In short, climate change combined with anthropogenic excess is acting as the implacable gravedigger of Amazonian archaeology and, probably soon, of an irremediable biodiversity (Rostain 2021): at least 12% of all flowering plants of the world's biodiversity are found in the Amazonian rainforests (Gentry 1982), so excessive deforestation would cause a global imbalance.

Jorge Ben Jor would have said "Chove-Chuva"[1].

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Note

1 "It is raining".

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2 The *Milpa* Cycle as a Sustainable Ecological Resource

Anabel Ford

Introduction: Human Influence in the Maya Forest

The ever-changing Maya landscape depended on the relationship between fields and forest and the natural resources of the Maya forest that provisioned ancient economies. For ancient Mesoamericans, all aspects of the landscape, including cultivation, were rainfall dependent (Whitmore and Turner 1992, 2005) and based on human labor, stone tools, and fire, in the absence of plow or cow (Denevan 1992; Toledo 1990). Clearly, demand for cropped fields inherently reduces land for forests, while at the same time, research indicates that more cleared land increases erosion and reduces fertility (Hooke 2000; Montgomery 2007). As Malthus (1798) wrote more than 200 years ago, the choice is cast for populations utilizing cultivated fields and forest, and today, there are still debates that question the incompatibility of food production and biodiversity (Green et al. 2005).

The ancient Maya civilization was based on an agricultural system engaged with the lived landscape (Ford and Nigh 2015; Martinez-Reyes 2016; Steggerda 1941) and associated with investment of labor, knowledge, and skill in directing exuberant tropical growth targeted towards human needs. The Maya civilization developed and expanded for millennia, and their livelihoods and economies were based on reliable land management practices, accommodating variations and change in climate and weather patterns across time and seasonal variability over the year with flexible and resilient strategies and practices.

The domesticated Maya forest has been managed, based on Traditional Ecological Knowledge (TEK) and practices, to meet all the basic household needs: farmlands with varying soil qualities, materials for construction and utensils, fibers and spices, resources for food production, and habitats for hunted animals (Ford 2020). Swidden farming, typified by the *milpa* cycle, is the deliberate agricultural practice that embeds the field in the context of the local environment (Conklin 1954, 1957, 1971; Dove 1983, 1993). The word *milpa* comes from the Aztec word for cultivated place, *milli pan*. As a contraction, it is commonly used to refer to a maize field. Curiously, however, a

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cultivated place could be an orchard, or even a well-managed forest. It was the prejudice of the Spanish to focus only on one part of the cultivation practice. The Spanish, with Western perceptions, considered cultivable land to be equated with *arable* land (see Wilson 2002); however, arable land means plowable land. Traditional land-use practices of the Americas (Mt Pleasant 2011) and small holders around the world do not use the plow.

The *milpa* cycle of land use is based on the cleared field, but involved the directed management of the succession of mature forests. It is flexible in the production of foods and household necessities even in the face of environmental challenges (Fedick and Santiago 2021). The topography and diverse landscape, comprising upland ridges and hills interspersed with wetlands and their ecotonal transitions, is an essential palette for the development of strategic land cover designs that mitigated vagaries of rainfall while maintaining soil fertility. Settlement patterns reveal a continuum of land-use intensity, from densely occupied uplands to sparsely inhabited lowlands (Ford and Clarke 2019). The graduation between uplands, lowlands, and wetlands provided access to diverse habitats that facilitated living in, and engagement with, the Maya forest, expanding knowledge of the landscape with every generation, century, and millennia. TEK builds over the longue durée, and mirrors the scientific practice of observation, skill, and trial and error.

Popular interpretations of Maya civilization often focus on their downfall – the idea that the ancient Maya outstripped their own resources leading to a "collapse" (Diamond 2005). Beginning with early Spanish accounts, Western narratives tend to downplay or ignore the Maya forest as a garden. Ironically, the plentiful resources that provisioned early Spanish armies were amassed from Maya forest gardens, and yet perceptions of an unpopulated and wild landscape have been the norm. Acknowledging the evident bounty available in forest gardens sets the stage for examining the resources upon which the Maya depended.

Unrecognized and maligned as "slash and burn" and shifting agriculture, the complex landscape management strategies that are embedded in the forest itself are consistent with traditional swidden sequences around the world (see Conklin 1957, 1954; Dove 1983; Gertz 1963). Burning is an important part of the practice that relies on strategic fire management skills. *Yum Ik'ob*, or Masters of Wind in Mayan, tells of the respect for fire (Nigh and Diemont 2013). Opening field spaces with fire enriches the soil with ash (Handelsman 2021) and systematically reduces fuel load on the landscape. Managed as a horizontal matrix with vertical variations of a heterogeneous mosaic of *milpa*-forest-garden cycles, the orchestrated sequence of succession, from annuals to perennials, is founded on TEK practices (Ford and Nigh 2015). These practices have developed with experimentation, building a regenerative cycle of sophisticated low tech practices (Watson 2020) that are resilient under variable climactic and ecological conditions.

Horizontal and Vertical Landscape Dynamics

An understanding of the Maya landscape starts with the geography (White and Hood 2004; West 1964). The karst limestone platform of southern Mesoamerica, including Mexico, Guatemala, and Belize, effects the spatial distribution of resources and relates to local variations in drainage and seasonal water distribution (Beach et al. 2009). Rain is absorbed into the permeable limestone bedrock foundation of the Maya forest. Precipitation varies from 500 mm in the dry northwest Yucatan Peninsula to 4000 mm in the southeast. The splendid ancient cities of Tikal and El Pilar are in the central area (see Figure 2.1), where rainfall ranges from 1,500 to 2,000 mm. Water drains from the rocky hills, ridges, and escarpments, where the densest ancient settlements and the famous hardwoods are located, to collect in scattered depressions and wetlands (Dunning et al. 2002, 2020; Ford and Fedick 1990). This environment provides the resource base used by the ancient Maya and contemporary society. Land cover differs with local climate, rainfall, and slope conditions; for instance, the upland forests are characterized by the tall trees that thrive in the fertile yet shallow soils. This is the landscape the ancient and contemporary Maya adapted.

Water, a critical resource for plants and animals, and water availability in tropical Maya forest environment, where surface water is scarce, is unevenly distributed over the year (e.g., Kramer and Hackman 2021). The supply is therefore an issue that must be resolved daily. This makes management of land cover essential, as well as vegetation cover which protects soil and contributes organic matter and stored water while inhibiting soil loss. This creates a matrix of diverse assets reflected in the uses of the area, both in the past and present.

The Development of the Maya Civilization

Climate and vegetation in the region have undergone many changes over the Holocene. Initially arid, the aridity gave way to a tropical warm wet environment around 8,000 years ago. These significant climatic variations in precipitation and vegetation are well reflected in the pollen record, which indicate expanding forests and high rainfall (Haug et al. 2003; Leyden 2002), resulting in the tropical characteristics of the region observed today. Minimal evidence of human occupation is recognized, yet we know these occupants were mobile horticulturalists (Ford and Nigh 2015).

Mesoamerica and the Maya area underwent major changes around 4,000 years ago with the widespread emergence of permanent settlements. This coincides with nearly 2,000 years of intensive environmental changes and climate chaos reflected in the precipitation data for the region (Haug et al. 2001; Medina-Elizalde et al. 2016; Mueller et al. 2009; Vela-Pelaez et al. 2018). The move to settle the landscape can be seen as a consequence

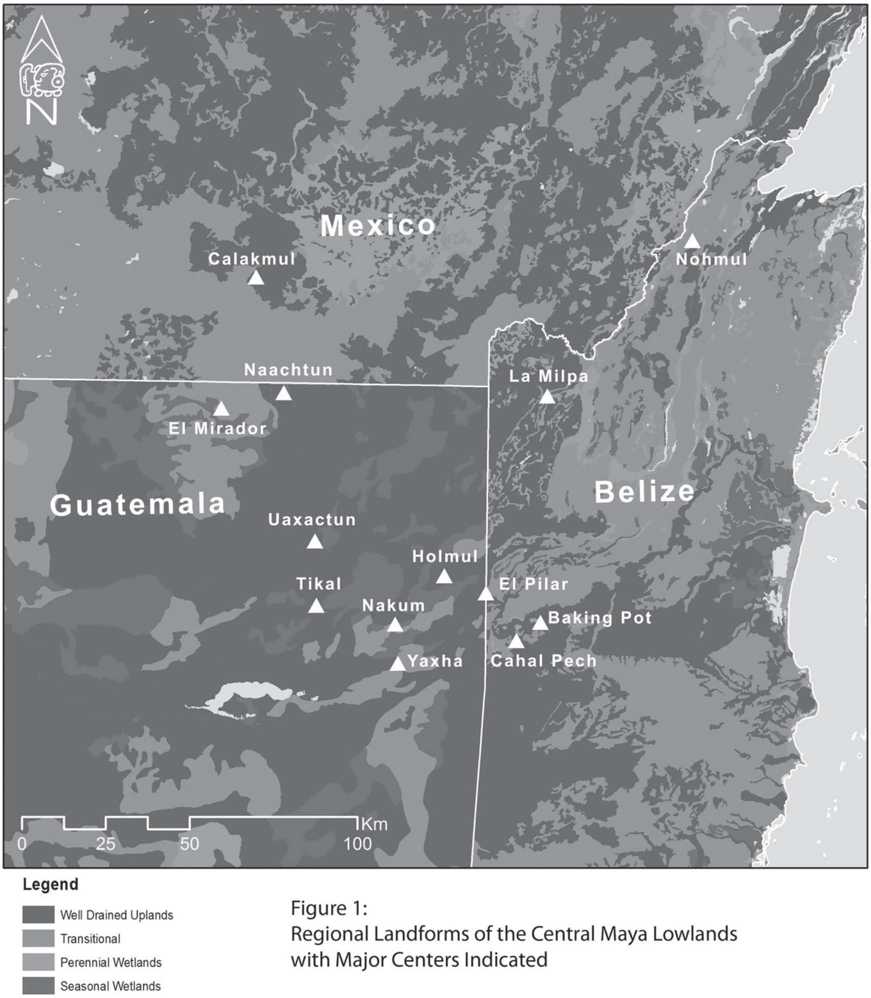

Figure 2.1 The Maya forest geography with ancient Maya sites indicated.

of climate uncertainty. The investment in the landscape is likely a response to the abrupt precipitation and consequent vegetation impacts, suggesting people shifted their focus to landscape management, creating incipient forest gardens. Only 1,000 years after the onset of the climate chaos, and in the context of an overall drying trend, permanent settlements dominated the Maya area. These settlements were the bases for Preclassic Maya cities, such as Mirador, and later the likes of Tikal and El Pilar and others. Small at the beginning, early centers later became major players in the administrative hierarchies that depict the Classic Period.

The emergence of the Classic Maya civilization is marked by the growth of settlements in the Late Preclassic and Early Classic periods bridging the first millennium CE. Successful adaptations are characterized by increasing social complexity and the emergence of culturally distinctive features, such as the famous Maya hieroglyphs. Settlements expanded in all well-drained uplands (see Figure 2.1). There is a distinct concentration of occupation in these well-drained areas that dominate the central lowlands of the region (Bullard 1960; Fedick and Ford 1990). This growth and expansion are evidence of subsistence intensification (Ford and Nigh 2009). Evidence shows that settlements expanded into the margins of wetland areas, the less preferred zones (Ford 1986; Ford et al. 2009). This transitional period from the Preclassic to the Classic period coincides with the stabilization of the precipitation regime, albeit at a lower, dryer level (see Table 2.1).

The Late Classic, between 500 and 900 CE (see Table 2.1), saw a systematic and consistent growth and expansion of residential settlements and civic centers (Culbert and Rice 1990). Preclassic civic centers attained their most extensive size at this time, as exemplified by the enormity of Tikal, which comprised more than 150 hectares of monumental architecture. Large and dense occupation of the well-drained ridges first settled during the Preclassic (Canuto and Auld-Thomas 2021; Ford 1986; Ford and Nigh 2015) were now filled.

Bearing in mind that lake core data emphasize wind borne pollen (Ford and Nigh 2009), scrutinizing the evidence demonstrates more of the complexity of the landscape. Details in the pollen data show a plethora of wind pollinated annual and perennial forbs. These are cast as disturbance, and rightly so, but these forbs are typically found in *milpa* fields and the succeeding regeneration. The proportion of forbs implies human influence, but in the form of land cover characteristic of second growth (Chazdon 2014).

Macrobotanical remains in archaeological contexts provide a new line of evidence that demonstrates that the use of forest trees depended on trees comparable to patterns that are found today (Dussol et al. 2017, Machuca et al. 2020; Morell-Hart et al. 2022; Thompson et al. 2015). Adding the archaeological record to our analyses reveals greater diversity of peoples' use of plant and tree species than interpretations simply taken from the lake cores. Archaeobotanical data suggest the landscape reflected *milpa* cycle species, which would also explain the palynological data which emphasizes the presence of annual and perennial forbs. The representation of successional species and those that favor open canopy gaps dominate regional lake core pollen evidence (Ford and Nigh 2015).

The end of Classic Maya civilization, known as the Terminal Classic, dates around 900 CE, beginning around 1,100 years ago. This period is characterized by a decrease in monumental architectural construction and maintenance of the temples, plazas, and ball courts that were the highlight of the Classic. While there has been significant emphasis on drought (Douglass et al. 2015, 2016; Evans et al. 2018; Haug et al. 2003; Hodell

Table 2.1 Paleoenvironmental and Cultural Chronology

Years Before Present	*8000–4000*	*4000–3000*	*3000–2000*	*2000–1400*	*1400–1100*	*1100–800*	*800–500*	*500–Present*
Human Ecology	Hunting & gathering	Early settlement	Emergent centers	Civic center expansion	Center and settlement growth	Civic center demise	Settlement refocus	Conquest depopulation
Precipitation	Long stable wet	Initial climate chaos	Continued climate chaos	Return stability dry	Stable dry	Medieval warm wet	Little Ice Age extremes	Instability
Wind-Borne Plants	Moraceae dominate	Moraceae varies, forbs rise	Moraceae drop, forbs climb	Forbs dominate, pines peak	Forbs dominate, grass variable	Moraceae rise, forbs decline	Moraceae expansion forbs decline	Moraceae continuity, forbs drop
Land Use	Mobile horticulture	Settled horticultural forest gardens	Settled forest gardens	Expansion of *milpa* forest gardens	Centralized *milpa* forest gardens	Community *milpa*-forest-gardens	Dispersed *milpa*-forest-gardens	Disrupted *milpa*-forest-gardens
Cultural Period	Archaic	Formative Preclassic	Middle - Late Preclassic	Late Preclassic-Early Classic	Late Classic	Terminal Classic Postclassic	Late Postclassic	Colonial, national, global

et al. 2001; Hoggarth et al. 2015; Kennett et al. 2012, 2013; Roman et al. 2018 among others) and there is continual evidence of a drying precipitation trend, the resolution of these data make such interpretations unclear. The current driver provoking the beginning of the Terminal Classic is overpopulation, apparently the cause of deforestation and soil degradation (Turner and Sabloff 2012). Yet, the actual causes are difficult to match. The Classic Maya "collapse" is under constant reevaluation, more recently seen as an environmental transformation of economic and political disruptions (Demarest et al. 2004; Lucero et al. 2015; Yaeger 2020) with a concomitant redistribution of farming populations (Ford and Nigh 2015).

The Postclassic, dating from 1000 CE to Spanish conquest, is a time of political transformation and reorganization, following the upheavals that produced dilapidated monumental architecture in city centers across the Central Lowlands. Centers in the old Maya core area gradually fell into disuse as counterparts in the north expanded. During this period, farming populations, unconstrained by taxation and corvee labor, continued living in the tropical woodlands (Fisher 2020). Though suggested as a diaspora (Lucero et al. 2015), there is no direct evidence that farmers left this area with its well-developed natural resources. The populace endured social upheavals and changes until faced with the brutal Spanish colonization (Alexander 2006), which culminated in the ultimate disorganization of Maya society, under the weight of the oppressive colonial regime.

Historical–Ecological Perspectives on Maya Forest Products

The Maya forest was first encountered by Europeans when the Spanish conquerors invaded at the beginning of the 16th century. Confused by the diversity they faced, the Spanish could not appreciate the value of the forest they were traversing, seeing it as wild and untamed. Mystified by the variety, they focused on what was familiar: any agricultural field, the shelter of houses, waterways and lakes, and resources ripe for exploitation. Their thirst for valuable trade goods and resources drove their treks, and limited provisions for their armies kept them focused on short-term goals.

As Cortez and his entourage were in possession of a map (Prescott 1879: 269) mentioning gigantic trees, plentiful wild fruit, and cacao orchards, they were able to adequately house and feed their expedition with appropriated stores encountered along their way (Cortés 1971; Diaz del Castillo 1927). Writings of these early conquistadores, and later explorers of greater Petén (Jones 1998; Schwartz 1990), note that the world they encountered was largely forested. Early on in the Yucatan, after the conquest, the first governor of Yucatan did not appreciate the Maya relationships with plants and issued an ordinance in 1552 disallowing trees and fields in towns, ordering them to be destroyed:

> *… they should* ***not sow any*** **milpas** *within the town that they construct houses close to one another, that all shall be clean,* ***without sown land or groves****; and if there were any, they should be burned.*
>
> (after Roys 1952: 157, emphasis mine)

Spanish confusion with annual cropped *milpa* infields and scattered *milpa* outfields within the forest led to the misrepresentation of the Maya *milpa*-forest-garden cycle – a system that intervenes in and works with natural regeneration cycles. Preparation and use of fields within the forest, as the basis of a land cover mosaic that sustained life in the Maya forest, was largely invisible to Western eyes.

While there continued to be attempts to suppress the *milpa* practice, the *milpa*-forest-garden cycle has persisted as an important land management practice. As recognized from the conquest and colonial times to the present (Teran and Rassmusen 1995), the landscape created by the *milpa* cycle embraces infield home gardens, and the diverse accessible outfields interspersed among secondary growth and mature, closed canopy forests (Ford et al. 2021). There is a patchwork that is created by the field-to-forest cycle that demonstrates resources accessibility that could fulfill daily requirements of food, condiments, fiber, oils, fuel, gum, furnishings, supplies, medicine, toys, construction materials for buildings, household utensils for cooking, spinning, baskets, and habitat for animals. In other words, it met all everyday needs.

Envisioning the Maya Forest Cropscape

Classified as a biodiversity hotspot (Mittermeier et al. 2000), botanists studying the alpha diversity of the Maya forest show that the well-drained uplands are replete with ethnobotanically salient species (Campbell et al. 2006; Ross 2011). The Maya *milpa*-forest-garden was intensively managed, as reflected in the composition of perennial forest plants, tall trees, and understory shrubs that are economically important. Documented Maya resource management appears to have influenced forest structure and composition in observable ways. The well-drained uplands preferred by the ancient Maya farmers (Ford et al. 2009) are associated with a relative homogeneity of species, indicated by high beta diversity. This is best explained by human selection revealed in the economic utility of the dominant plants of the Maya forest today (see Table 2.2). These dominant plants have persisted in the native environment and are adapted well to the climatic vagaries of the Maya forest.

Rainfall agriculture (Tuxil 2004; Whitmore and Turner 2005) obviously requires rain. Yet, in the Maya forest, too much rain is just as ominous as too little (Lundell 1978). For Maya farmers, bad years are measured by the timing of rain as related to the harvest. If a deluge is delivered at a time when maize

Table 2.2 The Top Twenty Dominant Plants of the Maya Forest

Common Name(s)	*Scientific Name*	*Pollinator*	*Primary Use*
Wild Mamey, Mamay Silvestre, Ts'om	*Alseis yucatanensis*	moths	food
Milady, Malerio, Kibche	*Aspidosperma cruentum*	insects	construction
Cohune, Corozo, Tutz/Mop	*Attalea cohune*	insects	oil
Breadnut, Ramon, Yaxox	*Brosimum alicastrum*	wind	food
Tourist Tree, Gumbolimbo, Chaca	*Bursera simaruba*	bees	medicine
Give-and-take, Escobal, Kum	*Cryosophila stauracantha*	beetles	production
Monkeyapple, Cabeza de Mico, Succotz	*Licania platypus*	moths	food
Cabbage Bark, Manchich, Manchiche	*Lonchocarpus castilloi*	insects	construction
Sapodilla, Chico Zapote, Ya	*Manilkara zapota*	bats	food
Wormwood, Palo de Gusano, Jabin	*Piscidia piscipula*	bees	poison
Yellow Zapote, Mamey Cireula, Caniste	*Pouteria campechiana*	insects	food
Black Zapote, Zapotillo Hoja Fina, Box Ya	*Pouteria reticulata*	insects	latex
Bay leaf palm, Guano, Xa'an	*Sabal mauritiiformis*	insects	production
Redwood, Palo Colorado, Chaltekok	*Simira salvadorensis*	moths	instruments
Hogplum, Jobo, Huhu	*Spondias mombin*	insects	food
Mahogany, Caoba, Chacalte	*Swietenia macrophylla*	insects	construction
Mayflower, Maculiz, Hokab	*Tabebuia rosea*	bees	construction
Kinep, Guaya, Wayum	*Talisia oliviformis*	bees	food
Fiddlewood, Flor Azul, Yaxnik	*Vitex gaumeri*	bats	construction
Drunken Baymen, Paragua, Tamay	*Zuelania guidonia*	bees	medicine

is maturing, it is devastating. With tropical storms and hurricanes (Kramer and Hackman 2021), crop damage is always a possibility. Successful crop yields have to do with the timing of rains, not necessarily the amount.

While the annual climate has been easily defined by wetness and dryness, the annual cycle is more complex. Precipitation, from which average rainfall is estimated, is connected to distant influences. The warm wet period is dependent on the movement of the Intertropical Convergence Zone (ITCZ), while the intensity and frequency of rain is contingent on the frequency and intensity of storms and hurricanes. The Atlantic heralds the cool wet period, coinciding with the North America winter locally known as *nortes*. The intervening dry season varies in length according to the persistence of *nortes* and emergence of hurricanes and is the cause of many uncertainties when initiating the *milpa* field plantings. The predictability of the dry period, when fields are prepared by selecting, cutting, and burning, is a critical point of departure. Sufficient rain at the critical growing phases is required for crops to mature. Nevertheless, there must not be too much rain to flood fields or to damage crops. These three distinct seasons are acknowledged by local farmers. The wet seasons are divided by the dry season that begins around March, known as *Yaax K'in*, or first sun. This is a time to prepare the *milpa* fields. The field preparation is in anticipation of the warm wet period of May–June, known as the *Noh Pak'al*, the principal planting period for the Maya (Victoria Bricker, pers comm 2017). From November to December is the cool wet period called the *Yaax Pak'al*, or first planting. This period is not expected to be as reliable as the *Noh Pak'al*.

The asynchronous cycling of fields to forests develops a landscape mosaic that, at any one time, presents diverse fields amid building perennials and mature closed canopy. There is an important environmental interaction among the embedded fields in the regenerating forests. Nascent perennial trees are nurtured in the fields below the maize canopy. As the perennial trees and shrubs gain ascendency over the maize, they take over the canopy, at first low second growth and then higher canopy (Ford et al. 2012). It is the canopy that is different: the diverse field crop canopy is largely maize while the forest garden canopy is composed of valued trees.

From the farmer's point of view, too much or too little rain is *not* measured annually. Annual measures of rainfall, while telling of the overall precipitation, misses critical factors that farmers must consider (Kramer and Hackman 2021; Tuxill 2004). At the intimate scale of the field, the weather is evaluated based on daily observations of insects, birds, and other animals (see also Whitaker's chapter in this volume).

While farmers may expect the annual cycle to give two maize yields corresponding to the two wet periods, the largest and most reliable will be from the May–June planting with a September–October ripening, depending on the selection of the maize race (Reina 1984; Tuxill et al. 2010). There may be an opportunity for a dry season planting depending on rainfall and other indicators, so variation and unpredictability are ever present (Reina 1967).

Intentionally located to take advantage of variability in drainage, outfield *milpa* plots are placed heterogeneously across landscapes that may be too wet or too dry. The catalog of edible plants numbers nearly 500 species (Fedick 2020), and many edibles are drought tolerant (Fedick and Santiago 2022). This includes specific maize varieties (Tuxill et al. 2010; Fenzi et al. 2017).

Favored trees are protected and cared for in the forests and the fields (Ford and Nigh 2015), and, along with resprouting saplings in the open fields, provide shade that reduces temperature as they speed the regeneration process and maintain biodiversity. These dynamic land-use practices enhance flexibility and adaptability under unpredictable and changing rainfall and other climate conditions. The mosaic of land cover from field to forest moderates temperature and manages water, past and present, for both drought and deluge. These ingrained and multidimensional low-tech practices dependent on TEK enhance resilience and flexibility and enable nimble responses to short term and erratic shifts in weather regimes as well as more persistent climatic trends.

The *Milpa* Cycle

The result of ancient Maya cultivation has enriched the landscape by prioritizing useful species and intervening in natural forest cycles. Collaborating with contemporary Maya farmers has revealed a sophisticated knowledge-base that contributes to the continued maintenance of the forest as a garden (see Ford and Nigh 2015). A simple focus on the agricultural field does not credit the importance of wider land-use patterns and cycles. The open fields provide gaps that that are adjacent to perennial second growth and mature forest. By selectively cutting trees to promote resprouting, choosing those species that accelerate the conversion to succession perennials, the landscape is always in motion. Fields that are cut in the dry season are burned, creating an area for annual sun-loving food crops selected from hundreds of edibles (Fedick 2020). The newly burned fields are fertilized by nutrients left in the soil from ash. Maize, beans, and squash, the “three sisters” of New World fame, lead the species that are grown, but are no means the limits. An average of 30 crops may be found in a cropped *milpa* field; this is only a selection from hundreds of edibles available to the Maya. Companion plants are managed for attracting pests and for their contribution to soil properties (Gliessman 1983). The result is a polyculture field that can be sustained for about four years, rotated within an estimated 20-year cycle, fostering perennial trees that emerge with the natural cycle of forest succession and the culturally directed growth towards useful ends (Campbell et al. 2006).

The Products of the Forest

Forest products derived from the Maya *milpa*-forest-garden complex were managed to mitigate climatic variability and environmental changes that are experienced over the course of a single year as well as over multiple years. The endurance of the Maya forest gardens is largely related to the integration with the natural cycles and rhythms of the landscape. The key practices are designed to conserve water, moderate temperature, build soil fertility, and check erosion. Temperature is moderated by the tree canopy that at the same time reduces evapotranspiration from the understory and retains moisture in the soil. Perennial cover increases root penetration, which helps to mitigate erosion and increases organic matter, improving soil fertility. The mosaic of the system builds tree cover with each asynchronous and regenerative cycle.

The mosaic landscape produced by the *milpa* cropscape ensures reliable access to goods and provides environmental services to meet the basic needs for food, fodder, fuel, and overall well-being of people and their environment. These were available because local inhabitants invested in forests *and* gardens. The result is a dynamic mosaic landscape that immediately surrounded homes and communities. Rarely would something need to be found more than an hour from the home base. Even remedies derived from forest plants cover most ailments encountered in the household.

Discussion

Tropical forests are regularly dismissed as fragile landscapes with resources that are inadequate for sustaining large populations without substantial alteration (see Gourou 1980). This is the very attitude currently putting these environments at risk. Yet long-surviving food-production practices, involving sophisticated understandings of forest ecology and the benefits of managing vegetation for land cover, suggest Indigenous populations in the tropics did indeed develop sustainable practices, strategies, and methods to support themselves in such environments. The example of the Maya *milpa*-forest-garden is one case among many, which is worthy of detailed investigation to identify Traditional Ecological Knowledge from the past that can inform development programs and policies of the future.

The historical outcome of ancient Maya land use, and the resilience of Maya forest, is related to historical ecology and traditional land use. With the expansion of ecological imperialism, the inappropriate and unsustainable "conventional" farming (Sumberg and Giller 2022) based on cattle ranches and plowed monocrops has expanded at the expense of the forest. This was not the trajectory of the ancient Maya, and there are lessons to be learned. Calls for conservation have promoted the creation of protected areas that restrict access to the forest and guarantee no Maya forest cropscape in the future. The real threat to the Maya forest is the loss of traditional Maya farming practices. Indigenous strategies and TEK, preserved in the archaeological record and documented in ethnographies, illustrate the value of exploring the past to develop innovative solutions to address the critical sustainable development goals.

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3 Confronting Climatic Instability in Coastal California Through the Lens of Archaeology and Historical Ecology

Torben C. Rick, Gabriel M. Sanchez, and Shannon Tushingham

Introduction

From the poles to the tropics, 21st century climate change permeates virtually all issues facing Earth's ecosystems and human society, including in the Mediterranean climate regions of California, the Mediterranean Basin, Chile, Australia, and South Africa (Alessandri et al. 2014; Polade et al. 2017). In California, the effects of climate change include increasing drought and fire frequency, periodic mass flooding and erosion, sea level rise (SLR), and increasing instability (Polade et al. 2017; Sweet et al. 2022; Williams et al. 2022). The challenges of 21st-century climate change are increasing historical inequities and amplifying social justice issues (Levy and Patz 2015).

Here, we explore the archaeology of coastal California, focusing on the intersections of historical ecology and climate change. We discuss terminal Pleistocene and Holocene environmental change, focusing on how Indigenous people in California responded to and transcended long-term climatic oscillations. Examples from California's North Coast (NC), San Francisco Bay region (SFB), and Santa Barbara Channel (SBC) highlight human–environmental interactions across the Holocene and demonstrate how colonialism exacerbated many contemporary climate challenges. Finally, we emphasize the important efforts of California Tribes to reassert stewardship of their homelands.

People and Climate in Coastal California

With approximately 5,500 km of coastline, California is typified by environmental, cultural, and linguistic diversity in the past and present (Codding and Jones 2013; Mooney and Zavaleta 2016). Rainfall along California's coast increases as it stretches north, from the semi-arid coasts of southern Alta and Northern Baja California to the northern coastal redwood forests (Mooney and Zavaleta 2016). California's mild coastal climate and diverse ecosystems have long been magnets for people, beginning with Indigenous settlement more than 13,000 years ago, followed by waves of European and

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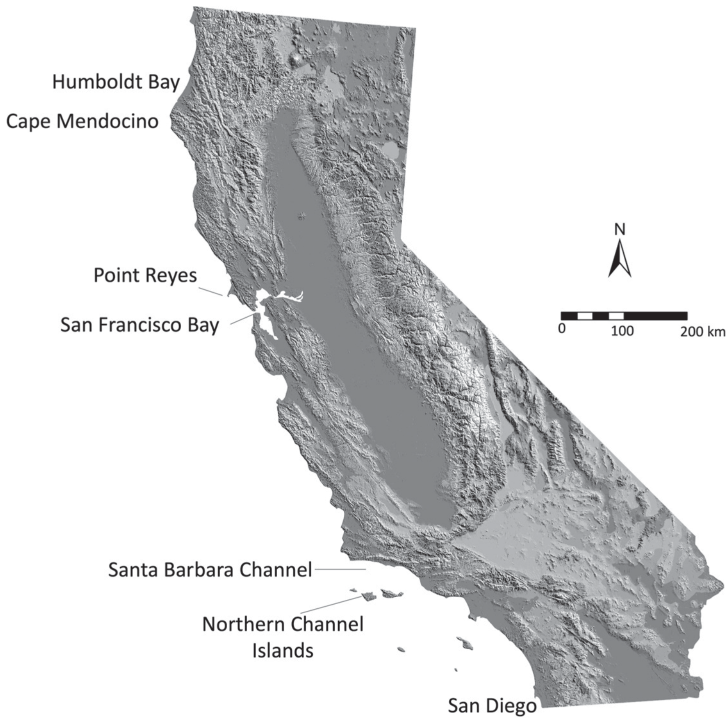

Figure 3.1 California and major places discussed in the text.

Euro-American colonization and the establishment of a series of missions (Braje et al. 2020, 2021; Johnson 1989). Colonialism resulted in major population declines of Indigenous people throughout the Americas due to introduced diseases, violence, and massacres, and sought to transform Native identity and lifeways through forced assimilation (Cameron et al. 2016; Johnson 1989). The introduction of a variety of Old World crops and livestock and serial depletion of marine mammals, salmon, and other fishes transformed California's terrestrial and marine ecosystems (Dartt Newton and Erlandson 2013; Lightfoot et al. 2013; Lufkin 1990).

Today, California has the leading economy in the United States and the fifth largest globally, including a more-than-$50 billion agricultural industry (California Department of Food and Agriculture 2020). However, California's economies and ecosystems are heavily threatened by climate change (Thorne et al. 2018). For instance, global warming has exacerbated droughts in California and the American West and poses major future threats (Keeley and Syphard 2021; Polade et al., 2017; Williams et al. 2022). Limited water and increased irrigation needs also strongly impact salmon fisheries and other resources (Dettinger et al. 2015). California's population of around 40 million people is heavily concentrated along the coast, further amplifying the challenges posed by climatic instability (US Census 2021).

Persisting alongside contemporary climate challenges are exceptional archaeological and paleoecological records of past climate change in California, particularly for the Holocene (Barron et al. 2003; Heusser et al. 2000; Kennett 2005; West 1989, 1993). Similarly, California's Indigenous communities have rich cultural heritage and traditional ecological knowledge (TEK) that provide insight into climate challenges. Archaeology and Indigenous knowledge are becoming increasingly important for evaluating contemporary environmental issues in California, where Tolowa, Wiyot, Yurok, Karuk, the Amah Mutsun Tribal Band, Chumash, and other California tribes are demonstrating the power of Indigenous knowledge for combatting climate change and wildfires, fisheries management, and coastal habitat protection (Berkey and Williams 2019; Lake et al. 2017; Lightfoot et al. 2021; Marks-Block and Tripp 2021; Sigona et al. 2021).

Archaeology, Historical Ecology, and Climate Change in Coastal California

The North Coast

The NC is renowned for its Coast Redwood forests, dramatic coastlines, high annual rainfall, and interior mountains. Typified by a mild Mediterranean climate, the NC is bounded by mountain ranges where a more continental climate dominates. North of Cape Mendocino, people lived in sedentary plank house villages and practiced "aquatic foraging" that revolved around hunting, gathering, and fishing, with rivers serving as major transportation corridors (Ames 2002; Binford 1990). Rocky headlands, sandy beaches, estuaries, coastal lakes, and lagoons support diverse wildlife that have historically been magnets for people. This includes Humboldt Bay, the second largest estuary in California (after SFB) (Barnhardt et al. 1992: 66).

Offshore and montane lake sediments, geoarchaeology, and marine life abundance proxies all document past climatic and environmental variation, including changes in sea surface temperature, ancient coastlines and landforms, wildfires, vegetation, and wildlife (Barron et al. 2003; Finney 2000, 2010; Heusser et al. 2000; Lake 2007; Meyer 2007; Skinner et al. 2009; West 1989, 1993). Archaeological research provides complementary information about past human interactions with wildlife. Native oral histories document ancient floods and climatic events, providing additional nuance to our understanding of climate change (Fitzgerald and Ozaki 1994).

The earliest archaeological sites in the NC date to 11600–8200 cal BP, coinciding with gradual warming after the LGM. Compared to interior rivers and uplands, few coastal sites pre-date 3000 cal BP. However, tectonic activity, coastal subsidence, flooding, and fluvial deposition altered, destroyed, and submerged various landforms, and likely early archaeological sites (Fitzgerald and Ozaki 1994; Losey 2005; Minor and Grant 1996). Today, many coastal archaeological sites are threatened by such processes, with local tribes, agencies, and archaeologists increasingly tasked with salvaging information from sites (Figure 3.2).

At interior Pilot Ridge, Borax Lake Pattern sites (8000–6500 cal BP) represent multi-purpose camps of mobile people focused on upland resources. Lower artifact diversity and specialized Middle Holocene upland sites coincide with pollen records that document significant vegetation change (e.g., reduced oaks) that may have drove people to lowland river sites where salmon and acorn resources were abundant (Hildebrandt and Hayes 1993; West 1989). Excavations at the Smith River Valley demonstrated that people inhabited interior river zones by the Early Holocene and intensified settlement by 3100 cal BP, while maintaining mobility (Tushingham 2009).

Little is known about the Early–Middle period transition as few sites date between approximately 6,500–3,500 years ago. This period coincides

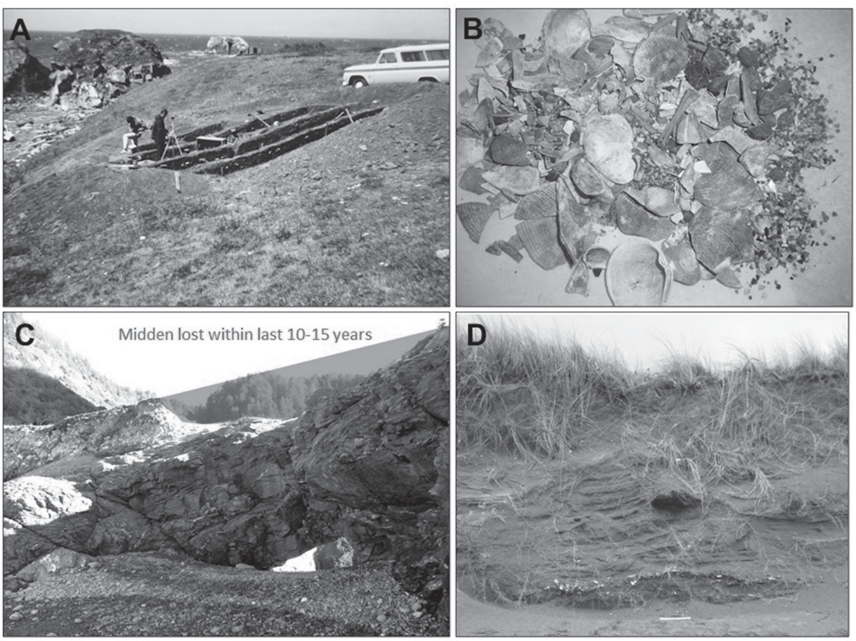

Figure 3.2 Part A: Point St. George (CA-DNO-11), one of the earliest NC sites; Part B: Coastal midden sample with shellfish, burned nuts/seeds, fish/mammal bones, and artifacts; Part C: Shell midden destroyed within past two decades due to coastal erosion; Part D: Buried earth oven feature from a smelt fishing camp (CA-DNO-22) later destroyed by a storm.

with more xeric climatic conditions, including cooler winters and sea surface temperatures (1–2°C cooler) than earlier and later periods (Barron et al. 2003). Between 7000 and 4000 cal BP, slowing SLR led to the formation of critical habitats, including dunes and tidal marshes (Meyer 2007). By 5200 cal BP, coastal redwood and alder forests became more widely distributed as precipitation increased, possibly resulting in the "development of the North Coastal temperate rainforest" (Barron et al. 2003). Late Holocene vegetation communities were similar to modern day conditions, and salmon runs were likely abundant during this time (Lake 2007).

Sediment core studies (Finney et al., 2000, 2010; Rogers et al., 2013), suggest macroscale changes in climate are connected to variation in marine life, including salmon. Salmon populations are overall resilient, though they are subject to boom-and-bust cycles influenced by climate change (Quiñones et al. 2014). Since cool-moist climatic conditions trend with more predictable and abundant anadromous fish runs, the drier Middle Holocene was likely relatively salmon-poor prior to 5500 cal BP (Lake 2007: 31–32). By 4000–2000 cal BP, conditions were ideal for salmon (cool-moist) and, combined with the stabilization of river systems between 3000 and 2000 cal BP, may be linked to increased settlement of valleys (Lake 2007). Archaeological data suggest intensive use and bulk storage of salmon was delayed until about 1300 cal BP (Tushingham 2009). However, there are many nutritional, cultural, and organizational reasons for not over-exploiting salmon, including cultural practices documented ethnohistorically (Suttles 1990; Thornton et al. 2015; Tushingham 2009).

People harvested small forage fish (e.g., smelt, herring) for at least 1300 years in the NC (Palmer et al. 2018; Tushingham and Christiansen 2015; Tushingham et al. 2019). Food webs and higher trophic species depend on these keystone species, but modern landscape changes and overfishing have extirpated eulachon from most river mouths, and beach spawning smelt species are also rare. Forage fish are vulnerable to climate change, habitat disturbance, and other natural and anthropogenic factors (Kaplan et al. 2013). Ancient DNA analysis of fish bone provides important data on these fish populations and sustainable use by humans over archaeological time scales (Palmer et al. 2018). In recent decades, there has been an alarming decline in forage fish populations, including extirpation of some species and genetic groups on the NC and elsewhere (McKechnie et al. 2014).

By the Late Holocene, redwood plank house villages, intensive storage economies, and mass harvest technologies focused on salmon and forage fish expanded at river locations and the coast (Tushingham 2009; Tushingham et al. 2019). Archaeological data suggest that the Medieval Climatic Anomaly (MCA, 1150–650 cal BP) does not seem to have significantly altered this way of life. This is despite environmental data showing drought and a peak in fire frequency at 1000 cal BP (Mohr et al. 2000), declines in salmon habitats (Lake 2007), and a reduction (and subsequent recovery) of redwood and alder trees at 700 cal BP (Barron et al. 2003). Alternating changes in the amount of redwood and alder versus pine pollen in coastal forests indicate cyclical, rapid changes in effective moisture and seasonal temperature associated with enhanced ENSO (Barron et al. 2003). Linguistic data suggest potential movement of people, but archaeological data document cultural continuity and resilience in the face of environmental and climatic cycling during this time.

People observed and responded to variation in resource abundance and likely developed and applied TEK to foster ecological resilience and avoid devastating impacts of resource shortfalls (Lake 2007; Thornton et al. 2015). Ancestral TEK was applied to variable climatic circumstances, such as the MCA and Little Ice Age, resulting in intentionally maintained habitats through burning (Lake 2007: 26). Cultural burning was a means of maintaining forest regimes and wildlife habitats, and was likely applied as climatic conditions alternated between warm and dry to cool and moist (Anderson 2005; Lake 2007). Pre-contact fire history data show significant oscillations compared to later times as Native American communities and cultural burning practices were disrupted during Euro-American settlement (Lake 2007; Skinner et al. 2009). Fire suppression and increased fuel loads have led to catastrophic fires, a situation made more urgent by climate change. Data on precontact fire frequency, burning regimes, and seasonality is critical information for contemporary land managers to develop solutions to these issues (Skinner et al. 2009).

San Francisco Bay Area

The SFB is the largest estuary in the western United States and drains 40 percent of California's landscape (Okamoto and Wong 2011). The Bay has experienced several cycles of climate change in its history. Indigenous people have witnessed these events as the modern SFB reached its current form during the Holocene (Atwater et al. 1977, 1979; Malamud-Roam et al. 2006, 2007). The SFB is a drowned river valley that became submerged c. 10,000 years ago. Inundation of the SFB, San Pablo Bay, and Sacramento–San Joaquin Delta stabilized around 6,000 years ago and reached its pre-contact configuration (Atwater et al. 1977, 1979). After the inundation of the Bay, stabilization of the shoreline, and extensive tidal marsh and mudflat formation, the record of human habitation within the SFB becomes more evident. At this time, the iconic shell mounds of the SFB Area were formed, representing extensive complexes of constructed mounds that included human burials, animal burials, marine shells, vertebrate remains, ash, and rocks (Lightfoot and Luby 2002) (see Figure 3.3).

Given the connections between the formation of the SFB and global climate change, numerous studies investigated past climate change in the region (Ingram et al. 1996a, 1996b; Ingram and DePaolo 1993; Malamud-Roam et al. 2007, 2006; Stine 1994). According to these records, Early Holocene California was characterized by generally warm temperatures

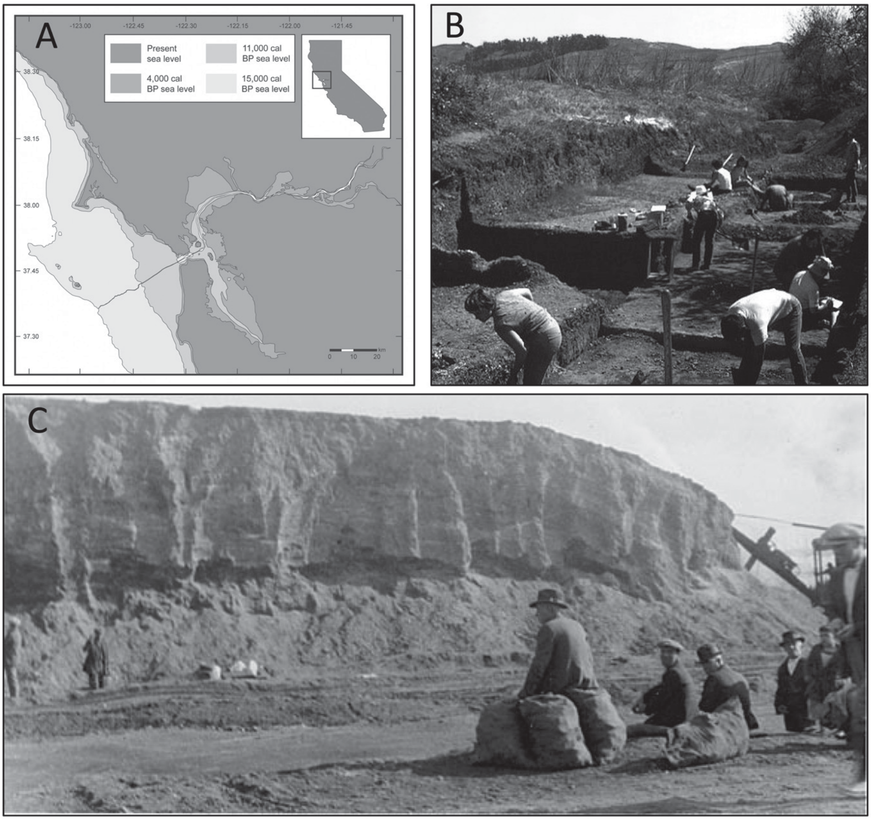

Figure 3.3 Part A: Map of sea level change in the San Francisco Bay Area from 15,000 years ago to modern times. Part B: Excavation of the Patterson Mound, CA-ALA-328. Part C: Destruction of the Emeryville shell mound (CA-ALA-309) in 1924.

with decreased moisture (Malamud-Roam et al. 2007). During the Middle Holocene, around 6000–5000 cal BP, the bay shorelines stabilized, and tidal marshes began to form around the estuary's edges (Atwater et al. 1979; Malamud-Roam et al. 2007). Shortly after this stabilization, regional archaeological sites became more prominent, as evidenced by the development of the shell mound complexes near the bay shore. Therefore, the Middle Holocene is a critical point in the archaeology of the SFB Area as the majority of archaeological sites were inhabited during the Middle and Late Holocene.

During the Late Holocene, around 4000 cal BP, paleoclimate data indicate higher freshwater inflows signifying an end of the decreased moisture and warming temperatures of the Middle Holocene. High sediment loads were delivered to San Pablo Bay by more significant river flows (Ingram et al. 1996a, 1996b), and shifts in oxygen isotopes associated with increased freshwater inflow and lower salinities corroborate these trends (Maynard et al. 2018; Pritchard et al. 2015). Therefore, cooler and wetter conditions characterized the SFB and contributed to watersheds between 4000 and 2000 cal BP (Malamud-Roam et al. 2006). After this cooler and wetter period, conditions became more arid after 2000 cal BP due to periods of droughts punctuated by wet events within overall drier conditions (Malamud-Roam et al. 2006, 2007). After 2000 cal BP, isotopic data suggest short-term fluctuation but overall increasing salinity in the Bay (Malamud-Roam et al. 2006, 2007).

Within California archaeology and that of the SFB Area, the climactic event that has garnered the most academic research is the MCA (Malamud-Roam et al. 2007, 2006; Mann et al. 2009; Stine 1994). The MCA within California is argued to have resulted in abrupt and extreme hydroclimatic shifts, from extreme dryness to excessive wetness and back to dryness, over several hundred years (Stine 1994). During this same time, significant changes are seen in the archaeological record, including population change, settlement patterns, increased violence, disease, shifts in political organization, subsistence change, and a breakdown in regional trade networks (Jones et al. 1999; Jones and Schwitalla 2008; Moratto et al. 1978; Schwitalla et al. 2014). While climatic instability has been a primary explanation for these patterns, Beaton (1991) and Bettinger (1991) have argued that population growth and economic intensification rather than climatic instability are the primary drivers.

Within the SFB Area, evidence for increased violence is generally lacking during the MCA. As summarized by Schwitalla and colleagues (2014), evidence of blunt force trauma, human dismemberment and/or trophy taking occurred prior to the MCA during the Early Middle Period (2500–1530 cal BP) and/or in the Protohistoric/Historic Period (230–50 cal BP). On the other hand, evidence for sharp force and/or projectile point trauma remained consistent throughout all temporal periods evaluated – including the MCA – and increased only during the Protohistoric/Historic Period. In addition, evidence for this type of trauma was lower in the SFB than any other portion of the Central California Coast analyzed in the study (Schwitalla et al. 2014). Human settlement patterns during the MCA seem largely unchanged (Lightfoot and Luby 2002; Milliken et al. 2007).

Climatic change has not been a primary explanatory framework regarding shifts in Indigenous foodways during the MCA in the SFB. Instead, within the SFB, interpretations regarding shifts in subsistence practices are often explained by an intensification of Indigenous foodways related to increasing human populations, competition, and economic intensification through a human behavioral ecology framework. Through this theoretical lens, population growth rather than climate is a primary driver (Basgall 1987; Beaton 1991; Bettinger 1991; Broughton 1999;

Hylkema 2002). Therefore, unlike the SBC, archaeologists within the SFB have tended to focus less on abrupt cultural adaptations related to the MCA and other climatic events.

Santa Barbara Channel

The SBC is located in southern California and includes the Northern Channel Islands (NCI) (see Figure 3.1). The coastline here abruptly shifts to face east–west, rather than the north–south facing coast that characterizes much of North America's Pacific Coast. The more protected coastline and offshore islands provided a variety of unique opportunities for people living in the region (Kennett 2005; Rick et al. 2020). The SBC is generally drier than areas to the north, with a dearth of lakes that are often central to understanding local climate. Still, a few pollen records exist and the region has one of the highest resolution marine climate records in the world (Anderson et al. 2010; Kennett and Kennett 2000; Kennett 2005) (see Figure 3.4).

The earliest archaeological evidence for Indigenous people in the area occurs between approximately 13,000 and 9,000 years ago, when the SBC transitioned from wetter and more forested conditions to warmer and drier conditions following the Last Ice Age (Anderson et al. 2010; Kennett

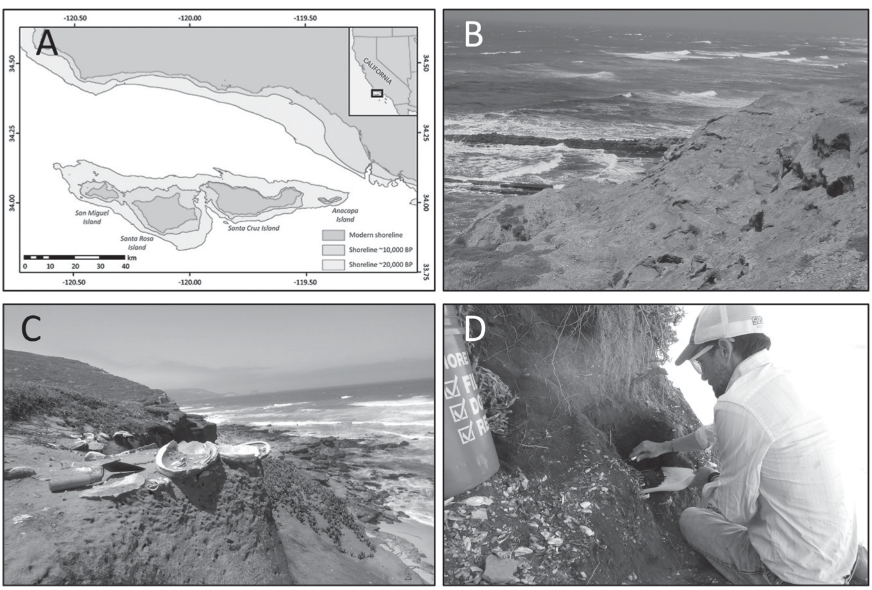

Figure 3.4 Part A: Map of Santa Barbara Channel shoreline changes from 20,000 years ago to present. Part B: Location of approximately 12,000-year-old site, CA-SRI-512. Part C: Red abalone shells at a 7,000-year-old site, CA-SRI-388. Part D: Excavation of a shell midden near Point Conception.

2005) (Figure 3.4). Dozens of terminal Pleistocene and Early Holocene sites have been documented in the SBC, particularly from the NCI (Gusick and Erlandson 2019). Perhaps the greatest climate challenge facing these earliest peoples was from SLR, which resulted in dramatic shoreline and habitat changes and posed challenges for human settlement and coastal foraging, which reduced kelp forest habitat, but also produced productive estuaries (Graham et al. 2003)). SLR shrunk the coastline and the NCI, which had coalesced into a single mega-island, broke apart into four islands by c. 9,000 years ago (Reeder-Myers et al. 2015). Though SLR likely submerged archaeological sites, we know that people during this time harvested shellfish, aquatic birds, seals, sea lions, sea otters, and fishes, used diverse chipped stone artifacts, and had sophisticated land stewardship practices that were key to meeting new climatic and environmental challenges (Braje et al. 2021; Gusick and Erlandson 2019).

The Middle Holocene, about 8000–4000 years ago, began an overall warmer and drier period (Kennett et al. 2007). Increased aridity between 6300 and 4800 cal BP had limited effects on Middle Holocene people in the NCI, but on the warmer Southern Channel Islands, historically occupied by the Gabrielino-Tongva, drought seems to have stimulated early village formation and large exchange networks (Kennett et al. 2007). While Middle Holocene marine climate was generally warm, periodic marine cooling may have enhanced the availability of cooler adapted marine shellfish like red abalone (*Haliotis rufescens*), an important resource on some of the NCI (Glassow 2015). There is growing evidence that ENSO and other marine climatic perturbations may have periodically declined during the Middle Holocene and possibly increased the formation of sand beach habitats (Vellanoweth and Erlandson 2006).

During the Late Holocene, the Chumash in the SBC lived in large villages, some with approximately 1,000 residents and connected by exchange networks and ritual systems (Arnold 1992). Explanations for Chumash sociopolitical developments draw heavily on climate change, including an early marine climate record (Pisias 1978) that led Arnold (1992) to suggest that unstable marine climate and possible extended ENSO events between 800 and 650 cal BP drove people to coalesce around productive village locations, engage in greater exchange, and promote increased social hierarchy (Arnold 1992). A revised marine climate record for the SBC, however, showed that the Late Holocene actually was a time of relatively cold, unstable marine climate without a clear sign of an extended ENSO (Kennett 2005; Kennett and Kennett 2000). Researchers instead emphasized severe droughts during the MCA from AD 1100–1350 (Johnson 2000; Kennett 2005) as the catalyst to Chumash sociopolitical developments and perhaps a factor that pushed some of the Chumash to Spanish missions in the 19th century (Larson et al. 1994). Some have also correlated evidence for heightened interpersonal violence and declines in human health to environmental challenges and increasing human population (Lambert 1993).

Still others have noted that climate and environment were one component of change that people were able to weather, and that social systems were also driven by internal political dynamics and changing social relations that played out over centuries or millennia (Erlandson and Rick 2002; Gamble 2005; Gamble et al. 2001; Rick 2011).

Climate was an important catalyst for changing long-term cultural dynamics in the Santa Barbara Channel, but people also actively shaped and stewarded regional ecosystems during the Holocene. This shaping included burning and landscape clearance by the Chumash, translocating various plant and animals species, tending geophyte and other plants, and influencing a variety of nearshore marine ecosystems (Anderson et al. 2010; Braje et al. 2021; Erlandson et al. 2009; Gill et al. 2019; Hofman and Rick 2018; Timbrook et al. 1982). This stewardship continues into the present, as Chumash tribal members play an active role in environmental management, including TEK, to inform future challenges in the SBC. Marine monitoring by the Wishtoyo foundation, the Santa Ynez Band of Chumash Indians fire department, and the proposed Chumash Heritage National Marine Sanctuary to the north of the SBC will be crucial for more effective management and stewardship in the coming decades.

Discussion and Conclusions

In a time of rapid global change, understanding past human–environmental interactions provides perspectives on how we arrived at the present and helps plan for the future. Although typified by a Mediterranean climate, California's coast is diverse, with variability in rainfall and habitat and significant climate change during the Holocene and Late Pleistocene. Archaeologists have documented correlations between past climate change and cultural developments, especially increases in drought and aridity that may have been catalysts or drivers of some sociopolitical change. However, many cultural developments appear to have had little to no connection to climate change.

SLR and changing coastal habitats are a major concern in California today (Sweet et al. 2022). SLR projections predict a foot of SLR over the next 30 years, which could result in coastal flooding, erosion, changes in nearshore habitats, and the need to relocate settlements, resulting in billions of dollars of infrastructure change (Sweet et al. 2022). SLR has been a major challenge facing California's Indigenous peoples for thousands of years (Graham et al. 2003). Some of the most dramatic changes are evident from the terminal Pleistocene through c. 5,000 years ago when SLR dramatically slowed. During this time, the SFB, Humboldt Bay, and a series of estuaries formed and submerged former river valleys. This created new opportunities as the SFB and other estuaries provided new sets of resources for people to harvest (Lightfoot and Luby 2002). In the SBC, SLR resulted in a reduction of coastal shelf environments and kelp forests (Graham et al. 2003). Much like in the SFB and NC, people in the SBC took advantage of newly formed estuaries, with many of the smaller estuaries forming during the Middle Holocene (Erlandson et al. 2019). SLR posed challenges for people living along the coast as they adjusted to changing shorelines, but people transcended these challenges. Today, SLR is rapid and dramatic, heavily influenced by storm surge and other patterns (Sweet et al. 2022). With California's coastal populations numbering in the tens of millions, many past Indigenous strategies of relocation and resource switching will be difficult to implement, driving major resettlement patterns and economic changes. Much like the past, resilience and flexibility will be imperative for future success (Rick et al. 2020).

California is currently embroiled in a major drought and intensified wildfires (Keeley and Syphard 2021). Drought in the American West is now worse than the MCA droughts that partly influenced cultural developments in parts of California (Williams et al. 2022). The archaeological and climatic records from California underscore the effects of drought and other issues in the past, from the more arid SBC to the wetter NC. In the SBC, MCA drought may have resulted in social circumscription and increased hierarchy as people coalesced into villages around major water sources (Kennett 2005). Still, the archaeological record points to the complex ways in which people addressed these challenges, including producing asphaltum-lined woven objects for water storage used since at least the Middle Holocene (Braje et al. 2021). In the SFB, increased aridity is evident in the last 2,000 years, but several scholars have argued that population growth, not climate change, is a major driver of cultural developments (Basgall 1987; Beaton 1991; Bettinger 1991). This agrees with other scholars in the SBC, who view climate as a component of a wide range of cultural and population changes that drove sociopolitical developments (Erlandson and Rick 2002; Gamble 2005). This variability is important as we look to the future in archaeology, where climate was significant in the past, but environmentally deterministic models only present part of the story. Finally, archaeologists in the NC demonstrate interconnections between drought and aquatic resources, noting that increased aridity and xeric conditions influenced salmon abundance, with Middle Holocene dry periods usually having lower salmon abundance (Quiñones et al. 2014). Drought and inter-related increases in fire frequency and intensity pose major challenges for the future, but historical ecology and TEK can help address these challenges (Lake et al. 2017; Marks-Block and Tripp 2021).

Historical ecology documents the long-term use of coastal resources by Indigenous peoples in California that can inform contemporary conservation (Braje et al. 2021; Erlandson et al. 2009; Palmer et al. 2018; Sanchez et al. 2018). Some examples include long-term sustainable reliance on salmon and small forage fishes, and intensive abalone, oyster, and other shellfisheries (Braje et al. 2021; Erlandson et al. 2009; Palmer et al. 2018; Reeder-Myers et al. 2022; Sanchez et al. 2018). The archaeological record also documents resource depression and evidence for size and abundance declines in some organisms, demonstrating that California tribes coped with periodic overharvest (Broughton 1999). Still, the overarching current of sustainable coastal land use, despite intensive harvest and the formation of anthropogenic landscapes, demonstrates that people had complex systems for buffering against overharvest and the effects of climate change and other environmental perturbations. These systems are often difficult to detect in the archaeological record, but increasing collaborations between Indigenous scholars and archaeologists are helping to untangle these patterns and provide a road map for more productive and inclusive archaeology and historical ecology (Lightfoot et al. 2021; Sigona et al. 2021).

During the 18th and 19th centuries, as the Missions and other colonial institutions took hold, Indigenous stewardship of California's environments declined as people were displaced from ancestral villages, denied access to coastal and other resources, and faced major upheavals caused by disease, violence, and forced removal (Dartt-Newton and Erlandson 2013; Lightfoot et al. 2013). Such changes resulted in a dramatic reorganization of California's ecosystems, while the cessation of Native American burning resulted in an increased fuel load that is contributing to increased fire today (Marks-Block and Tripp 2021). California's NC Tribal communities are active managers of local habitats, including cultural burning and fisheries and wildlife conservation efforts today (Berkey and Williams 2019; Long et al. 2021). Similar programs are emerging in central and southern California and will expand in the future (Lightfoot et al. 2021), including the proposed Chumash Heritage National Marine Sanctuary. Historical ecology and archaeology are increasingly important as we work to merge the past with the present to restore Indigenous connections to the land and seascapes of their ancestral homelands. Our hope is that archaeologists will continue to focus on the nexus of historical ecology and social justice, as we work to use the past as a vehicle for fighting the effects of climate change and the atrocities waged on California tribes for more than two centuries by Euro-American society.

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4 Indigenous People Prevented Climate-Induced Ecological Change for Millennia

Evidence from the Prairie Peninsula and Fire-Loving Forests of Eastern North America

Natalie G. Mueller

Climate change effects human society directly, for example through rising sea levels, dangerous heat waves, and changes in storm severity. But many of the effects of climate change are mediated through ecosystem change, which shapes food supply, among many other things. In the present, the effects of climate change on ecosystem structure and function are heterogeneous and not easy to predict (Bellard et al. 2012; Walther 2010). Given this unpredictability, episodes of past climate change and variability are an important source of knowledge about what to expect in coming years. However, there are disciplinary impediments to making causal connections between climate change, ecosystem change, and the responses of human societies. Archaeologists are polarized. Some are prone to assume that any instance of past climate change caused ecological change and had catastrophic effects for humans. This camp tends to blame climate change for causing the depopulation of cities or regions, sometimes glossed as collapse (Douglas et al. 2016; Fagan 2008; Pompeani, et al. 2021). The other camp considers any implication that the environment was a driver of human history to be deterministic, and so are not willing to critically engage with paleoecological data (Kohler and Rockman 2020).

Meanwhile, paleoecologists search for generalities between changes in climate parameters (temperature, precipitation, seasonality) and ecosystem change (Williams et al. 2011), but they usually do not consider evidence for human action as a confounding factor in these models. This is especially true in North America, where settler colonial educational systems encourage scientists to imagine the ancient landscape as empty of people. The term *pre-settlement* as a synonym for *pre-Euroamerican invasion* is ubiquitous in ecology and paleoecology, erasing at least 20 thousand years of human history on the continent (Bennett et al. 2021). There is also a disconnect in scale between regional climate data and local paleoecological and archaeological data. This presents a problem for understanding how humans adapt to climate change because, until very recently, humans relied on local, not global

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or even regional, systems to obtain food. These persistent issues limit the flow of actionable insights from the past into how we might respond to climate change today. We can better understand the ecological effects of climate change on a human scale by combining multi-proxy regional and local paleoecological records with archaeological data and by considering the possibility that, like us, past human societies were capable of manipulating ecosystems to mitigate climate-induced change.

Historical ecology explicitly asks what role human skill and action played in ecological change, rather than assuming that all past ecological changes were caused by natural (construed as non-human) and climatic processes. Further, historical ecology does not assume that climate change always has unmanageable effects on human societies. This orientation has been fruitful across the western hemisphere, where multidisciplinary teams in collaboration with Indigenous knowledge holders have revealed extant forest gardens in the Pacific Northwest (Armstrong et al. 2021), successful water and forest-product conservation at one of the great Mayan cities (Lentz et al. 2015), the transformation of Californian landscapes by anthropogenic fire to increase yields of food and fiber plants (Anderson 2005), and the creation of hyper-fertile soils on a massive scale in the Amazon (Iriarte et al. 2020), among other paradigm-shifting discoveries. These studies broaden our understanding of the possibilities of human environmental impacts to include those that *increase* sustainability and biodiversity, inform contemporary management and conservation decisions in these ecosystems (Maezumi et al. 2018; Nikolakis and Roberts 2020), and can provide powerful scientific justification for the return of land to Indigenous stewardship (Fletcher et al. 2021).

In eastern North America, existing paleoecological data suggests a radical societal response to climate change after the mid-Holocene (8000–4000 BP): Indigenous people preserved prairies and pyrophytic (fire-loving) forests on a regional scale through ecological management that mimicked more arid climate conditions. Acting in defiance of climate change, Indigenous people held back the succession of forests in the "Prairie Peninsula" (Transeau 1935) east of the Mississippi river and prevented the "mesophication" of eastern forests for thousands of years (Abrams and Nowacki 2008), from the end of the mid-Holocene Warm Period c. 5,000 years ago until Euro-American colonization. Both the eastern prairies and nut-producing forests were domesticated landscapes, created through the skillful use of fire to support plants and animals that were necessary for the continuation of Indigenous lifeways (Fritz 2000; Fritz 2007). These ecological manipulations represent landscape domestication on a grand scale and open our minds to the possibility that a society can live through climate change and variability without traumatically disentangling itself from its sustaining ecosystems.

Williams and colleagues (2011) develop two contrasting paradigms to explain ecological change: extrinsic and intrinsic. Extrinsic ecological change is caused by abrupt climate change. In such cases, we expect that there will be a symmetry between ecology-independent proxies for climate change

Table 4.1 Paleoecology and climate proxies used to reconstruct the prairie peninsula

Proxies	
Paleoecology proxy	**Ancient environmental attribute**
Pollen	Local plant community, with biases
$\delta^{13}C$	Relative composition of C3 and C4 pathway plants, sometimes glossed as grassland/forest
Ecology-independent climate proxy	
$\delta^{18}O$	Evaporation/precipitation
Aragonite: calcite ratios	Evaporation/precipitation
Detrital mineral accumulations	Erosion
Ostracodes and diatoms	Local water level
Interface of ecology and climate	
Charcoal accumulation	Fire frequency and/or severity (fuel abundance and moisture + ignition)

and paleoecological reconstructions (Table 4.1), where expected changes in response to climate change occur at multiple sites and effect many taxa in the same way. In the case of intrinsic ecological change, change is driven by internal dynamics, including local biotic and abiotic factors, resulting in "heterogeneous local responses to a common regional climate forcing" (Williams et al. 2011). Intrinsic change may be caused by purposeful human actions, among many other factors (e.g., local species extinctions and introductions, fire, and geomorphological change). I will use this heuristic to examine the prairie peninsula of eastern North America and argue that tallgrass prairies first expanded due to extrinsic causes, but were maintained by intrinsic, anthropogenic causes after the mid-Holocene.

The Prairie Peninsula

For over a century, Euroamerican settlers were puzzled by the tallgrass prairies that extended east of the Great Plains, across the Mississippi river as far as central Ohio and Kentucky (Figure 4.1). In a 1935 paper, botanist Edgar Transeau dubbed this region the "prairie peninsula," and proposed several explanations for these tallgrass prairies encircled by forests. The source of the general puzzlement was the theory that precipitation and temperature should have allowed forests to become the dominate type of ecosystem in this region (Transeau 1935). Yet early ecologists did not all agree on this point, and the debate about the relative importance of climate in determining the location of forest-prairie boundaries (FPBs) continues to this day (Danz et al. 2011; McAndrews 1966; Nelson and Hu 2008; Williams et al. 2009). Here, I will examine the paleoecological and archaeological evidence for two different scenarios that could explain the presence of the prairie peninsula at the time of Euroamerican colonization: (1) there is nothing odd about tallgrass prairies in the region, given what we know about the Late Holocene climate of the midcontinent; or (2) the prairie peninsula should have been forest given the Late Holocene climate of the midcontinent, but Indigenous land management held back the succession of prairies to forests in large parts of the midcontinent from the end of the mid-Holocene warm period until Euroamerican colonization.

Nothing to See Here

The simplest explanation for the prairie peninsula is that there is nothing to explain. There is a long-standing debate within ecology and paleoecology about the degree to which climate determines the location of biomes and the transitions between them (ecotones), and how rapidly ecotones shift in response to various aspects of climate, such as temperature, seasonality, and aridity. For understanding prairie-forest dynamics globally, one key region has been the Northern Great Plains (Figure 4.1). Pollen studies going back to the 1960s have investigated the movement of the Northern Great Plains FPB since the region was last deglaciated, about 12,000 years ago (Brown

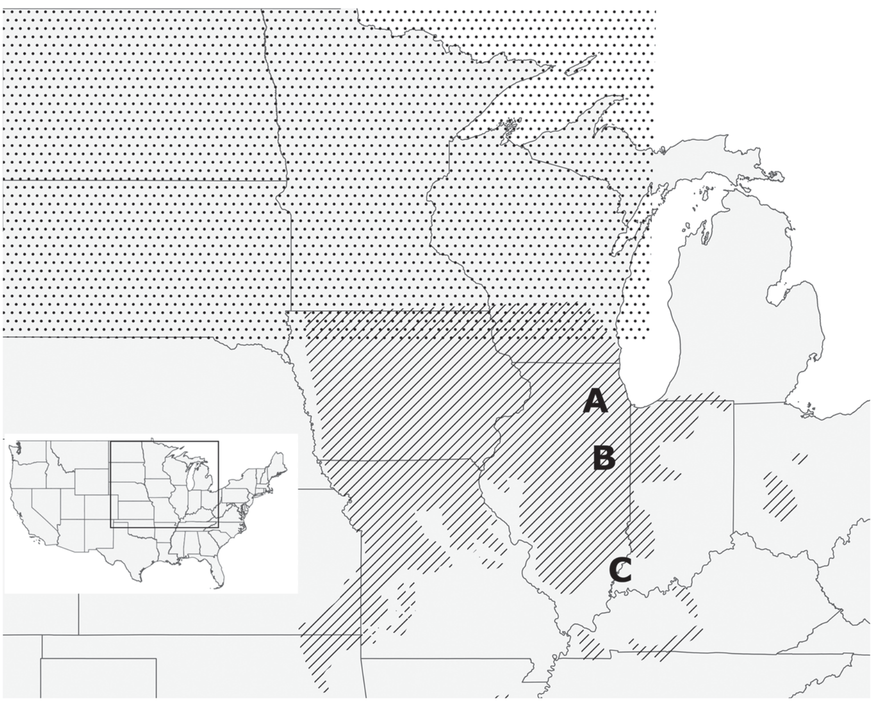

Figure 4.1 Northern Great Plains region, dotted. Prairie Peninsula region, diagonal lines. A, B: paleoecology study sites within Illinois' Grand Prairie reported in Nelson et al. 2006. C: Riverton site, where earliest evidence of domesticated Eastern Agricultural Complex has been recovered.

et al. 2005; Clark et al. 2001; Grimm 1983; McAndrews 1966; Nelson and Hu 2008). Williams and colleagues (2009) drew on this research to map percentage of woody cover over time, using fossil pollen records calibrated with modern surface sediment pollen analogues. Cumulatively, the pollen record shows that the prairie rapidly advanced eastward during the early Holocene until c. 8000 cal BP, reaching its maximum eastward extent by 7000 cal BP, and began to retreat westwards after 6000 cal BP (Williams et al. 2009).

Early researchers used the eastward movement of the FPB on the Northern Great Plains to infer that the mid-Holocene was warm and arid. They initially based their *climate reconstruction* on an *ecological reconstruction* using pollen data (Table 4.1), assuming that the expansion of grasslands was an indicator of hot dry conditions because average climate conditions differ between forests and grasslands today. Forested areas are characterized by higher annual precipitation, especially snowfall; lower annual temperatures; and shorter summers, resulting in less evapotranspiration and more soil moisture (McAndrews 1966). But the pollen record in and of itself does not constitute direct evidence of past climate conditions, and paleoecologists now demand independent proxies for climate, "to avoid the circularity of using pollen data as an indicator of environmental changes and also as a measure of the response of vegetation of environmental change" (Nelson and Hu 2008: 179).

For example, Nelson and Hu (2008) used lacustrine sediment mineral composition, carbonate $\delta^{18}O$, and charcoal influx in combination with pollen from lake cores to independently assess aridity, fire regime, and vegetation throughout the Holocene on the Northern Great Plains. Each indicator registers abrupt aridification around 8000 cal BP, which coincides with the rapid eastward expansion of the tallgrass prairie apparent in pollen records. Independent proxies for climate (e.g., lacustrine sediment mineral composition, carbonate $\delta^{18}O$) also mirror the pollen record for the end of the mid-Holocene Warm Period and a return to a cooler, moister climate by 3500 cal BP (Table 4.2). Like many other researchers who have focused on the Northern Great Plains, Nelson and Hu concluded that, while soil and topography play some role on a local scale (Danz et al. 2011), the location and movement of the FPB is primarily driven by climate – in particular, aridity (Brugam et al. 1988; Clark et al. 2001; Nelson and Hu 2008; Williams et al. 2009). In other words, ecological change on the Northern Great Plains is best explained by extrinsic factors, and the human societies who lived there must have adapted their lifeways as the FPB shifted.

By contrast, in the heart of the prairie peninsula, central Illinois' Grand Prairie (Figure 4.1), we see a lack of fit between paleoclimate data and paleoecology data during the Late Holocene, indicated by shading in Table 4.2. Here, it is worth quoting the most in-depth multi-proxy paleoecological reconstruction of the prairie peninsula sites at length:

> Our [charcoal accumulation] profiles from Chatsworth Bog and Nelson Lake suggest that fire activity become elevated ~500–1000 years prior to the full establishment of prairie, ~6200 yr. BP. Because this change in fire

importance did not coincide with any major shifts in our aridity and vegetational records, it is possible that increased fire ignitions resulted in more burns, contributing to prairie expansion in the eastern prairie peninsula. Both Native Americans and lightning might have been important ignition sources, but evidence of ignitions beyond the historical record is conjectural. *Fires may also have been important for the maintenance of prairies*. For example, a marked increase in effective moisture occurred ~5800–5400 yr. BP, as evidenced by changes in all proxy indicators at both of our sites. This change, however, did not cause woody taxa to expand and prairie taxa to decline, probably because fires remained important.

(Nelson et al. 2006: 2534, emphasis added)

The authors actually highlight two incongruencies in their data: one between climate and ecology proxies, when an increasingly moist climate

Table 4.2 Paleoecological and climate timeline in Northern Great Plains vs. Prairie Peninsula

Northern Great Plains (Nelson and Hu 2008; Nelson et al. 2006; Williams et al. 2009)		*Stage of Holocene*	*Prairie Peninsula, Illinois (Nelson et al. 2006)*	
Paleoecology	*Paleoclimate*		*Paleoclimate*	*Paleoecology*
Plains largely forested, eastward expansion of prairie begins 9000 cal BP	Wet and cool, becoming drier and warmer Abrupt increase in aridity at 8000 cal BP	Early Holocene (11500–8000 cal BP)	Wet and cool, becoming drier and warmer Peak aridity 8500 cal BP	Fire-sensitive forest, with prairie expansion after 9000 cal BP
Maximum eastward extent of prairie occurs 7000–6000 cal BP, followed by westward retreat	Fluctuating aridity, gradually becoming wetter and cooler	Middle Holocene (8000–4000 cal BP)	Arid, gradually becoming wetter, with a 2nd peak in aridity at 6200 cal BP	Becoming more forested. At 6000 cal BP abrupt increase in prairie taxa + fire-tolerant trees
Westward retreat of prairie continues, followed by stasis from 2000 cal BP–present	Less arid	Late Holocene (4000 cal BP-present)	Less arid	Fire-tolerant savannah is stable until Euroamerican colonization

does not lead to an increase in forest around 5,600 years ago, and one in their fire data, where neither ecological nor climate changes accompany a spike in fire activity around 6,000 years ago. Both of these incongruencies could be explained by Indigenous use of fire to manipulate ecosystems. While the authors of this study are correct that there is no way to directly reconstruct fire ignition sources in the past, there is a rich archaeological and historical record from this region that can provide circumstantial evidence for this scenario. I now turn to the hypothesis that within the prairie peninsula, ecological change (or lack thereof) was primarily intrinsic during the Late Holocene. This possibility is suggested by (1) a mismatch between ecologically-independent climate proxies and paleoecological reconstructions in Illinois' Grand Prairie (Nelson et al. 2006), and (2) the regional contrast between the Late Holocene westward retreat of the prairies on the Northern Great Plains and the stasis of prairies and savannas further south.

The Prairie Peninsula Should Have Been a Forest. So Why Wasn't it?

Nelson and colleagues highlight fire as the likely cause of prairie statis during the Late Holocene at their Illinois sites (Nelson et al. 2006). Several variables affect the frequency and severity of fires, which is reflected in charcoal accumulation in lacustrine paleoecological records. These include fuel type and amount, aridity, and frequency of ignition. Perhaps counter-intuitively, increasing charcoal influx is sometimes associated with more moisture in grasslands (Brown et al. 2005; Leys et al. 2018). Paleoecologists hypothesize that more precipitation allows for the accumulation of more biomass on these generally arid landscapes, which turns into more fuel for fires. However, in the prairie peninsula region, with its overall greater biomass, fuel was probably not a limiting factor (Nelson et al. 2006). This leaves aridity (fuel moisture) and ignition frequency as possible explanations for increased charcoal influx. Charcoal influx remains high in the prairie peninsula through a period of maximum humidity around 5400 cal. years BP, leaving only an increase in ignition frequency to explain this charcoal record (Nelson et al. 2006). Sources of ignition can be climatically-driven (lightning strikes) or anthropogenic.

While it is currently impossible to detect either ignition source directly, in places where paleoecological reconstructions for the historic period have been conducted, changes in land use were far more important for determining changes in fire activity than climate. For example, in eastern Oklahoma, researchers examined fire scars on oaks at the FPB and documented a decrease in fire frequency that coincided with the forced removal of the Osage and the settlement of the area by Euroamerican ranchers (Allen and Palmer 2011). This decrease was not correlated with any data related to changes in climate, including aridity (Allen and Palmer 2011). A fine-scale Late Holocene paleoenvironmental record from the Ozarks in southern Missouri shows an era of intensive burning coincident with the known Osage occupation of this region in the historic period, but it is not correlated with any know episode of aridity (Nanavati and Grimm 2020).

Fire was the primary method that Indigenous people in eastern North America used to manipulate ecosystems on a landscape scale. Both their techniques and the ecological results are well-documented in the historical record of the prairie peninsula. On the Grand Prairie, the Illinois people used fire to create a patchy landscape of ecological edges that the French recognized as both anthropogenic and extremely productive (Morrissey 2016; Morrissey 2019). As Morrissey explains,

> In spatial terms, what the protohistorical Illinois did was locate themselves in the midst of migrating plant communities. Exercising their agency, they used fire and other tools to halt and shape these ecological migrations, prioritizing a diverse mix of vegetation and preventing woodlands from crowding out other formations.
>
> (2019: 67)

Indeed, *prairie* peninsula is somewhat of a misnomer, since this region during the time Euroamerican colonization was really more of a vast ecotone, an undulating edge between forest and grassland that was maintained through continuous burning by Indigenous people (Anderson 2006).

Drawing on their own observations and then-contemporary accounts of burning by Indigenous people, early Euroamerican observers concluded that Indigenous people intentionally maintained the prairies using fire in order to create habitat for bison, their most important game animal (Transeau 1935). But the projection of this scenario further back in time was not supported by subsequent archaeological research, which suggested that bison hunting was not very ancient east of the Mississippi, and that ancient Indigenous societies relied on floodplains and forests, not prairies, for sustenance (Simon 2009; Styles and McMillan 2009). Ironically, as the consensus on the prairie peninsula's anthropogenic nature dissolved in the second half the 20th century, the evidence for Indigenous transformation of eastern *forests* using fire mounted. Delcourt and Delcourt's classis paleoecological studies in Kentucky and Tennessee documented the clearance of forests for agriculture beginning around 3000 cal BP (Delcourt and Delcourt 2004; Delcourt et al. 1986; Delcourt et al. 1998). Environmental historians and geographers argued that the open, nut-producing, game rich forests observed by Euroamerican settlers were anthropogenic (Cronon 1983; Denevan 1992). Abrams and Nowacki marshalled extensive ecological and historical data to argue that Indigenous management, mostly using fire, created vast fire-tolerant, nut-producing forests of oak and hickory in eastern North America (Abrams and Nowacki 2008). Since the advent of Euroamerican fire-suppression policies, these forests have been undergoing a process of "mesophication," as fire-tolerant trees are replaced by fire-sensitive and shade tolerant taxa

(Nowacki and Abrams 2008). All of this was consistent with the growing archaeobotanical record, which showed that nuts from fire-tolerant oaks and hickories were staple foods for Indigenous societies in this region for thousands of years.

Unlike the archaeological record, historical accounts of the midcontinent's Indigenous peoples clearly show that prairies were sources of very important foods and part of a lifestyle that relied on habitat heterogeneity on a local scale (Gilmore 1919; Gonella 2007; Moerman 1998; Morrissey 2019). New archaeological evidence casts doubt on the longstanding belief that this lifestyle was new at the time of Euroamerican colonization. First, contrary to conventional wisdom, bison were present on the prairies at least as far east as Illinois throughout the Holocene, and people were hunting them (McMillan 2006). Second, although they have usually been considered floodplain or ruderal weeds, my preliminary data suggest that the wild progenitors of some of the plants domesticated in this region (e.g., *Iva annua*, *Hordeum pusillum*, and *Phalaris caroliniana*) are common in the disturbed and biodiverse prairies created by bison grazing and anthropogenic burning (Mueller et al. 2020). These crop progenitors are dispersed in the dung and fur of bison (Rosas et al. 2008). The combination of burning, bison grazing, and seed dispersal in tallgrass prairies creates dense, easily harvestable stands of the annual forbs and cool season grasses that were cultivated by ancient people in this region along bison trails (Anderson 2006; Coppedge et al. 1998; Mueller et al. 2020).

I have recently hypothesized that plant domestication occurred in this region through the interaction of people and bison, as ecosystem engineers and seed dispersers, on these anthropogenic prairies beginning around 6,000 years ago, when the paleoecological evidence for human maintenance of prairies in Illinois appears (Mueller et al. 2020). It is at this time, during what archaeologists call the Middle Archaic (8000–6000 cal. BP), that the earliest evidence for interactions between people and the plants they would eventually domesticate appear in the archaeological record (Simon 2009). Domesticated sub-species of several crops had evolved by the Late Archaic, c. 4000 cal BP. They first appear as a crop complex at the Riverton site, on the edge of Illinois' Grand Prairie (Smith 2011) (Figure 4.1).

Directions for Further Research

North America's tallgrass prairies are some of the most endangered ecosystems on earth, having been reduced to 1% of their historical extent. Displaced largely by industrial agriculture, these ecosystems are valued by non-Indigenous North Americans for their contribution to biodiversity, rather than as sources of useful plants and animals for human societies. But tallgrass prairies were very important to Indigenous communities, who intentionally maintained prairies on a vast scale for thousands of years using anthropogenic fire. Historically documented tallgrass prairies in the North American midcontinent would have been covered in forests if not for frequent anthropogenic fires after the end of the mid-Holocene. Multiple lines of evidence attest to the anthropogenic nature of this prairie peninsula in the humid midcontinent, and the chronology of prairie retreat and advance on a local scale (Nanavati and Grimm 2020; Nelson et al. 2006). These insights could help us to re-discover tallgrass prairies as productive landscapes shaped by traditional ecological knowledge.

Understanding tallgrass prairies as productive, managed environments also has the potential to reshape our understandings of the origins of agriculture in North America. Current archaeological data and theories do not explain why ancient people managed prairies. Bison, the most obvious prairie resource, are not well-represented in the archaeological record of this region, which is instead dominated by forest and river-dwelling animals. Nor have prairies been considered as sites for the origins of agriculture. In this region, the prevailing theory about the beginnings of agriculture is that people took advantage of yearly flooding to cultivate annual plants on scoured riverbanks (Smith 1992). These data and theories suggest that forests and rivers were the foundation of ancient food production and are not compatible with the emerging body of evidence that Indigenous communities intentionally sustained tallgrass prairies on a regional scale, in defiance of climate change and variability and ecological succession. There will always be a bias in favor of the preservation of riverine archaeological sites, but greater efforts should be made to identify and understand sites in the prairies, especially during the Middle Archaic when human maintenance of eastern prairies likely began.

From paleoecologists, we require more temporally fine-scale studies that focus on the Middle and Late Holocene and explicitly consider the possibility that humans were a factor in shaping ecosystems (Nanavati and Grimm 2020). This kind of work could strengthen the hypothesis explored here – that is, that the prairie peninsula was created by anthropogenic fire – and contribute to other instances of human maintenance of important ecosystem through periods of climate change and variability. Consistently applying Williams and colleagues' (2011) criteria for distinguishing between extrinsic and intrinsic ecological change in the past could reveal other local incongruencies that point to human ecological engineering. In the coming decades, we are faced with the necessity of devising strategies to protect and maintain the ecosystems we rely on for food security when climate change would otherwise transform them. Settler colonial society in North America is not the first human society to live through climate change and variability in this region, but we do have a deficit of detailed ecological knowledge compared with the continent's Indigenous peoples. Though it would have been better to do so hundreds of years ago, it is not too late to learn from their strategies and techniques, or to relinquish control of lands into the hands of more knowledgeable Indigenous managers.

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5 Indigenous Land Use and Fire Resilience of Southwest USA Ponderosa Pine Forests

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Introduction

Fire is a key ecosystem process in many environments (McLauchlan et al. 2020) and was particularly important in shaping the evolution and historical ecology of dry conifer forests in western North America that are dominated by ponderosa pine (*Pinus ponderosa*) and related species (Moore et al. 1999). Because fire has been historically ubiquitous in these forests, the relative contribution of Indigenous burning has often been unclear (Allen 2002). Nevertheless, the impacts of more recent human activities over the past 150 years have unquestionably reshaped the role of fire in these dry pine forests, especially in the southwest region of the United States of America. Overstocking of cattle and sheep beginning in the 1870s first removed grassy fine fuels, thus inhibiting fire spread before logging and active fire suppression in the early 20th century created multi-decadal fire-free periods in forests across the southwestern region of the United States (hereinafter "the Southwest").

The removal of fire by grazing, logging, and active suppression fundamentally reduced the fire resilience of these forests (Coop et al. 2020; Savage and Mast 2005). For these forests, the term "fire resilience" refers to the ability of forest stands to experience fire and maintain their basic structure, function, and ecosystem services while avoiding fire-induced ecological transformations into other biome types, such as grasslands or shrublands (Coop et al. 2020; Stephens et al. 2016). High-severity fires, in which there is a high degree of canopy mortality, create opportunities for such transformations to alternative vegetative states. However, low-severity surface fires are a keystone process in these forests, removing most young conifers and maintaining a widely spaced, open, elevated canopy that is resistant to generating crown fires. Surface fire regimes sustained high fire resilience by shaping fuel structure – it was difficult for fire to get into the canopy, or to travel very far when it did (Moore et al. 1999) (see Figure 5.2A–B). Without fire to remove young trees, the trees could infill and provide both vertical and horizontal continuity of canopy fuels, thus allowing crown fires to establish and propagate (Savage et al. 1996). This reduced the fire resilience of these forests and increased the likelihood of

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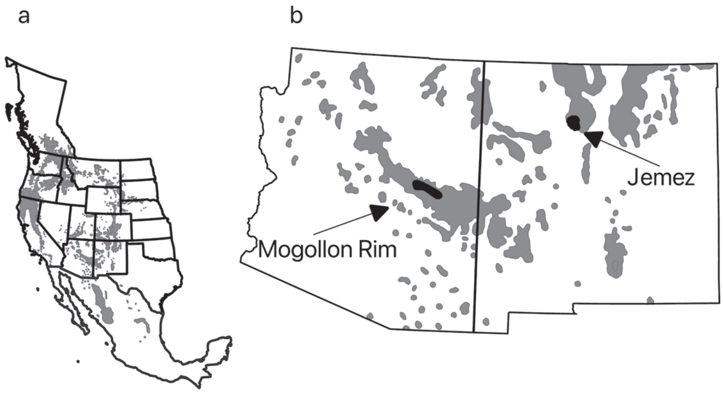

Figure 5.1A–B The distribution of ponderosa pine (gray areas) in western North America (Part A) and in the Southwest US (Part B). The location of the Mogollon Rim and Jemez study areas are indicated by black polygons (Part B).

transformations to alternative vegetative states (see Figure 5.2C–D), such as grasslands or shrubfields depending on the local seed sources, the rootstock of resprouters, and post-fire microclimates (Coop et al. 2020; Guiterman et al. 2018; Savage and Mast 2005; Savage et al. 2013).

Fuel-limited fire regimes such as those that characterized the historical Southwest are potentially vulnerable to periods of reduced fire resilience due to climate-induced changes in ignitions or fuels (Whitlock et al. 2010). Historical surface fires had close relationships with interannual variability in precipitation because of the necessity for abundant and continuous surface fuels for surface fires to spread widely (Swetnam and Betancourt 1998; Swetnam et al. 2016). Years with widely spreading fires – those years when most of the cumulative area burned – tended to be dry years preceded by 1–3 wet years that produced abundant, continuous surface fuel to allow a limited number of ignitions to spread widely through those continuous surface fuels. This sub-decadal wet-dry switching was often associated with El Niño–Southern Oscillation and its influences on rainfall patterns (Kitzberger et al. 2007; Swetnam and Betancourt 1998). While much of the last 1,500 years had frequent wet-dry switching that favored widely spreading lightning fires at decadal timescales, there were periods in the transition from the Medieval Climate Anomaly (c. 900–1250 CE) to the Little Ice Age (c. 1400–1850 CE) (Mann et al. 2009) when such wet-dry switching was less frequent and lower magnitude (Roos and Swetnam 2012), potentially reducing surface fire spread and creating multi-decadal fire-free periods and reduced fire resilience in some Southwest forest stands.

Native American communities have lived in these forests for millennia but their long-term legacies on Southwest fire histories is debated. What were the

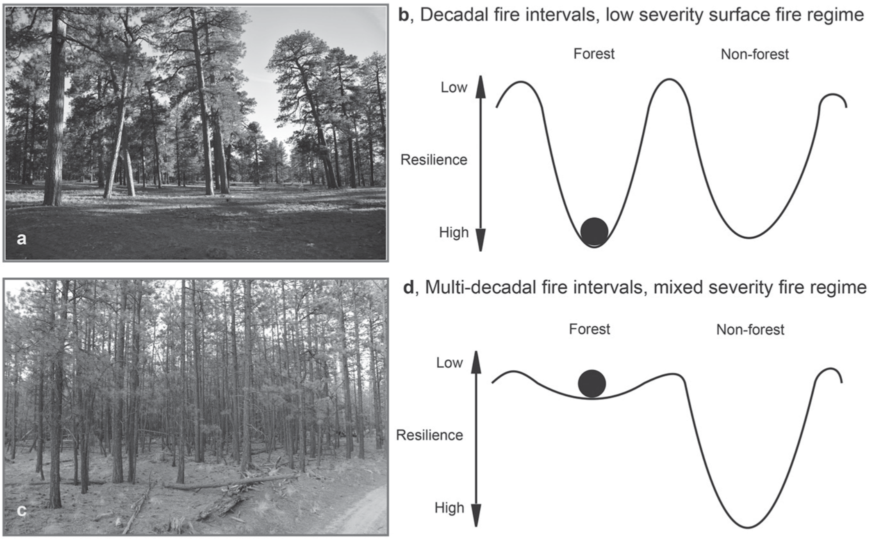

Figure 5.2A–D Illustrations of open-canopied ponderosa pine forest with grassy understory and elevated crown maintained by frequent surface fires (Part A) (Defiance Plateau, AZ. Photo: C. Guiterman), and a hyper dense "doghair thicket" created by a century of fire suppression (Part C) (Jemez Mountains, NM. Photo: C. Roos). Conceptual ball-in-basin diagrams illustrate how frequent surface fires act as a balancing feedback that removes small trees and maintains the open and elevated canopy that is resistant to drought and large hot fires (Part B). By contrast, without frequent surface fires as a key functional process, regeneration runs unchecked, reducing the fire resilience of pine stands and making them more vulnerable to crossing a threshold into an alternative vegetative state (e.g., shrubfields or grasslands/meadows) when fire does return (Part D).

consequences of Indigenous land use and fire management on the fire resilience of these forests? Could the high-frequency, low-intensity Indigenous patch burning documented in the Southwest (Roos, Laluk, et al. 2023; Roos et al. 2021; Swetnam et al. 2016) and elsewhere (Bliege Bird et al. 2012) have improved the fire resilience of these forests in the context of climate variability even with abundant lightning (Allen 2002)? Here we combine archaeology, paleoecology, and paleoclimate reconstructions to show that fire use by Native American communities in ponderosa pine forests enhanced the fire resilience of occupied ponderosa pine forests by providing "response diversity" (Walker et al. 2006) with lightning ignitions. We follow Walker and colleagues in our use of "response diversity" to mean "diversity of responses to disturbance [or environmental change] among species or actors contributing to the same function in the social–ecological system" (Walker et al.

2006). We suggest that Indigenous burning contributed to response diversity and fire resilience in these fuel-limited forests because of their ability to overcome limitations of horizontal surface fuel continuity with more ignitions as climate patterns varied.

The modern wildfire problem in the Southwest is fundamentally a problem in historical ecology. Having been shaped by millennia of low-severity surface regimes, the last century of human land-use has led to a fundamental departure from this historical ecology. Restoration of frequent surface fire regimes in the Southwest is a classic example of applied historical ecology, wherein historical ecological information is applied to contemporary management and ecological restoration (Swetnam et al. 1999). Legacies of Indigenous use have often been left out of these applications, however, as the ambiguity of Indigenous fire management within histories of frequent fire presents interpretive challenges (Allen 2002). Here, we deliberately concentrate on the historical ecology of culturally and temporally variable Indigenous fire management to understand the consequences of Indigenous activities on the fire resilience to support an Indigenous applied historical ecology of Southwest forests.

Archaeological and Environmental Context

We concentrate on ponderosa pine forests in the Jemez Mountains of New Mexico and along the Mogollon Rim in east-central Arizona that were home to ancestors of Pueblo and Western Apache people (see Figure 5.1B). Southwestern ponderosa pine forests span elevations 1,700–2,300 masl and are dominated by one canopy species, ponderosa pine, with rare contributions of piñon (*P. edulis*) and/or various juniper (*Juniperus* spp.) at lower elevations, and Douglas-fir (*Pseudotsuga menziesii*) and Southwestern white pine (*Pinus strobiformis*) at higher elevations. Historically, understory plant communities were dominated by bunchgrasses (especially *Festuca arizonica*), forbs (especially those in Asteraceae and Amaranthaceae), and some shrubs, including various species of oak (*Quercus* spp., which in the case of *Q. gambelii* can also grow in tree form as occasional co-dominants), sumac (*Rhus trilobata*), and manzanita (*Arctostaphylos* spp.). These forests are dotted by rare, small meadows (< 25 ha) with a similar composition of grasses and forbs as were present in the historical understory (Allen 2004; Kaldahl and Dean 1999).

Average annual precipitation in these forests ranges from 420–500 mm. Annual precipitation has strong bimodality of peak rainfall during the summer monsoon in July, August, and September and a second, smaller mode from cyclonic winter storms from the Pacific from October to March. April, May, and June are reliably dry, creating conditions each year when fires can ignite and spread. Average low temperatures are above freezing from April through October, the primary growing season for both wild plants and crops, although late (spring/summer) and early (summer/autumn) frosts are not uncommon (Kaldahl and Dean 1999).

Frequent, low-severity surface fires were historically ubiquitous in these dry conifer forests in the Southwest and across western North America (see Figure 5.1A) until livestock grazing, logging, and fire suppression led to a near total cessation of wildfires beginning in the late 19th century (Swetnam and Baisan 2003; Swetnam et al. 2016). Fire-scarred ponderosa pines can be tree-ring dated to the year and often to the portion of the growing season when the surface fires occurred (Dieterich and Swetnam 1984). From c. 1700–1900 CE (the period of greatest sample replication in the tree-ring fire-scar record) (Margolis et al. 2022), fires tended to occur in a stand once or twice per decade in surface fuels during the arid foresummer (April–June) or at the onset of the monsoon with dry lightning storms (July) (Fulé et al. 1997; Moore et al. 1999).

Native populations have been using the Mogollon Rim and Jemez Mountains for at least 12,000 years (Haury 1957; LeTourneau and Baker 2002), although long-term occupation of these areas did not begin until c. 200 CE in the Mogollon Rim region (Haury and Sayles 1985 [1947]) and 1100 CE in the Jemez area (Roos et al. 2020; Roos et al. 2021). Here, we concentrate on the perennial Ancestral Pueblo occupation in both areas after 1100 CE and the intensive Western Apache use of the Mogollon Rim by 1550 CE. Between roughly 1000 and 1275 CE, the Ancestral Pueblo archaeology of the Mogollon Rim was characterized by widely distributed small villages, hamlets, and farmsteads in the form of 5–30 room masonry pueblos (Herr 2001; Mills and Herr 1999; Mills et al. 1999). Although the settlements were small, this was the period of greatest population size in the region (Newcomb 1999) and community religious structures (Great Kivas) integrated dispersed communities (Herr 2001). Grinding stones to process maize (*Zea mays*) and paleoethnobotanical remains all indicate a dependence upon farming (Huckell 1999). By the late 1200s CE, populations coalesced into a few large pueblos separated by 20+ km. Ethnographically and archaeologically, we know that Pueblo people used fire for myriad purposes, including burning to establish and clean agricultural fields and irrigation ditches; to promote wild plant resources for food, medicine, and craft materials, as well as for promoting habitat for preferred game animals; and in religious pilgrimages and practices (Bohrer 1983; Gifford 1940; Roos et al. 2021; Sullivan and Mink 2018; White 1943).

The Mogollon Rim area was also home to Western Apaches, who were seasonally mobile forager-gardeners who lived in ponderosa pine forests and adjacent woodlands from spring through autumn as part of seasonal mobility patterns (Graves 1982). Apache Elders describe traditions of their presence in eastern Arizona since time immemorial (Welch and Riley 2001). Apache archaeology is notoriously challenging, but a combination of archaeology (Herr 2013), ethnohistory (Forbes 1960), and oral tradition (Basso 1983) highlight intensive Western Apache use in the Mogollon Rim region by 1550 CE. Western Apaches used fire in many activities, including those described for Ancestral Pueblo peoples (Buskirk 1986; Griffin et al. 1971).

Hemish Pueblo people maintain oral traditions about their migration to the southern Jemez Mountains (Tosa et al. 2019), a process that has now been dated to as early as 1100 CE (Roos et al. 2020; Roos et al. 2021). These were small farming groups. For the first couple of centuries, populations and settlements were relatively small – no more than several hundred people (Kulisheck 2005). By the early 1300s CE, a much larger wave of migration grew the population to several thousand, with much of the population concentrated in large, aggregated villages and towns that were the home settlements for an agricultural society (Liebmann et al. 2016). Early in the 17th century, Spanish missionaries forced Hemish people into the valley below the forested mesas and the Hemish population declined by more than 85% in a matter of decades. Hemish people maintain at least 27 uses for fire and wood (fuel) that vary from domestic, village, agricultural, and landscape contexts (Roos et al. 2021).

Historical Ecology, Climate, and Resilience

Most of the area burned in Southwest ponderosa pine forests happened in years with large, widely spreading surface fires (Swetnam and Betancourt 1998). Prior to livestock grazing, logging, and active fire suppression by government agencies, widely spreading fires occurred in these forests typically at decadal intervals. However, on millennial timescales, multi-decadal intervals between widely spreading fires sometimes occurred, and likely created areas of fire refugia, where fuels could accumulate and young trees could establish. This resulted in reduced fire resilience of particular forest stands when fire did return (see Figure 5.2C–D). Co-occurring wet periods, unusually long intervals between fires, and tree-recruitment events have been documented in multiple places in the Southwest, particularly for the early 1600s CE (Brown and Wu 2005; Swetnam and Brown 2011). Most fire-scar records, however, are not old enough to cover the period of interest here (i.e., the past millennium). Instead, we use a published regression model of past fire activity that calibrated tree-ring precipitation reconstructions to a regional network of 45 fire history sites and >700 fire-scarred trees across the southern Colorado Plateau that encompasses both of our study areas (Roos and Swetnam 2012). This 1,400-year reconstruction of climate-driven fire activity indicates that climate conditions potentially produced several multi-decadal intervals between years with widely spreading fires (see Figure 5.3D). This was especially the case before the period best documented in the fire scar record (i.e., 1700 CE to present). In addition to multiple 20+ year long periods between widely spread fires, there were four periods of 50+ years in the fire activity reconstruction wherein annual climate fluctuations were lower amplitude and fire-spread may have been limited. During those periods (1170–1226, 1255–1314, 1360–1454, and 1543–1622 CE), wet-dry switching may not have produced abundant and continuous surface fuels, or these fuels were too moist to allow fire to spread, and fire resilience declined in some stands.

As a result, those stands may have been vulnerable to high-severity fire and transformations to alternative vegetative states (Savage and Mast 2005).

Temperature and precipitation have also varied in ways that could influence fuel production, flammability, fire spread, and the potential for crown fires. Prolonged wet periods (pluvials) can reduce fire spread by making fuels too moist to burn and can increase germination and stand infilling by synchronizing recruitment during these pluvials (Brown and Wu 2005). Droughts can impact fire spread and crown fire potential by making fuels in mesic topographic positions more flammable (Margolis et al. 2017). The Medieval Climate Anomaly (MCA; c. 900–1250 CE) was characterized by multiple warm and dry episodes (see Figure 5.3B–C) when mesic forests would have been more vulnerable to crown fires (Cook et al. 2010; Salzer et al. 2014;

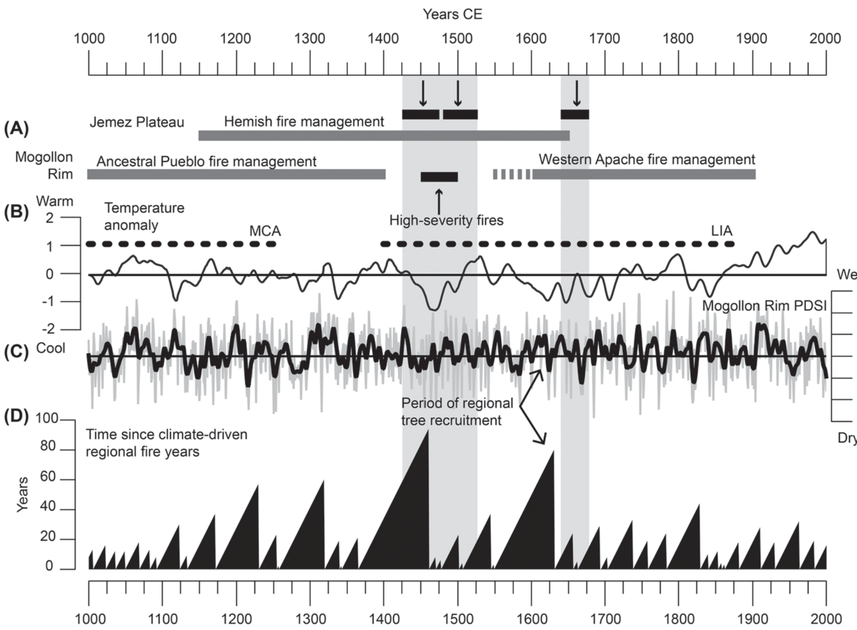

Figure 5.3A–D Synthesis of periods of Native American fire management (deliberate burning, wood harvesting; gray bars in Part A) and high severity fires (black bars in Part A indicated with arrows) in the Mogollon Rim (Roos et al. 2023) and Jemez Plateau areas (Roos et al. 2021) and temperature (Salzer et al. 2014) (Part B) and Palmer Drought Severity records (Cook et al. 2010; Williams et al. 2020) (Part C), and the cumulative duration since climate predicted fire years from Roos and Swetnam (2012) (Part D). Approximate boundaries for the Medieval Climate Anomaly (MCA) and the coldest period of the Little Ice Age (LIA) are marked (Part B). The early 17th century period of regional tree-recruitment associated with prolonged cool, wet conditions and longer fire-free periods is indicated (Part C) and (Part D).

Williams et al. 2020). Because they burned so frequently, drier forests would have required some combination of reduced fire spread and increased germination to build the vertical fuel continuity to become vulnerable to crown fires. Across the region, studies of buried strata in alluvial fans have identified periods of episodic high-severity fires in contexts with both semi-arid and mesic mixed-conifer forests. From Flagstaff, Arizona (Jenkins et al. 2011), Durango, Colorado (Bigio et al. 2017; Bigio et al. 2010), and both the Jemez (Fitch and Meyer 2016) and Sacramento Mountains (Frechette and Meyer 2009) of New Mexico, pyrogenic debris flows were most common during the warmer and drier MCA and in the periods of megadroughts in the 1400s and 1500s, or co-occur with reductions of fire spread predicted in the regional tree-ring model (Roos and Swetnam 2012). As significant as these high-severity fires could have been, during the past two millennia they probably burned much smaller patches when compared to modern high severity fires (Allen 2016; Bigio et al. 2010; Orem and Pelletier 2016).

In the eastern Mogollon Rim region, there is stratigraphic evidence of high-severity fire and post-fire erosion in the mid-1400s (see Figure 5.4D), but only in watersheds that were spatially distant from locations of intensive Native American settlement and land use (see Figure 5.3A) (Roos, Laluk, et al. 2023; Roos 2008). We lack evidence of high-severity fires during the MCA but cannot exclude that they occurred at a distance from Indigenous settlements but in occupied areas where periods of Indigenous patch burning bracketed a period of lighting-driven low-severity fires (see Figure 5.5A–B). High-severity fires during the mid-1400s are consistent with prolonged fire intervals between 1360 and 1454 CE in the fire-climate model, and warm and mild to wet periods between 1350 and 1425 CE, when increased germination of pines would have been likely (see Figure 5.3B–D), but it is notable that areas with Indigenous burning did not experience this because of the legacy of prior land-use.

In the Jemez Mountains, charcoal, pollen, and tree-ring records indicate that Ancestral Pueblo (Hemish) farmers managed woody fuel and fire for centuries between 1100 and 1650 CE (Roos et al. 2021; Swetnam et al. 2016) (see Figure 5.5D). Tree-ring records indicate that most of these fires were small and patchy, creating a fine mosaic of burned and unburned areas (see Figure 5.5C). As a result, fire-climate relationships were disrupted (Swetnam et al. 2016), further reducing the impact of multi-decadal climate variation on fire occurrence. Spatially distant from the areas of most intensive Hemish land use and burning, however, there is soil charcoal and tree-ring evidence for high-severity fire patches and the conversion of forests to alternative vegetative states (Guiterman et al. 2018; Roos and Guiterman 2021). For example, two large (100–300 ha) patches of Gambel oak (*Quercus gambelii*) shrubfields were established by high-severity fires in the 1400s and in 1522 CE (see Figure 5.4B–C). A third was established in 1664 CE within decades of the cessation of Hemish fire management (see Figure 5.4A). In all three cases, the pyrogenic transition to alternative states occurred within or shortly

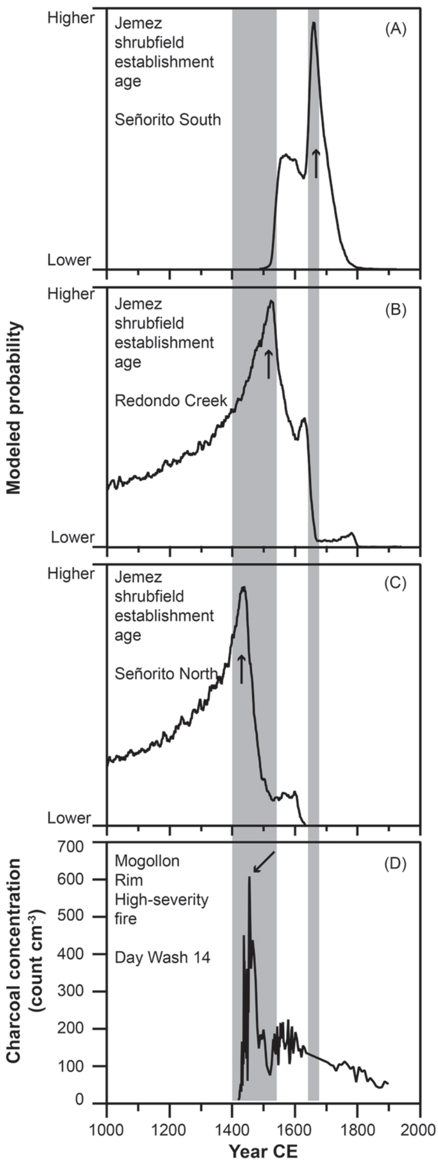

Figure 5.4 Evidence for the timing of high-severity fires (gray bars) at locations at a distance from Indigenous fire management in the Jemez Mountains (Parts A-C; Roos and Guiterman 2021), and in the Mogollon Rim area (Part D; Roos et al. 2023). Parts A-C are the modeled probability of the pyrogenic establishment of permanent shrubfields (an alternative stable state to pine forests). Part D is charcoal concentration from sediments that match modern analog samples from high-severity fires. Arrows indicate high severity fire dates for each location.

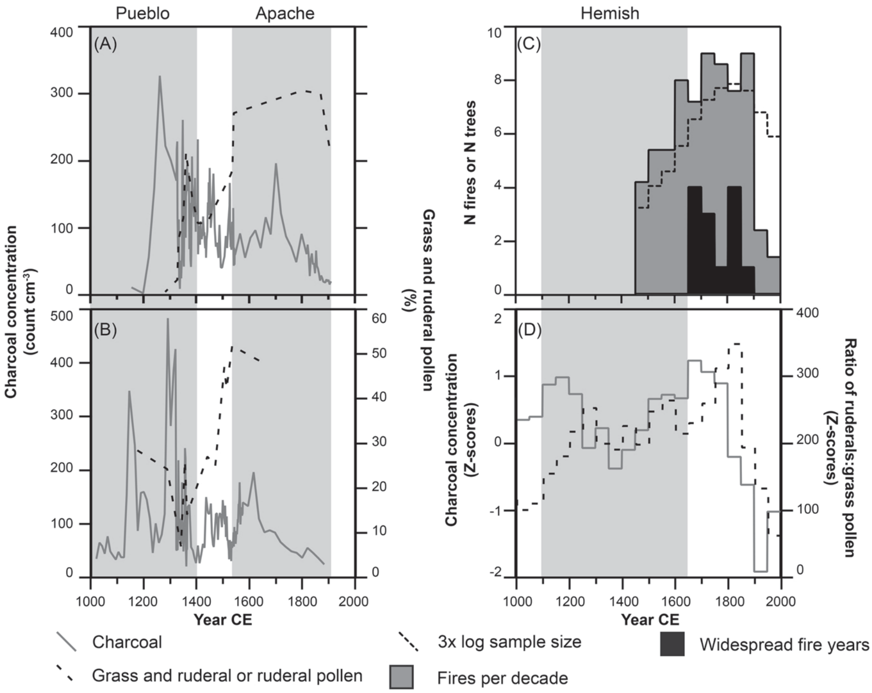

Figure 5.5A–D Charcoal concentrations and pollen of disturbance-loving plants for the Forestdale Valley 6 (Part A) and 10 (Part B) on the Mogollon Rim (Roos et al. 2023), and the Jemez Plateau (Part D) (Roos et al. 2021). Tree-ring based frequencies of all fires (gray) and widespread fires (>25% trees scarred, black; Part C), and sample depth (dashed line). These illustrate elevated charcoal concentrations at both during Ancestral Pueblo occupations of the Mogollon Rim (1100–1400 CE) and Jemez Plateau (1100–1650 CE). Apache burning produced lower charcoal because of repeated patch burning in fine fuels (grasses and ruderals) that produce less charcoal when they burn.

after periods of reduced fire spread in drier contexts and wet and warm or very wet periods conducive to germination and stand infilling (see Figure 5.3). Shrubfields are much rarer in the Ancestral Jemez landscape (2.2% of forest area) than the larger landscape (5.1% of forest area) and those shrubfields in the Hemish landscape may post-date the period of intensive occupation indicating that transitions to alternative vegetative states due to high-severity fire were rare or absent in the most intensively used cultural landscape (Roos et al. 2021).

In the Southwest, recent high severity fires and transitions to alternative vegetative states began in the 1950s, after 50–80 years of fire exclusion (Cooper 1960; Savage and Mast 2005). Four such periods of 50+ years between 1170 and 1622 CE (Roos and Swetnam 2012), when climate drivers of fuel production were infrequent, indicate that forests were equally vulnerable to fire during geographically and culturally variable Indigenous occupations of the Southwest. In the Mogollon Rim region, in areas that were never perennially occupied or were depopulated by 1325 CE, stratigraphic evidence indicates that high severity fires or pyrogenic transitions to alternative vegetative states happened between 1360 and 1450 CE, the longest period of reduced fire spread in the fire–climate model and following a warm and wet period that would have supported stand infilling (Roos, Laluk, et al. 2023; Roos 2008). By contrast, in areas where Indigenous burning persisted until at least 1400 CE there is no evidence for high severity fires or state transitions. These patterns of Indigenous moderation of fire severity are replicated in the Jemez Mountains. In both cases, the long fire-free interval from the fire–climate reconstruction coincided with warm and wet periods that would have facilitated synchronous germination and recruitment of young conifers (Brown and Wu 2005; Swetnam and Brown 2011), potentially reducing the fire resilience of some stands where fire was limited.

Discussion

Small patch burning produces pyrodiversity that can have important ecological consequences. Differences in the spatial pattern of fire can allow fire sensitive taxa to coexist with flammable ones (Trauernicht et al. 2015). Even when fire frequencies are roughly similar between Indigenous and lightning-dominated fire regimes, cultural burning can modulate fire–climate relationships (Bliege Bird et al. 2012; Roos, Guiterman, et al. 2022; Swetnam et al. 2016; Taylor et al. 2016).

As demonstrated here, ancient landscapes that were subject to Native American fire management were more resilient to episodes when climate may have reduced fire spread than landscapes that were not intensively managed. One property that supports ecological resilience is the redundancy of species (or agents) within key functional groups (functional redundancy) (Walker et al. 2006). In this sense, Native American ignitions were "functionally redundant" with the primary non-human ignition source, lightning. This redundance has sometimes made it unclear just how important Indigenous burning was (Allen 2002). However, in this context, Native American burning also gives the system "response diversity" (i.e., redundant agents do not respond to change in the same way) (Walker et al. 2006), in that cultural ignitions do not respond to climatological, environmental, or social conditions the same way that lightning does (if lightning responds at all). When surface fuels are abundant, spatially continuous, and dry enough to burn, this may not matter for fire resilience because lightning ignitions can spread widely. During climate episodes when fire spread was limited by discontinuous surface fuels or fuel moisture then the response diversity provided by Native American burning could have been critical for maintaining fire resilience by keeping low-severity surface fires on landscapes where it otherwise may have been less frequent (see Figure 5.2).

This conclusion has implications for fire management today. Dry pine forests that had historical fire regimes dominated by frequent, low-intensity surface fires are widespread across western North America (see Figure 5.1A). These same forests are now fragmented by roads, fire breaks, and other human infrastructure, including homes in the wildland–urban interface, but more than a century of fire exclusion has made for an overabundance of fuels to carry fires into and through the forests and their canopies. Even as managers leverage natural ignitions for "wildland fire use" (van Wagtendonk 2007) and emphasize management for forest resilience (Stephens et al. 2016), Native American fire management has a lot to offer for ensuring that ecologically and culturally beneficial fires happen where and when they are needed, especially when lightning ignitions and fire spread are insufficient to support the same goals. The historical ecology of Indigenous fire management both supports calls for incorporating cultural burning (Lake et al. 2017) but also the more general call for more prescribed burning and even managing other human ignitions to support fire resilient forests in western North America (Kolden 2019), thus making the case for an Indigenous applied historical ecology of Southwest forests (Swetnam et al. 1999).

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6 Different Relational Models have Shaped the Biocultural Conservation over Time of *Araucaria araucana* Forests and Their People

Ana H. Ladio and Mauricio Sedrez dos Reis

Introduction

Araucaria araucana, known as Pewen (in Mapuzungum, Mapuche language), is a cultural keystone species for Mapuche people (see Figure 6.1A). The Mapuche people are the largest indigenous group in Argentina and Chile and are characterized by their strong maintenance of ancestral traditions (Ladio and Molares 2017). Archaeological, historical–ecological , and ethnobotanical evidence shows that the species has been part of the food sovereignty of Pewenche and their ancestors since 3000 BP. The seeds (pine nuts), called ngulliw in Mapuche language, are collected from this conifer (Reis et al. 2014).

The Pewen landscape has held a strong material and symbolic significance for these communities since before the arrival of European colonizers in the region. According to their cosmovision, humans and non-humans that inhabit Pewen forests establish relationships of reciprocity and permanent dialogue (Mariman et al. 2006). For this reason, the communities that inhabit their forests define themselves as Pewenche, Pewen's people (che in Mapuche language), with a great sense of belonging and pride.

However, after the military onslaught known as the "Desert Campaign" (late 19th century), Pewenche communities were decimated and uprooted from the Pewen forests in Argentina (Bandieri 2005), and suffered the same fate in Chile after the so-called Pacification of Araucanía (Mellado and Cossio 2015). For the surviving communities, the only option was to become livestock herders – mainly cows, sheep, and goats – in addition to collecting pine nuts in marginal areas. According to Sanguinetti (2008), these practices would be detrimental to the regeneration of Pewen, given that the animals feed on their seeds and other accompanying plant species of the forest.

The geographical distribution of this endemic gymnosperm covers the latitudinal strip between 37º S and 42º S on both sides of the Andes Mountains in Argentina and Chile, occupying an estimated area of 5,000 km^2 (González et al. 2006). The area of occurrence of *A. araucana* involves a wide range of environments with precipitation ranging from 4,000 mm to 900 mm annually (Veblen et al. 1995), including both mixed forest types and practically pure formations in the Patagonian steppe (González et al. 2006).

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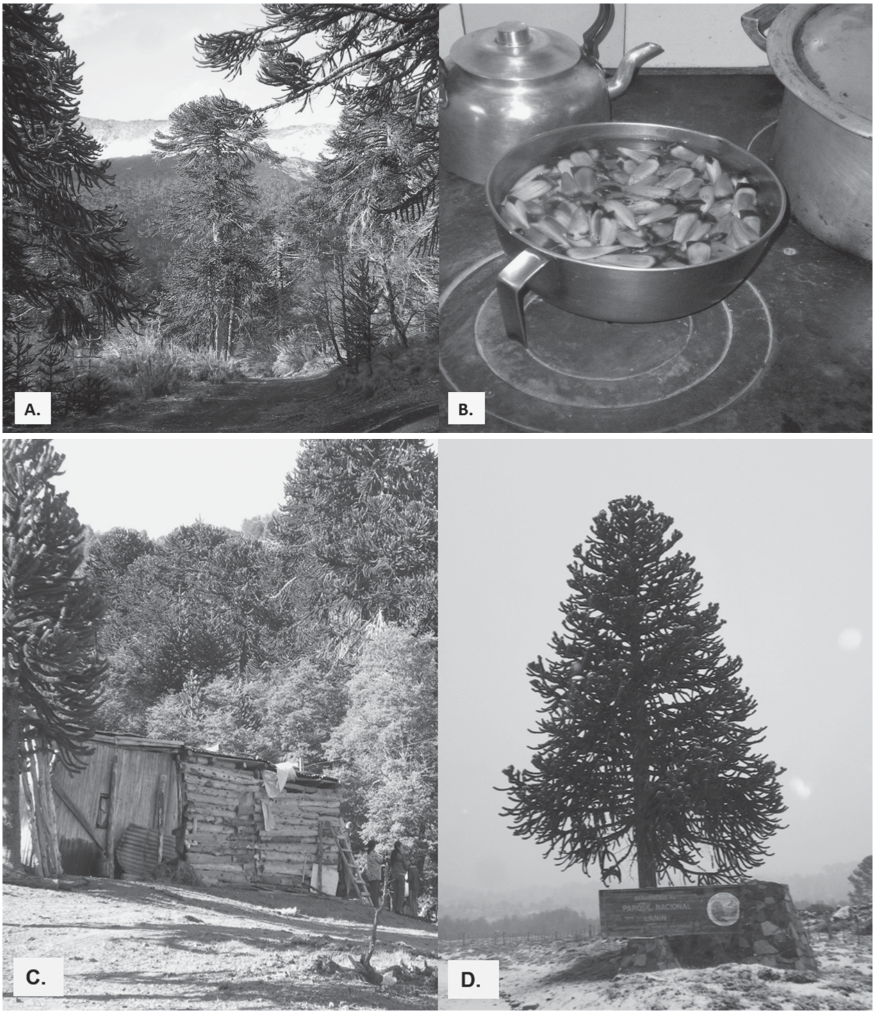

Figure 6.1A–D *Araucaria araucana*, Pewen (in Mapuzungum, Mapuche language) is a cultural keystone species for Pewenche people. Part A: Pewen forests in Neuquén (Argentina). Part B: Boiled seeds as traditional food recipes. Part C: Pewenche transhumant family and their temporary home in Pewen Forest. Part D: Pewen tree in Lanin National Park (Argentina). (Photographs by Author).

The Pewen forests are not exempt from the effects of climate change, especially considering their location in the extreme north of Patagonia, where temperature and precipitation variability will be accentuated in the future, with a tendency towards higher temperatures and greater drought (Hadad et al. 2020). According to Varas-Myrik et al. (2022), the Pewen forests located at lower altitudes at the southern end of their distribution are at maximum risk from climate change because of their lower adaptability to future temperatures in the region. The species is currently considered threatened according to the International Union for Conservation of Nature (IUCN) (Premoli et al. 2013).

Pewen stands out for its high adaptive capacity and particular interactions with diverse animals and humans (Reis et al. 2014). All these aspects allow the species to counteract its slow growth and its limited reproductive and seed dispersal capacity (Sanguinetti 2016). Likewise, they allow it to compete to resist changing scenarios governed by disturbances and climate variability, which are the expected forecasts for the region (Sanguinetti 2016). *A. araucana* is a species that responds well to disturbances, such as fire, and that regenerates in open environments, such as steppe. It also tolerates shade in its initial stage of development. Its seeds are large and its dispersal is barochoric; that is, the seeds fall to the ground under the effect of gravity and their own weight (Reis et al. 2014).

Pewen forests are a paradigmatic case to understand the role of culture and colonial processes in the modeling of territories over time. The current problems of conservation of species in Argentina and Chile also place Pewenche, their millenary inhabitants, in a situation of vulnerability, although this aspect receives less attention among conservationists. Historical ecology provides a useful framework for understanding these long-term processes regarding *A. auracana* and their people, mainly involving the key concepts of "cultural forests" (Balée 2013) and "domesticated landscapes" (Erickson 2006).

Particularly, relational models (RMs) are a conceptual tool that could contribute operationally to the analysis of the spatial–temporal pattern of people's use of Pewen over time. These consist of a set of preferences, principles, and virtues that explain the degree of responsibility toward nature that different cultural groups have developed (Muradian and Pascual 2018). These models call for taking into account the diversity of cognitive frameworks conditioning the interaction with different species.

Starting from the model presented by Muradian and Pascual (2018), who identified seven different RMs, we have described and analyzed the RMs that have prevailed in Pewen forest management over time (18th–21st centuries) to reflect on its contribution. This analysis was conducted from an ethnobiological approach and considered the foundations of a decolonized position in ethnobiology (McAlvay et al. 2021). In addition, the RMs were adapted to the local context. We described and analyzed RMs in the case of Pewen forest management based on bibliographical sources. The analysis of these models allowed us to evaluate and integrate fragmentary and scattered information on the subject and to glimpse the importance of a more complete study of local RMs, their temporal historical variation, and the factors that affect them.

Pewenche Local Ecological Knowledge

In addition to their use as food, Pewen forests in their fruiting season have been used by Pewenche as hunting grounds, given that they are attractive sites for fauna such as pudú (*Cervus pudu*), huemul (*Cervus chilensis*), guanacos (*Lama guanicoe*), pumas (*Puma concolor*), and birds (Montalba and Stephens 2014). Aagensen (2004) noted that Pewen trees are currently used on rare occasions for house construction, but more commonly their fallen branches are used as fuelwood.

Ngulliw are usually consumed boiled or roasted on fire in different preparations (see Figure 6.1B) mainly to obtain flour, with which bread, soups, stews, and stuffing are made (Cortes et al. 2019; Canale and Ladio 2020). The preparation of the popular drink called "mudai," used in traditional festivities, also stands out (Herrmann 2005). Studies currently conducted that have measured the impact of pine nut harvesting practices by human populations have shown that if these practices are maintained in a traditional manner, they do not seem to affect the regeneration opportunities of the species (Gallo et al. 2004; Sanguinetti 2008).

The practices of transhumance and collection of pine nuts have been key to the supply of this food since time immemorial for Mapuche communities (Ladio 2001). From pre-Hispanic times to the present day (see Figure 6.1C), practices of transport, exchange, barter, and storage of pine nuts have been used as strategies to extend the period of use and place of consumption (Aagesen 1998; Ladio 2001; Herrmann 2005). The transhumant Mapuche communities that live far from forests consume part of the pine nuts directly at the collection sites, but a large quantity (more than 100 kg per trip) is destined to be transported to the sites of residence (Ladio and Lozada 2000).

Methodology

Our methodology was based on an in-depth bibliographical analysis involving a wide range of sources on the historical ecology, ecology, archeology, history, and ethnobiology of Patagonia. First, a bibliographic review was performed through the databases Scielo, Scopus, and Google scholar, using as keywords the scientific name of the species and the terms Pewen or Pehuen. Next, we applied a content analysis to the documents, looking for ideas and testimonies that were related to the RMs proposed by Muradian and Pascual (2018). We selected 40 texts in total that offered valuable information on this topic. Given the varied nature of the documents and their distinct epistemological approach, the data analysis was qualitative-interpretative (Albuquerque et al. 2014).

Regarding the seven RMs, further details can be found in Muradian and Pascual (2018), but in the present paper we describe them as follows: (1) domination, when there is intentional degradation of nature, considered as an obstacle and without rights; (2) exploitation (termed by the original authors as utilization), when nature is only considered an element of consumption and services; (3) wardship or custody, when nature is protected for its intrinsic value; (4) stewardship, when practices are performed allowing the perpetuation of ecological cycles and cultural life systems simultaneously; (5) ritualized exchange, when a relationship of obligation with nature is established; (6) devotion, when nature is considered a deity superior to human beings; and (7) detachment, when nature is invisible to humans and the relationship is non-existent. In the present work, some RMs were re-adapted (considering the local and historical circumstances of Patagonia) and also interpreted from an ethnobiological point of view.

Results

Through qualitative analysis of the distinct documents on the history of the use of *Araucaria* forests, six RMs were evidenced: domination, exploitation, stewardship, custody, ritualized exchange, and devotion. Studies of Pewenche communities show RMs centered on stewardship, ritualized exchange, and devotion. However, these three typologies, identified by Muradian and Pascual (2018), in this context need to be unified because they are not representative in the case of Pewen. Together with stewardship, ritualized exchange and devotion are part of what we referred to in an integrated way as mutual nurturing, following Pazzarelli and Lema's (2018) ideas; that is, interactions that bear sociality links and flows of substances between humans and non-humans. Mutual nurturing is an RM that involves simultaneous management practices, ritual exchange ceremonies, and devotion that cannot be separated in any way.

It should be noted that we did not find studies that allow us to interpret the case of detachment in Pewen forests. It is very likely that several people who live with the species do not feel any attachment to it, that this tree is invisible in their lives, and that they do not feel any responsibility for its conservation. According to Rozzi (2012), in the current global society, the knowledge that most citizens, teachers, authorities, and students have about biological and cultural diversity is very low, acquired in urban contexts, and distanced physically, emotionally, and ethically from nature (Rozzi 2012). This pattern of disconnection was also evidenced in Patagonian cities in a study conducted with teachers (Ladio and Molares, 2013), so further research should be done in this area concerning *A. araucana*.

The RMs that are significant for Pewen forests are described in detail.

Stewardship

The stewardship RM is the founding basis of the relationship of Pewenche with Pewens and is based on the pillars of kume mogen (good living in Mapuzungum), which are: complementarity, solidarity, reciprocity, and balance with all human and non-human beings that inhabit the Mapu (Ladio and Molares 2017). Toledo Martel and Krell (2007) and Reis et al. (2014) showed that Pewenche maintain a close and intimate relationship with this tree that is absolutely regulated; their communities have developed social control mechanisms that ensure that seed harvesting is accomplished in the post-dispersion phase and in compliance with strict cultural norms that avoid excessive harvesting. On the other hand, it includes concrete management practices that favor forest regeneration and the individuals' care based on the local ecological knowledge that has been accumulated over millennia and transmitted from generation to generation.

According to Reis et al. (2014), sexual and/or asexual regeneration mechanisms have been favored by Pewenches' practices, either intentionally or accidentally, since ancestral times. For example, using small-scale fire for hunting, used by populations before its prohibition by the governments of Argentina and Chile, was a practice that took advantage of the successional dynamics of the species and that could potentiate a process of mutual advantage (co-evolution), expanding the opportunities for development of Pewen forests and increasing the availability of food for human groups associated to these environments.

On the other hand, the practice of storing pine nuts involves burying them in silos, swamps, or orchards during winter to keep them fresh for up to a year after harvesting (Ladio and Lozada 2000). Often these pine nuts germinate, according to the villagers themselves, and these new shoots are later protected by families in their peri-domiciles (Ladio and Molares 2017).

According to Reis et al. (2014), the existence of sophisticated storage practices and long-distance transport of pine nuts, evident in both the archaeological and ethnobotanical records (Ladio, 2001; Herrmann, 2006; Solari et al. 2007), and the speed with which the species reached the full extent of its occurrence after the glaciations and before the arrival of Europeans reinforce the importance of human groups in the construction of *Araucaria* forests for food production. In this sense, several authors have suggested the importance of anthropic action by cultivation or abandonment of seeds in sites associated with ancient routes that were used in the past by Indigenous people (Hajduk et al. 2009).

Another fundamental aspect is the evidence of intentional seed cultivation during the "piñoneo" at collection sites as part of cultural norms of gratitude to Mother Earth and protective forces (Ladio and Molares 2017). Following Herrmann (2006), factors facilitating germination of the seed recognized by Pewenche include mainly manually digging it into the soil.

There is also an empirical record of practices of favoring and incentivizing Pewen trees, protecting them from frost, healing branches in case of wounds or pests, and so on, as well as transplanting saplings – generally in domestic settings – when people observe that the saplings are in unfavorable situations at the original sites (Ladio and Molares 2017). Without these practices, many of these individuals would no longer exist.

These are intentional management practices based on a relationship of interdependence and of mutual nurturing because Pewen trees provide food and Pewenche must care for these trees. As pointed out by Pazzarelli and Lema (2018), mutual nurturing is a relationship of protection and care allowing life to continue, involving practices that enable an exchange of vital forces between people and plants. The mode of relationship does not separate nature from culture (Ladio 2020); Pewen trees and Pewenche are members of the Ñuke Mapu (Mother Earth in Mapudungum) who possess equal rights. The Pewenches' dominant emotion is a sense of belonging to the Pewen forest: the shared identity between people and trees because both are part of an indivisible totality.

Ritualized Exchange and Devotion, Mutual Nurture

The stewardship RM does not occur alone, but occurs in complementation with ritualized practices and devotion. However, as we already stated, these cannot be described separately as proposed by Muradian and Pascual (2018). The Mapuche cosmovision is not an exchange toward an entity considered superior; it implies an egalitarian vision of mutual nurturing that is based on effective management practices conducted by people toward a plant considered sacred.

As explained above, the interdependence of Pewenche communities with Pewen, and its significance for identity and survival, is of such magnitude that it is expressed by placing the tree at the center of their spiritual and religious life, for example, through cults. Pewen forms part of one of the most important collective ceremonies for Pewenche, called Ngillatun (Herrman 2005), where the sacred and central area (rewe in Mapuzungum) in which this three-day, open-air ceremony takes place contains a Pewen tree (Toledo Martel and Krell Rivera 2007). In this ceremony, held annually, the commitments of mutual care are renewed (Ladio and Molares 2017); through offerings, dances, and prayers, the Pewenche give thanks and request for fertility of the land, good harvest of pine nuts, good weather, good reproduction of animals, and abundant rain, and also ask for certain needs of the community. These RMs are framed in practices of association with a way of interaction tending to balance: plants are equal to humans and the emotion that directs humans is the obligation to maintain balance through the necessary cults. If these ceremonies are not performed or Pewen is misused, ngen (the protective spirits in Mapudungum) can punish people or communities (Ceballos et al. 2012).

Domination

From the 16th century – with the beginning of Spanish colonization in the region – until the 19th century, Pewen forests and their people suffered the domination RM in a drastic way. For example, in the words of the conqueror

Pedro de Valdivia in 1550 in Chile, "I had the food that was in the region gathered and put it in our fort, and I began to run the land and conquer it. [. . .] In four months, I brought peace to all the land, which will serve the city that I have settled here" (Torrejon and Cisternas 2003). In this domination typology, forests were seen as spaces to conquer because wild nature was considered to be opposed to civilization. This type of model has destruction and hostility as its interaction mode. Pewen trees were seen as inferior elements, and relationships were based mainly on emotions of fear of the unknown. As was pointed out by Aagesen (2004), colonizers saw the forest as an enemy and they often eliminated forest cover with fire in their quest to clear land for pasture or cultivation. Pewen trees (and their people) were seen as an obstacle to progress, so trees were felled and intentionally decimated, jeopardizing the Pewenches' food security as their food system disintegrated. Few documents give an integrated account that notes that (in the same way as with Pewen) a process of Pewenche genocide began in both countries through persecution, enslavement, and systematic slaughter; besides that, the results of infectious diseases strongly reduced their population numbers, and their lands were plundered (Aagesen 2004; Aigo and Ladio 2016).

The main tool of forest domination was fire. Father Felipe Gómez de Vidaurre, in his *Historia y Geografía Natural y Civil del Reino de Chile* (of 1789, but published in 1889), warned the government to prohibit the clearance by fire. He stated that "in Chile the least precaution is not taken and each one believes that he or she is entitled to make use of clearance by fire without any responsibility for damages to the government or the neighbor." In other words, in the following century, a destructive and domineering outlook was still in force. At the time of the Independence (19th century), forest exploitation increased even more, especially with the aim of clearing land for agricultural activities (Montalva et al. 2014). In the case of Argentina, we have not found documents that account for this typology because the permanent presence of settlers and colonizers generally began in the 19th century (Bandieri 2005).

From an ethnobiological point of view, this typology implies a dualistic model of interaction in which nature and culture are totally separated and forests are considered objects of domination (Ladio 2017). Certainly, this typology continues to operate and affect Pewen forest and Pewenche to this day, but due to cultural changes, advances in environmental conservation, and human rights issues, the expressions of domination have been explicitly reduced, at least in the case of forests. However, there is no doubt that the oppressive character of many of the current forestry (Toledo Martel and Krell Rivera 2007) or hydroelectric (Hasen Narváez, 2012) projects on Pewenches' lands, without prior consultation and based on dispossession and denial of the cultural other, show that this typology is still very much in force over Pewenche (Mariman et al. 2006), reproducing to this day logics sustained by ideological frameworks of the superiority of the conquerors' western Christian culture.

In this sense, the current Mapuche communities are not passive; they resist, fight, and question this domination model over Pewen forest and over nature (Alonso and Diaz 2018; Ladio 2020). Examples of this resistance are the mobilizations against the construction of the Ralco dam, a move that became a symbol of resistance of the Mapuche Pewenche communities of Alto Bío Bío in Chile (Herrmann 2006), and their resistance to the Pulmari project in Argentina (Valverde 2010; Alonso and Diaz 2018). This resistance to the domination RM over nature by Mapuche societies shows that the model is an interaction typology totally opposed to the philosophical foundations of their good life (kume mogen in Mapuzungum) (Ladio 2020).

Exploitation

Documents show that from the mid-19th century to the mid-20th century, Pewen forests suffered from the exploitation typology in both Chile and Argentina. Coinciding with the advent of the European industrial society that demanded more products and services, forests that produced indispensable primary resources were exploited to sustain the population growth and the settlers' lifestyles, cornering Pewenche to the most unfavorable areas, organized in community reserves or in fiscal lands of precarious tenure (Ladio and Lozada 2000; Aagesen 2004). Following Montalba and Stephens (2014), in 1872 the pressure to expand agriculture into Pewen forests and Pewenche was acute. The loss of these forests began to accelerate mainly due to timber use by settlers who began to inhabit the area (Montaldo 1974; González et al. 2006). According to Herrmann (2006), Pewen forests were used for the construction of railway sleepers, tunnel linings, ship masts, ceilings, furniture, as well as for mine construction and paper pulp.

By the beginning of the 20th century, 580,000 ha of forest had been cleared in Chile (Montalba and Stephens 2014). According to González et al. (2006), the effects of the European–Chilean colonization and then of logging in the 20th century were dramatic. For example, it is estimated that between 1930 and 1970, 30,000 ha of Pewen forests were cut in the Curacautín/Lonquimay area alone (Otero 2006). In Argentina, in the area of Lake Moquehue between 1943 and 1988, more than 500,000 m3 of *A. araucana* wood was harvested (J.O. Bava, personal communication).

This form of interaction is based on a utilitarian logic; that is, a model based on the rules of the market that was born with the industrial revolution, is still in force in the market logic of the present, and whose objective is the accumulation of wealth through the production of goods and services. The dualistic separation of nature and culture is part of the model, where nature is an object of exploitation (Ladio 2020). Pewen forests and Pewenche remain without rights, continuing forms of domination, although the motivation that dominates this other typology is the maximization of profits based on power over others. Different historical documents report that people from Pewenches' communities were used as slaves or laborers with no or little pay for agricultural activities (Mariman et al. 2006; Escolar and Saldi 2018). This typology is nourished not only by inequality, but also by the dispossession of indigenous lands of communal use transformed into private property.

However, since the mid-20th century *A. araucana* was listed first as "vulnerable" and then, in the beginning of the 21st century, as "endangered" in the IUCN Red List of Threatened Species, designations that consolidate landscape protections and harvesting prohibition for the species both in Argentina and Chile (Premoli et al. 2013). From then on, the species became involved in tourism projects (Herrmann 2006) and in the commercialization of pine nuts. In the case of those forests that remained in private ownership, tourism implied the commercial exploitation of scenic values, according to Muradian and Pascual (2018). The commercialization of pine nuts in large cities was a new form of commercial exploitation. For example, Pewen seeds are currently used as part of gastronomic tourism in the village called Villa Pehuenia (Neuquén, Argentina), where different types of products such as alfajores, preserves, and beverages are developed. While Pewen seeds are used as an object of commercialization for tourists, they are not part of the food customs of the locals, who do not seem to pay attention to aspects related to their conservation and overexploitation (Cassani 2013).

Tourism projects in Pewenches' communities have been organized under the logic of cultural and/or gastronomic tourism, which allows communities to transmit their culture as Pewenche (Cortes et al. 2019); they are an economic option given that most of the lands have been impoverished and have suffered serious deterioration due to long term overgrazing.

Custody

This custody RM regarding Pewen corresponds to the creation of national parks and/or provincial reserves that protect the species. For example, in Argentina, 35% of the current remnants are in protected areas, although several populations are degraded (Sanguinetti 2008). Most of the remaining Pewen are found in the Lanin National Park (PNL for its acronym in Spanish) created in 1937 (Parque Nacional Lanin 2011) (see Figure 6.1D). Since its creation, the abandonment of agricultural and forestry activities and the stimulation of tourism in its dependencies have been encouraged. Seven Mapuche communities live within the park, and three others are outside the park boundary but have their summer cattle grazing lands inside the park. First, Pewenche communities that remained in the jurisdiction of the park were forced very precariously to stop collecting pine nuts or to do so under strict and very restrictive special harvesting and grazing orders, affecting the survival of Pewenche families (Valverde 2006). Conversely, in the case of the colonists, controls on the use of the species were absent or applied with less insistence. Undoubtedly, a policy of expulsion of Pewenche settlers was implemented (Valverde 2006). This stage was marked by the exclusion or violation of the rights of pre-existing Pewenche populations in the area in order to establish protected areas, followed by the almost total marginalization of Pewenche members.

Similar situations are described for Chile. According to Aagesen (1993) and González et al. (2006), 50% of the distribution of the species is protected in various Chilean conservation units (National Parks: Laguna del Laja, Conguillio, Nahuelbuta, Tolhuaca, Huerqueheu, and Villarrica; National Reserves: Ralco, Malleco, Malalcahuello, Nalcas, China Muerta, Galletué, and Hualalafquén). However, the remaining Pewen populations are also highly degraded and/or threatened with high levels of fragmentation (Reis and Ladio 2012), and Pewenche have suffered exclusion from these lands.

This typology is based on the conception that the best way to protect a species is to separate forests from people and that forests should be cared for through strict control and delimitation rules given by specialized technicians that allow the reproduction of ecological cycles and the provision of ecosystem services of the forest. The interaction mode is preservation; plants must be cared for from a dualistic vision that separates nature from culture (Ladio 2020). From this vision, Pewen has an intrinsic value for which it must be preserved and the species has rights to be protected by law. The linked emotions are the love for the scenic, the aesthetic, and the pristine spaces.

According to Reis and Ladio (2012), the Pewen prehistoric, historic, and current management practices by Pewenche communities were not considered when the protected areas were delimited. In other words, the role of the ancestral human communities in the construction of Pewen forests has not been taken into account; in fact, these favorable anthropic processes have been stopped and emptied of their cultural uses and practices. In this sense, numerous examples of landscapes considered by science as "natural" are actually the product of human action over hundreds or thousands of years, as is the emblematic case of the Amazon rainforest (Levis et al. 2017) and the *Araucaria angustifolia* forests in Brazil (Reis et al. 2018). This decoupled view of nature and culture could jeopardize the environmental sustainability of many of the world's forests; it is known that about 40% of the best-protected green areas are in Indigenous peoples' hands and that their conservation has depended on their ancestral management practices (Ladio 2020).

Fortunately, this model of stewardship has been changing over time, especially with the advent of co-management in PNL in the year 2000 and the processes of recognition of community ownership in Neuquén (Argentina). Co-management can be defined as a situation in which two or more social actors negotiate to share the responsibilities of administration, management, and control over a territory or resource, seeking to integrate western forms of knowledge with the knowledge of local communities in order to develop sustainable practices (Trentini 2011). Currently, PNL is conducting joint actions based on interculturality with Pewenche communities to ensure the simultaneous survival of families and forests, understanding the cultural role of forests and the processes of co-dependence. Pewenche communities have become central allies for Pewen conservation; however, asymmetrical relationships still persist and represent permanent challenges for the Pewenche (Trentini 2011).

Conclusions

The different RMs shown in the present work demonstrate the importance of indigenous cosmologies in forest conservation. This chapter also shows that RMs involve biocultural processes of formation and transformation. That is, they are changeable and can vary over time according to the socio-cultural context. Finally, it is evident that the mutual nurturing RM of Pewenche communities is a model that has an environmental ethic that would be key to achieving greater sustainability in the use of the native edible plants of Patagonia.

RMs are useful as heuristic frameworks of analysis and serve as a first generalized approximation of the variety of cognitive approaches that exist with respect to a species. Knowing this variety would allow minimizing, transforming, or resolving with socio-environmental justice, interculturality, and equality the socio-environmental conflicts that are generated by different cultural outlooks. RMs make it possible to identify the limits, differences, and disputes among the different RMs in a territory only if they are analyzed from a historical, situated, and decolonized viewpoint that can integrate the complex processes of dispossession and subjugation that continue to affect the relationship between nature and culture, especially in the case of indigenous communities.

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7 Ancient and Ongoing Land-Use as Climate Change Mitigation in Ts'msyen, Haíłzaqv, and Wuikinuxv Homelands

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Despite decades of research on the topic, the notion of Indigenous peoples' homelands as culturally mediated and influenced spaces is still contested. Some government scientists, consultants, and bureaucrats in British Columbia (BC, Canada) assert that Indigenous and local knowledge systems, as they relate to environmental management and climate change, are largely anecdotal and not "scientific" enough to be utilized (McQuaid 2022). Debates about Indigenous peoples' historical and ongoing land-use also continue to be challenged in scientific and legal arenas, where it is generally asserted that Indigenous peoples in the Pacific Northwest of North America were only passive "hunter-gatherers" with little effect or impact on their lived landscapes (e.g., Narine 2022). Archaeologists and environmental managers dealing with material evidence of historical land-use are also perpetuating a "pristine myth" by failing to sufficiently contemplate the broader cultural landscape and environment within which people lived (see Lepofsky et al. 2020).

Here, we present research at the intersection of Indigenous/traditional knowledge and historical ecology in an age of climate change, documenting the transformation and management of people–plant landscapes in Ts'msyen, Haíłzaqv, and Wuikinuxv homelands. Forest gardening, orcharding, and regional settlement patterns have contributed to local biodiversity and elevated soil quality, while enhancing peoples access to important plant foods. These ancient and ongoing land-use practices are one avenue for mitigating climate change impacts and vulnerabilities (e.g., Turner, Cuerrier, and Joseph 2022). As seen in other chapters throughout this volume, human land-use has, in part, driven ecosystem changes throughout North America for thousands of years. We highlight a specific set of practices contributing to those changes, namely forest gardening and orcharding, and report on the knowledge, scale, and impact with which Ts'msyen, Haíłzaqv, and Wuikinuxv peoples modified their lived landscapes. We show that people did not merely adapt to or engineer technofixes to changing and variable climates; rather, through millennia of observation, experience, and lessons learnt, people created cultural landscapes to optimize both foodsheds and ecological systems within

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their own social institutions, governance structures, and culturally relevant pathways (see Berkes 2018).

Research focusing on the application of traditional knowledge to understand climate and biodiversity change in the Pacific Northwest has demonstrated the extent to which Indigenous peoples' unique perceptions and responses to climate change are rich, nuanced, and unequivocal (Cruikshank 2001; Turner and Clifton 2009; Thornton 2011). Emphasis on traditional ecological knowledge (TEK), landscape perspectives, and oral histories has lead researchers to conclude that many Indigenous communities on the coast are especially vulnerable and already impacted by climate change (Wyllie de Echeverria and Thornton 2019). Ts'msyen, Haíłzaqv, and Wuikinuxv homelands are known to be particularly sensitive to climate change and in recent years, compounded with unfettered resource extraction, have been impacted by ocean acidification, decreasing soil quality, floods, and drought. This has resulted in unpredictable fluctuations in staple food supplies (e.g., salmon, herring) and changing abundances and distributions of culturally important plant and animal species. These findings reinforce what people on the ground already know and have catalyzed an urgent call to better understand and act on lessening external and internal vulnerabilities of climate change, which unevenly impact community members the most (Sultana 2022). As climate change impacts and resource exhaustion (e.g., logging, mining, oil and gas) continue to weaken soil health and ecosystem services (e.g., pollination) and diminish biomass in Ts'msyen, Haíłzaqv, and Wuikinuxv forest systems, there are growing concerns that forest and food productivity will continue to be catastrophically reduced. Traditional food systems like forest gardening and orcharding, and traditional land-use byproducts like midden-enhanced forests, may be avenues for considering adaptive and culturally relevant strategies for balancing both biodiversity and food production in a constantly changing climate.

As historical ecologists attempting to understand social–ecological systems of plant management, we have attempted to move away from underscoring evolutionary/hyper-adaptive models and emphasize historical and localized contexts instead. We will first explore how some land use practices such as forest garden management and settlement patterns have had enduring and positive impacts on biological and functional diversity in Ts'msyen, Haíłzaqv, and Wuikinuxv territories. Second, we will show how historical–ecological research is informing current restoration and climate change mitigation projects in Wuikinuxv communities. Finally, we will demonstrate, to some extent, the importance of centring place-based narratives, unique community histories, and governance structures within our research praxes. We argue that failure to fully consider issues of land sovereignty and the social contexts within which "traditional knowledge" is exchanged obfuscates the purpose of this research in the first place (Williams and Hardison 2014). Based on a more comprehensive understanding of past and ongoing land-use in all the three communities, we hope to offer insights and a practical framework for examining traditional management practices that reinforce Indigenous self-determination as buffers against the effects of climate change.

Historical–Ecological Perspectives

Historical–ecological methods allow us to broaden definitions of ecology within an open-ended and extended framework that includes people as novel actors in all ecosystems. Equally important is that *history* is centralized as a critical component of how we define variables like change, success, and resilience, which will often be measured at a time scale that goes beyond the written record to include archaeological and paleoecological data and written and oral texts (Crumley 2019). Ts'msyen territory in north-western British Columbia is home to more than 5000 people whose archaeological heritage and oral histories span more than 12,000 years of occupation (Marsden 2002; Armstrong 2022). Some Ts'msyen land-use strategies have resulted in biologically rich forested ecosystems called *forest gardens:* semi-open forests of small fruit and nut trees, berry shrubs, and edible herbaceous plants and root foods. Broadly speaking, forest gardens can include sparsely mixed maple (*Acer* spp.) and birch (*Betula* spp.) in the top canopy layers of the forest; a sub-canopy layer of Pacific crabapple (moołks; *Malus fusca*), beaked hazelnut (wineeym desx; *Corylus cornuta*), black hawthorn (sexsaasax; *Crataegus douglasii*), saskatoon berry (gyem; *Amelanchier alnifolia*), wild cherry (q'elámst; *Prunus* spp.), and red elderberry (ło'ots; *Sambucus racemosa*); a shrub-layer of salmonberry (mu'gawks; *Rubus spectabilis*), various species of blueberry and huckleberry (sm'maay; *Vaccinium* spp.), soapberry (aas; *Shepherdia canadensis*), and highbush cranberry (łaaya; *Viburnum edule*); and a ground layer of wild onion (*Allium cernuum*), northern rice root (miyuubmgyet; *Fritillaria camschatcensis*), wild ginger (*Asarum caudatum*), and other herbaceous species. These foodsheds have been recently documented, alongside orchards of Pacific crabapples (described below) and are more biologically and functionally diverse than their surrounding conifer forests, which are more typical of the bioregion (Armstrong et al. 2021).

The combination of these specific food plants occurs exclusively at archaeological village sites and were managed to increase the productivity of desired foods and medicines. Using archaeological and ethnographic data, we have documented a number of forest garden indicator species like Pacific crabapple, hazelnut, and northern rice root that fall outside of their apparent natural range and are likely the result of ancient transplanting and encouragement (Turner, Armstrong, and Lepofsky 2021). Forest gardens are the definition of original (Indigenous) permaculture—integrated systems that create native plant foodsheds, balancing food yield and ecosystem processes so as not to deplete the soil or rely heavily on outside sources (e.g., extensive fertilizing, heavy watering, fossil fuels, etc.). The principles of permaculture are broad, but generally focus on the importance of system design, the cultivation of localized plant species, and the use of natural patterns and processes (like rain, succession, and microclimates) to optimize growth. Such practices tend to reduce negative or exhaustive impacts to the environment and lessen overall impacts and labor input.

These practices of working with natural biophysical phenomena, managing for succession, and tailoring management to both human and environmental needs are inherently adaptive to large-scale shifts in social–ecological systems (see Ford and Lepofsky and Solomon this volume). For example, despite more than 150 years elapsing since the cessation of management (when people were forcibly removed from their communities) forest gardens persist. Previous research has found that Ts'msyen-modified forest gardens offer a host of both ecosystem functions and services, such as habitat and resources for large mammals and pollinators amid relatively homogenous conifer landscapes (Armstrong et al. 2021). As climate change rhetoric tends to focus on the negative impacts people have on their lived landscape, Indigenous land-use and management systems offer an alternative perspective: that peoples' food procurement and land-use strategies can have positive impacts—ones that endure for centuries.

Ts'msyen forest gardens are observed today as relict ecosystems and as such, they are, of course, not static—they have changed and rearranged through time. Similarly, Ts'msyen societies are not fixed—people have subverted, made mistakes, reorganised, and reconfigured. For example, Ts'msyen oral texts are full of examples wherein people mistreated the land, overharvested, or were cavalier about resources. In 1936, Hereditary Chief Niss'daxok (Gitselasu) recorded oral narratives about the ancestral city of Temlaxam where acrimonious salmon, goat, and grizzly bears exacted revenge on people—in some cases killing whole cities for abusing the land. The survivors of the village went on to create new, less destructive societies where resources were revered or at least respected and not destroyed wantonly. Niss'daxok noted that:

> *Great disasters are the landmarks of a people who are wise. They mark the ending of a time of error. They set a starting point for a better mode of life.*
> (Wright 1962: 41)

As a result of living in the same land base for millennia Ts'msyen people had to ensure the ongoing productivity of resources through flexible styles of stewardship and mechanisms of ownership to ensure moderate and skilled harvests. Mistakes were learnt from and culturally coded into management strategies and protocols which were once foundational to forest garden management and are still summoned today. In the Ts'msyen community of Gitselasu, forest gardens continue to grow at the village of Gitseax. The village was previously thought to be around 250 years old, but using historical–ecological methods (analyzing soil formation processes, palaeoethnobotanical remains, radiocarbon dating), we have dated the forest garden to 480 +/– 26 cal. BP, effectively pushing back the date of occupation and analyses and showcasing the potential longevity of such skillful management practices (Armstrong et al. 2023).

Haíłzaqv and Wuikinuxv homelands, nestled in between the Pacific Ocean and the Coast Mountain range (see Figure 7.1), comprise one of the largest temperate rainforests in the world. Highly productive and biologically diverse, the territories are characterised by islands, inlets, forests, mountains, and deeply incised valleys. Thousands of years of continuous occupation by Haíłzaqv and Wuikinuxv has fostered an acknowledged prosperity of both people and ecosystems, which is reflected in the eco-cultural richness of the region today (Deur and Turner 2005). Inter-generational oral histories and historical–ecological evidence points to continuous and comprehensive use and modification of the landscape, despite it being considered "wild" and "untouched" by colonial outsiders (Deur and Turner 2005; Deur et al. 2013). People have inhabited these landscapes for at least 14,000 years (McLaren et al. 2018). Material evidence of occupation and land use includes the concentration of midden materials, dense deposits of shell, charcoal, ash, rock, bone, and other artefacts and organic matter—engineered at landscape scale (Roksandic et al. 2014; McLaren et al. 2015). Cultivation practices like selective harvesting, fertilization, tilling, transplanting, pruning, and burning—which have been employed for millennia—have also resulted in material changes in the vegetative landscape (Turner 2014).

Fertilization was a particularly common practice for promoting plant productivity in orchards and berry patches. People intentionally discarded waste products at the base of plants, incorporating seaweed, rotting wood, ash, clamshells, and animal remains into the soil (Deur and Turner 2005). Controlled burning at mixed severities was another common practice for modifying plant communities and controlling forest successional stages, which has been employed across this landscape for at least 700 years (Hoffmann et al. 2016). Practices like these are passed down over generations, through oral histories and lived experiences, and continue to this day (Housty et al. 2014).

The legacies of burning and fertilization are evident in the formation of unique soil signatures. Of particular interest is the neutralized pH and enhanced nutrient content of the soil, which have been shown to have a positive effect on contemporary plant communities. Notably, a pH closer to neutral allows nutrients to become more biologically available, which is favorable for plant growth (Mclean 1983). The historical use of fire leaves behind charcoal and ash, both of which increase soil pH, modify nutrient availability (especially of phosphorus), and enhance biological activities (Demeyer et al. 2001). Enriched soils that contain charcoal and higher levels of nitrogen and phosphorus are known to significantly increase plant growth and nutrition (Glaser, Lehmann, and Zech 2002). These conditions offer plants a refuge from the water-logged and nutrient-poor soils characteristic of coastal temperate rainforests (Banner et al. 2005).

Figure 7.1 Ts'msyen, Haíłzaqv, and Wuikinuxv study areas encompass vast territories throughout the inland and coast of British Columbia (Canada). Specific study areas are highlighted here.

Historical–ecological studies in the territory have shown that long-lived Haíłzaqv and Wuikinuxv villages have soils with more neutral pH, higher nutrient content, higher cation exchange capacity, and more organic matter (compared to surrounding forest controls) (Trant et al. 2016; Fisher et al.

2019). Research shows that some habitation sites tend to host plant communities with greater cultural importance and higher nutrient requirements (Fisher et al. 2019), while supporting taller and wider trees with higher wood calcium (Schang, Cox, and Trant 2022). Building on this research and considering three plant species with high cultural value for Haíłzaqv and Wuikinuxv, one of us (Hunter) investigated how peoples' unique histories and local ecologies affected important life history traits, specifically, enhanced nutrient leaf content of salal (nk̓vas in Haíłzaqv; nk̓wàs in ʼWuìk̓ala; *Gautheria shallon*), false azalea (ƛ̓ṇ́q̓wás in Haíłzaqv; ƛ̓ṇq̓was in ʼWuìk̓ala; *Menziesia ferruginea*), and red huckleberry (ǧvádṃ in Haíłzaqv; ǧwàƛ̓as in ʼWuìk̓ala; *Vaccinium parvifolium*). Each of these are important food plants with a long history of use. Salal and red huckleberry are prized for their productive berries, and false azalea for an edible fungus (p̓sp̓iy̓ú yis l̮uáł in Haíłzaqv; *Exobasidium sp. affin. vaccinia*; (Compton 1993)). Despite more than a century elapsing since fertilizing, there was a significant and lingering fertilization effect of nutrients from habitation sites, notably from phosphorus and sodium (Hunter 2021). Phosphorus and sodium content of sampled plant leaves was significantly higher on some habitation sites, which likely affected plant growth factors like better flower formation and seed production (Malhotra, Sandeep Sharma, and Pandey 2018). Likely most relevant to Haíłzaqv and Wuikinuxv is the fertilization effect on fruit. Sodium was higher in all shrub species, which also can be associated with improved plant growth (i.e., greater root and shoot biomass) and, in some cases, can compensate for potassium deficiency (Kronzucker et al. 2013).

The patterns observed among culturally important and specific plant species in Haíłzaqv and Wuikinuxv homelands are a result of ancient land-use (both active and passive), which has not been intensely altered in 125+ years. The tragic history of colonization and dispossession in this region has led to these habitation sites being without intense human occupation for over the last century. Despite this, peoples' use and occupation of the region has left an impactful legacy of beneficial soil conditions and, consequently, these sites continue to fertilize and promote the health and vigor of contemporary plant foods.

Like the example of forest gardens in Ts'msyen territory, Haíłzaqv and Wuikinuxv human-modified soils that are nutrient-rich and benefit plant communities exemplify the role that people have in creating and maintaining productive ecosystems. This work adds to the body of knowledge, both oral and written, that shows that plants can be important indicators of ancient human activities, and that long-term human use of sites has an important impact on biodiversity patterns we see today. Through repeated occupation of their territories for at least 14,000 years (McLaren et al. 2020), it is evident that coastal Indigenous communities have developed land-use practices that enriched nutrient-limited ecosystems. In a time of overlapping environmental crises—like climate change and biodiversity loss—it is important to be aware of the positive influence humans can have on the environment

Figure 7.2 Clockwise from top left: Exposed shell midden on Calvert Island, Haíłzaqv and Wuikinuxv territory; Pacific crabapple (Malus fusca) fruit; Patsy Drummond, Gitselasu community garden director in Gitsaex forest garden; Wuikinuxv community restoration event in February 2020.

and how this can offer a hopeful direction for resource management into the future (Figure 7.2).

Climate Change Mitigation and Restoration

Climate change and other environmental damage caused by unrestrained resource extraction (e.g., excessive logging, commercial fishing, mining) has adversely affected place-based communities who depend on and make livelihoods from the biodiversity, productivity, and integrity of their immediate environment (Liu et al. 2007). In many instances, land and ecosystems have become distressed in the absence of the management practices that once sustained them (Senos et al. 2006; Hoffman et al. 2017; Hoffman et al. 2019). Ecological restoration is one means of shaping, protecting, and conserving biologically diverse and culturally important ecosystems like forest gardens, orchards, and midden sites that enhance plant productivity and food availability. The practice of restoration is a process aimed at supporting the recovery of an ecosystem that has been degraded, damaged, or destroyed

(Gann et al. 2019) often by industrialized cultures and centralized colonial governments (Senos, Lake, and Turner 2006). Ecological restoration requires in-depth knowledge about ecosystems and their more-than-biophysical dynamics, including relationships with people; their values, activities, and patterns of resource use; and the impacts and interactions of both throughout time (Uprety et al. 2012).

Place-based communities like Wuikinuxv are well positioned to facilitate ecocultural restoration initiatives that are sensitive to past and future human land-use. An example of this is seen in the Wuikinuxv Nation's Pacific crabapple (lhènx̌ in 'Wuìk̓ala; *Malus fusca*, hereafter referred to as crabapple) orchard restoration project, which began in early 2020. The intent of this project is to increase productivity of crabapple trees throughout the territories by restoring historical orchards and cultivating volunteers (trees which have grown up on their own, as opposed to being deliberately planted).

Pacific crabapple is an iconic plant for dozens of coastal Indigenous communities; it is a dominant species in forest gardens, named in over 31 languages, and was important in ancient and historical diets (Turner 2014). Historical–ecological evidence supports the long-term interaction between Indigenous peoples and crabapple management throughout the coast. In Wuikinuxv territories, crabapple trees were used for multiple purposes: the hardwood was used for tools such as spoons and digging sticks, the bark was chewed for hunger suppression, and licorice ferns (*Polypodium glycyrrhiza*) and lichens (*Usnea* and *Alectoria*) were collected from crabapple branches and used as medicines and materials (Compton 1993). The fruits of crabapple trees are a culturally important food, served and gifted at feasts throughout the territories (Compton 1993). They can be eaten fresh, dried, or stored in oil or water (Compton 1993). Additionally, it is recognized that crabapple fruits are an important food source for bears, birds, and other animals throughout Wuikinuxv territories (J. Walkus personal communication 2021).

Wuikinuxv ancestors actively tended crabapple trees for generations. Elders have memories of several methods of tree management: (1) fertilizing with salmon carcasses and/or seaweed, (2) pruning limbs, (3) "cleaning" overgrown moss and lichens from tree branches and, (4) transplanting crabapple trees into groves or orchards near habitations sites (J. Walkus personal communication 2021). The cultivation and management of crabapple trees resulted in the establishment of crabapple orchards often with productive and concentrated fruit outputs—enough to supply the people and wildlife of the territories.

Violent colonial policies in the region have disrupted, among other things, traditional Wuikinuxv land management practices and some crabapple trees have not been managed in over 80 years, which may be the reason they no longer fruit. Furthermore, commercial overfishing and fluctuating water levels and temperatures due to climate change have decimated local salmon stocks. Salmon and crabapple fruit are two important food sources for grizzly and black bears (*Ursus arctos* and *americanus*, respectively) (Adams et al. 2017). The simultaneous declines of fish and fruits has resulted in bears scavenging in the village for food, creating potentially dangerous human–bear interactions. Western methods of bear control often result in bears being killed by Conservation Officers, which upset Wuikinuxv Nation members (J. Walkus personal communication 2021).

The Wuikinuxv crabapple orchard restoration project was developed to support bears and strengthen Wuikinuxv–landscape relationships. The project goals are to provide bears with more food in the form of crabapple fruit at sites throughout Wuikinuxv territory (and in doing so, entice them out of the village), and to reconnect people in the community with managing crabapple trees through participation in restoration, monitoring, and harvesting. In order to achieve these goals, the following objectives have been set: (1) survey existing orchard and volunteer sites throughout Wuikinuxv territories, (2) increase crabapple production using management methods remembered by Elders (e.g., pruning and fertilizing), (3) monitor the survival/production of re-managed trees, (4) monitor the bear consumption of crabapples at restoration sites, and (5) engage and encourage community participation through restoration and harvesting events. Additionally, trail cameras are deployed during the crabapple fruiting season to monitor bear visitation and crabapple consumption. These actions effectively extend Wuikinuxv stewardship of crabapple trees from the past to the present and into the future.

Wuikinuxv knowledge and localized practices have been used to inform survey and restoration sites. Elders provide inter-generational knowledge to determine which restoration treatments are applied to trees. Increasing crabapple production for bear consumption shows respect to animal relations and monitoring tree survival and crabapple production displays respect for plant life forms. Monitoring also demonstrates conduct that is committed to the sustainability and productivity of crabapple trees in the long-term, thus imparting knowledge and values on future generations. Encouraging community engagement in restoration events recognizes the value of human stewardship and further ensures long-term project sustainability by cultivating new human–environment relationships.

In our experience, Indigenous and localized knowledge and values are often considered "subjective" evidence until supported by Western science, maintaining a supposed superiority of Western practices over Indigenous ones (Liboiron 2021). We know that such entrenched and racialized epistemologies have exacerbated the effects of climate change by suppressing linked processes of environmental and cultural well-being, resulting in the erosion and degradation of both. However, Indigenous-led restoration projects can provide opportunities to strengthen movements of reconciliation, decolonization, Indigenous self-determination, and land rights (Dickson-Hoyle et al. 2021). Restoration and re-management of places that are important for peoples' livelihoods and identities and can also provide opportunities for teaching youth. Restoration efforts that equate to time spent on the land can demonstrate land-use continuity in territorial occupation that can help assert rights and access to traditionally managed lands. Restoring "relationships of mutual obligation between land and people" (Burow, Brock, and Dove 2018: 60) and considering people as beneficial components of functioning ecosystems can disrupt western scientific restraints and contribute to buffering impacts of climate change.

Governance and Land Use

There are fruitful and important discussions to be had when it comes to the scale and integration of traditional knowledge, historical ecology (localized/regional scales), and broader aspects of global climate change (Reyes-García et al. 2020). While climate change is a global phenomenon, it is experienced and managed at a local scale, and as such, it requires that we confront, among other things, colonial narratives of Indigenous land-use (as either "passive" or harmful) and support local land-use and restoration initiatives. However, we also recognize that small or localized efforts will not be enough to mitigate against global climate phenomena, like the acceleration of greenhouse gasses, ocean acidification, and other large-scale impacts that are out of the control of most land-based peoples. Globally, Indigenous and local peoples have fought to increase participation and political influence in global climate decision-making processes—as recognized in the Paris Agreement in the United Nations Framework on Climate Change, or the inclusive (and at times bold) language in the recent 2022 IPCC report. Yet some have argued that broader participation of Indigenous and local peoples in designing and implementing global climate change policies has been severely lacking (Tormos-Aponte 2021).

Furthermore, while non-Indigenous researchers are, in good faith, increasingly looking to Indigenous peoples' management practices to help solve problems like climate change, the irony of violently suppressing and erasing peoples' land-base and knowledge systems only to call on them decades later has not been lost on Indigenous scholars and writers and needs to be actively dealt with (Geniusz 2009; Wildcat 2010). For example, there is often little acknowledgment of the unevenly shared responsibility between those who have created the climate crisis and those who feel its impacts the most (Sultana 2022). At the core of these issues is the fact that decision-making is still deeply rooted in colonial hierarchies, allowing researchers and bureaucrats to obfuscate or cherry pick which aspects of Indigenous knowledge to uplift and which to mute (Reid et al. 2020). We argue that integrating only "some" of the whole picture of Indigenous land-use knowledge (e.g., TEK) and not others (e.g., rights and title, ownership, sovereignty) risks further perpetuating colonial dynamics that erase people from their land, while simultaneously failing to reach climate change mitigation goals.

Indigenous and non-Indigenous researchers have long criticized the cavalier and uncritical integration of "traditional ecological knowledge" within Western scientific and bureaucratic management paradigms (Nadasdy 2005;

Johnson 2010; Baker and Westman 2018). We echo concerns raised by these authors who rightfully point out the extractive nature of TEK studies, the incompatibility of these knowledge systems, and the selective nature of their integration. Traditional ecological knowledge is not a static set of principles or dataset that can be removed from broader cultural and social contexts. For example, we know that most aspects of Ts'msyen, Haíɫzaqv, and Wuikinuxv resource and environmental management praxes are based on ownership, governance structures, and social arrangements (Berkes 2018). Before settler colonial invasions, Ts'msyen societal organization was the product of millennia of enlightened environmental management accomplished primarily through political and intellectual traditions. Ts'msyen adawx (laws) outline the legal system of title and land ownership that explicitly define territorial boundaries and the use and management thereof. These laws predate the imposition of Canadian law (and before that, British law). The late Gitselasu Ts'msyen Elder Bert Bryant commented on ownership and the adawx:

> *That's the law once you pass it, it become ayaawx [adawx]. So if anybody says that Tsimshians got no law, that's . . . they don't know what they're talking about. 'Cause there is a law; otherwise this would have been a free country. You can camp anywhere you want and claim a big property, if there was no law.* ***But they did that so you don't go too far overboard . . .*** *That's our traditional law. It's up to the La ka gigyet.*
>
> (Armstrong 2022; emphasis our own)

Not going "too far overboard" perfectly describes the intersection of law and land stewardship under the adawx. Gitselasu ideologies like not taking more than you need, feeding Elders first, and leaving some for others are often both subconsciously respected and outwardly enforced. The caring and maintaining of owned forest gardens and apple orchards through physical acts like clearing, earth moving, fertilizing, and transplanting, but also passive management acts like restricting harvests, slowing development and logging, and involving youth in knowledge exchanges, together have allowed forest garden and orchards to persist, in some cases for at least 500 years, which shows how culturally situated practices can result in locally rich foodsheds (Armstrong 2022).

For researchers and bureaucrats seeking to integrate Indigenous land-use practices into their land management strategies (e.g., climate change mitigation, restoration, etc.), it is crucial that these ecosystems be understood as highly localized spaces and that they are conceptualised within specific institutions of Indigenous ownership and land sovereignty. The inclusion of forest gardens, orchards, and midden enhanced soils into climate change mitigation strategies should not be purely teleological—that is, by virtue of the purpose they serve (buffers against food insecurity, ecosystem functions, biologically diverse forests). Rather, they should be understood by the characteristics from which they arose (i.e., a Nation's own management protocols, duties under adawx, and so on). Our scientific evidence is not meant to bolster or prove what Indigenous peoples have always known, but to appease non-Indigenous decision-makers and bureaucrats who cannot comprehend the complexity and scale at which people modified the historical cultural landscape. When it comes to using Indigenous knowledge and practices to mitigate impacts and vulnerabilities of climate change small restoration projects are a start—but there are countless barriers along the way. There are logistical issues that need to be attenuated—short funding cycles, land-use access—and larger epistemological issues—colonial roots continue to run deep and paradigm shifts are slow to turn to action in BC climate change mitigation. For example, addressing climate change impacts will require Indigenous self-determination for advancing communities' own aspirations and resistance to ongoing resource extraction that causes further land dispossession (Whyte 2020).

Conclusion

For non-Indigenous people, recognizing that place-based and Indigenous communities hold knowledge about the Earth and other beings differently than Western scientists do (Black Elk and Baker 2020; Whyte 2013) and acknowledging that there is an unevenly shared responsibility for creating the climate and biodiversity crisis is critical (Sultana 2022). In many cases, including our studies presented here, the stewardship and modification of homelands has created beneficial ecological legacies centered within social arrangements and governance structures unique to each community. Balée's postulates for historical–ecological research posit that human societies have affected all of Earth's terrestrial ecosystems. The question of whether such impacts resulted in a net increase or decrease of biodiversity and available foods and resources depends not on the environment itself, but rather, on the ideological and cultural makeup of people living in it (Balée 2006). As we showed, not all human activity is inherently bad or will result in environmental degradation. As such, recognition of who and which societies contribute to environmental degradation and/or regeneration enables us to focus on developing more just (and likely more successful) outcomes for climate change mitigation.

Why has intensive, landscape-scale, perennial plant use and management been overlooked by archaeologists and ecologists until relatively recently (see Lightfoot et al. 2013)? It is certainly possible that researchers are now looking for instances of Indigenous management – given their success—and the dire global need to curtail climate change and the current misuse and exhaustion of landscapes. However, it is also apparent that until Indigenous histories and voices have been centred and hyper-local interpretations of plant management and plant use have been taken seriously, researchers have felt comfortable accepting Indigenous ontologies and reconsidering their own ideological positions on taken-for-granted pathways to knowledge production (i.e., dominant environmental science narratives). This ideological opening or paradigm shift, which seeks to reconcile long-standing colonial assumptions entangled within scientific imperialism, has been ongoing for years in disciplines like archaeology and environment sciences, but the integration has been imperfect. Here, we strived (also imperfectly) to create ideations of human–environment interactions that more fully: (1) interrogate how people can have profound and positive impacts on their lived landscapes, (2) consider the application of historical ecology and Indigenous knowledge for restoring and mitigating food systems, and (3) recognize that land rights, sovereignty, and other aspects of self-determination are the substrate upon on which successful Haíłzaqv, Wuikinuxv, and Ts'msyen management strategies operate.

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8 Clam Gardens Across Generations and Places Support Social–Ecological Resilience to Global Change

Dana Lepofsky and Anne Salomon

As the tempo and variability of global change accelerates, western scientists are increasingly looking to Indigenous knowledge systems for social–ecological models that might help us adapt today (e.g., Fernandez-Llamazares et al. 2021; Ford et al. 2016; Gómez-Baggethun et al. 2013; Hernandez 2022; Mistry and Berardy 2016). These knowledge systems reflect generations of people making ongoing, fine-scale observations about local environmental changes, experimenting with and adapting to these changes, and then conveying these observations and responses to others. While it may be that some aspects of Indigenous knowledge cannot be applied easily to current, fast-changing contexts, one foundational aspect of Indigenous knowledge systems is particularly relevant today: they are resilient because they encompass diverse responses to social–ecological change that are grounded in long-term, place-based knowledge and experience. By providing adaptive capacity, variability in responses to disturbances is a key principle of social–ecological resilience (Biggs et al. 2012; Elmqvist et al. 2003; Walker et al. 2004).

In this chapter, we explore aspects of place-based knowledge as expressed in traditional marine management systems in British Columbia (BC) on the Northwest Coast of North America. Specifically, we summarize some of the social and ecological mechanisms driving variation in clam gardens – rock-walled terraces build by Indigenous people that enhanced the productivity and availability of clams in intertidal soft sediment habitats. Clam gardens are one of a suite of management practices used by Indigenous peoples along the Northwest Coast of North America (see Figures 8.1 and 8.2) to sustain and enhance ecosystem productivity and social–ecological resilience in the face of a variety of perturbations, be they climatic, ecological, or socio-political (Jackley et al. 2016). To contextualize the initiation of clam garden building at least 3,500 years ago (Smith et al. 2019), we consider the ecological and social context of clam harvesting throughout the Holocene. Over this time, people would have experienced both minor and major climatic and socio-political shifts to which, we hypothesize, they adapted with innovative mariculture practices. Our review reveals that some elements of tending clams in clam gardens are consistent across the millennia and in different

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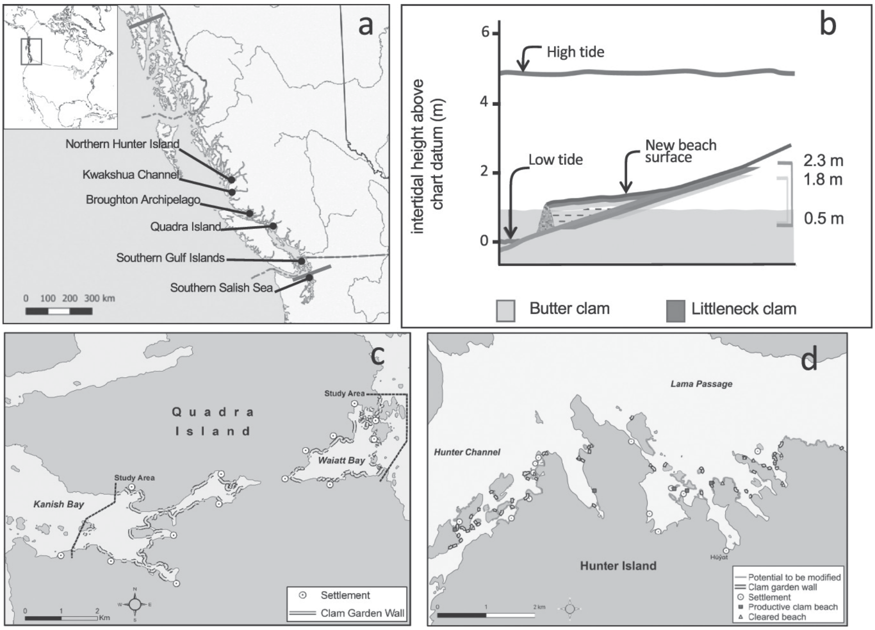

Figure 8.1A–D Part A: Along the Northwest Coast of North America, clam gardens have been documented from southeast Alaska to southern British Columbia and Washington. Part B: Illustration of a clam garden on a soft-sediment beach showing the common tidal range for butter clams and littleneck clams and the change in distribution and accessibility of clams at the ideal tidal height (approximately 1 m above chart datum) after a terrace is built. Part C: Clam gardens and human settlement sites in northern Coast Salish and Laich-Kwil-Tach territories, on northern Quadra Island, showing that all suitable foreshore was converted to clam gardens; Part D: Clam gardens and human settlement sites in Haíɫzaqv territory, on northern Hunter Island, showing variability in how the foreshore was managed.

regions of the coast, while others are unique to specific places and times. We surmise that the evolution and context-dependence in clam gardening practiced across space and time, as well as the exchange of this knowledge among communities and across generations, contributes to its resilience to global climatic and socio-political change.

Clams, Climate, and Northwest Coast Peoples

Clams are a reliable, resilient, nutritious, and abundant food for people on the Northwest Coast. They are common coastwide in a range of beach environments and thus are a broadly accessible food source. As broadcast

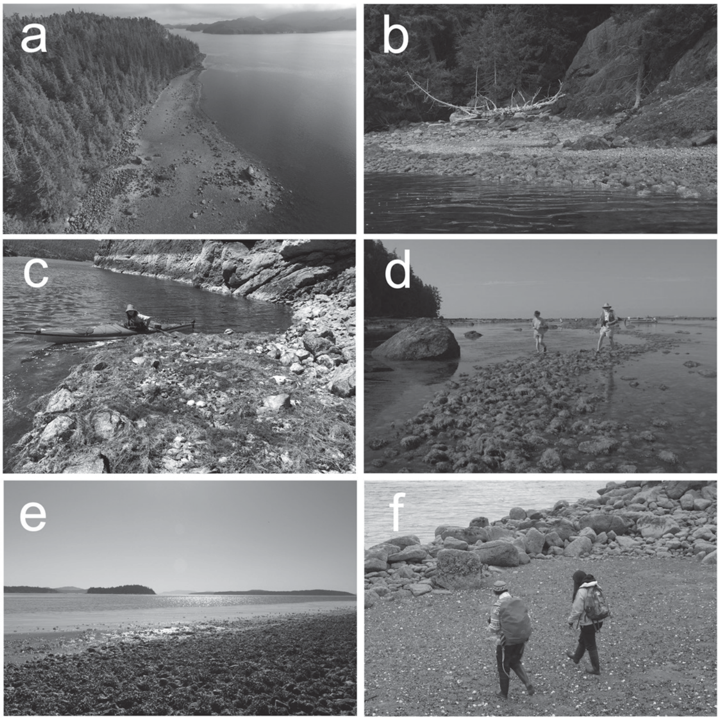

Figure 8.2A–F Structural variation in "clam gardens" in different social–ecological and oceanographic contexts in British Columbia (BC). Part A: Clam garden in BC's central coast where rocks have been moved both upslope along the treeline and downslope (photo Keith Holmes, Hakai Institute). Part B: Clam garden in the Strait of Georgia that sits at approximately 1.4 m above productive clam habitat today, possibly associated with a previously higher sea level. Part C: Small clam garden (approximately 3 x 5 m) in the Strait of Georgia covered by the invasive *Sargassum muticum* seaweed as well as sea lettuce (*Ulva* spp.) and rockweed (*Fucus gardneri*) – a sign that the garden is no longer tended. Part D: Long sinuous wall in northern Coast Salish territory located in the low intertidal that is likely the remains of a clam garden (photo Georgia Combes). Part E: Clam garden in the southern Gulf Island with a fringing kelp forest attached to the subtidal and low intertidal portion of the garden's rock wall. Part F: A cleared clam beach on BC's central coast.

spawners with an early age to maturity, relatively high recruitment rates, quick growth rates, and wide thermal tolerance relative to other coastal fisheries, clam populations tend to be resilient to moderate harvest pressure (Barber et al. 2018) and temperature variations (Weatherdon et al. 2016), making them a potentially sustainable source of food that could feed large numbers of people. For some groups, clams were a readily available food when other foods, such as salmon, were in short supply (Deur et al. 2015).

Many First Nations hold knowledge about ways to maintain and further increase clam abundance. These methods include removal of predators and rocks; restrictions on harvesting size, timing, and location; aeration of sediments through tilling; and the addition of coarse and in some cases calcium-rich sediments (Hul'qumi'num Treaty Group 2011; Deur et al. 2015; Lepofsky et al. 2015). These management techniques were likely applied to all clam harvesting beaches, including those with a rock walled clam garden. However, unlike the building and maintenance of a rock walled terrace, these other practices can be difficult to track in the ecological and archaeological records.

Based on ethnographic accounts and archaeological observations, four species of bivalves were of particular importance to coastal First Nations: butter clams (*Saxidomus gigantea*), littleneck clams (*Leukoma staminea*), cockles (*Clinocardium nuttallii*), and horse clams (*Tresus capax*). They were eaten fresh or smoked and dried for later consumption or trade. As local clam gatherers are well aware, each species has different preferred growing conditions (substrate, tidal elevation, burrowing depth; Kozloff 1987), which influences their accessibility to human harvesters, their suitability for cultivation in clam gardens, and their resilience to extreme climatic events and other disturbances.

While all four species can be found in clam gardens, in our experience, the beach terrace and associated shell middens are dominated by butter clams and littleneck clams, the dominant bivalves harvested from most clam gardens. Unlike cockles, these two species thrive in coarse sediments, characteristic of clam gardens. Furthermore, horse clams tend to grow in the low intertidal and more commonly in the shallow subtidal zones. Thus, they would only be accessible to harvesters for limited periods during the lowest low tides. We have only observed one clam garden in the extreme lower intertidal that we hypothesize may have been created to cultivate horse clams (see Figure 8.2C).

In addition, butter clams and littlenecks may be able to better survive weather extremes than cockles and thus may have been a more resilient food source through time. Since cockles tend to burrow at shallower depths, they may be more susceptible to heat extremes, as observed during the "heat dome" on the southern Northwest Coast in the summer of 2021. During that time, we observed that littlenecks and butter clams, which tend to burrow to depths of 15 to 25 cm, respectively, were not heavily impacted by the extreme heat; shallow burrowing cockles, however, experienced high mortality. As we discuss below, variation in ocean temperatures, among other factors, influenced the growth of clams in the deep past as well (Toniello et al. 2016). Understanding the long-term relationships between clams, people, and climate at the local level will be foundational for supporting stable and productive food systems into the future.

Other ecological factors influence people's abilities to sustainably harvest clam populations today and thus may serve as proxies for understanding past human–clam relationships. While large-scale oceanographic processes appear to drive intertidal clam population dynamics regionally, local factors such as predation, bioturbation, and eutrophication account for spatial variability among clam beaches (Barber et al. 2018). For example, over the past three decades, the North Pacific Gyre Oscillation (NPGO) has been associated with a pronounced decline in native littleneck clam biomass across the southern Salish Sea, a trend that has been reported from the Aleutian Islands in Alaska, through British Columbia, to northern Baja California (Dunham et al. 2007; Novoa et al. 2016; Shigenaka et al. 2008; Strickland et al. 2016). Yet, small-scale local drivers such as nearshore land-use change, freshwater input, temperature, salinity, alkalinity, and sediment characteristics can locally alter the magnitude of regional oceanographic processes and human-induced ocean climate change, including ocean acidification (Feely et al. 2010). The importance of local-scale variables in driving clam biomass and productivity highlights the relevance and context-dependence of local observations and clam management practices, especially in the context of changing climate.

Braiding Knowledge Systems and Disciplines to Study Clam Gardens

A hallmark of historical ecology is the diversity of methods and knowledge systems used to better understand the past, evaluate present conditions, and inform future decisions (e.g., Egan and Howell 2005; Pauly 1995). The approach recognizes both the place-specific interactions among people and their environments, and that large-scale and long-term effects will play out in local contexts in unique ways (Balée 2009; Crumley 1994; Dayton et al. 1998). As such, it allows us to explore variation through time in specific locales and thus honors placed-based knowledge, identities, and histories as they developed over generations – as people learned from the land and each other, through trial and error, by closely observing and experimenting with the ecological and social worlds in which they were actively embedded (e.g., Berkes and Turner 2006). Such knowledge systems develop both in daily life and in extraordinary events, and are reflected in local governance protocols, practices, and laws (Trosper 2011; Turner 2014).

The study of clam gardens has been exemplary of collaborative, transdisciplinary research that braids together knowledge systems. Through the Clam Garden Network (www.clamgarden.org), people are coming together to address a range of questions about clam gardens in past social–ecological systems and how that knowledge can be applied to current and future contexts. This has involved combining novel methods from archaeology and ecology, with Indigenous knowledge about clam harvesting and tending in clam gardens specifically, and ancestral environmental governance protocols and practices more broadly. The bulk of the archaeological and ecological work thus far has taken place on BC's Central Coast (northern Hunter Island, Kwakshua Channel), in the Broughton Archipelago, on northern Quadra Island, on the southern Gulf Islands, and in the southern Salish Sea (see Figure 8.1).

Indigenous knowledge is, of course, the thread that connects all clam garden explorations. By learning from discussions with current ecological knowledge holders and collating ethnographic records, including names for clam gardens (e.g., Deur et al. 2015; Hul'qumi'num Treaty Group 2011; Lepofsky et al. 2015; Olsen 2019), we have learned much about clam harvesting, cultivation, and systems of tenure. Furthermore, the importance of clams today as well as in the past to food security and sovereignty, governance, and social systems, are the motivation for much of the current clam garden research.

Taken together, Indigenous knowledge, archaeology, and ecology is a powerful triad for understanding ancient mariculture practices. Each source of data and knowledge can help support or nuance the other. For instance, the archaeological record demonstrates that in the past people gathered clams at many times of the year (Cannon and Burchell 2009). In contrast, traditional knowledge holders today note that clams were primarily harvested during the winter, in part because of fear of ingesting marine biotoxins during the warmer months. However, this proscription may be related to the association of 20th century warming of sea surface temperatures with increases in harmful algal blooms that produce biotoxins (e.g., Brandenburg et al. 2019). The adaptation to switch seasons of clam harvest to only safer months is an example of the resilience built into Indigenous knowledge systems.

The Making and Tending of Clam Gardens and Productive Food Systems

Clam Garden Construction

While there is some variation in clam garden form, all are composed of a wall composed of rocks rolled, carried, or floated lashed to beach logs or via canoe to the lowest-low tide mark. Wall trench excavations suggest that some walls were built to a particular height in a single building event (with rubble fill at the center of the wall), while others seem to have been built up more gradually. The Kwakwak'wakw term for clam gardens, lokiwey ("rolled rocks forming a wall"; Deur et al. 2105) and the Nuu-chah-nulth term t'iimiik ("something being thrown" or "move aside rocks") for one particularly good clam bed, describes this process of building a garden wall (Kennedy and Bouchard 1990: 386). The Haíłzaqv term ƛ̓ápaćl, meaning "to dig for clams in a container or enclosure" (pers. comm. Qíx̌itasu Elroy White), conveys the soft sediment terrace that exists landward of the rock wall.

In most cases, clam gardens are "stand alone" mariculture features, but in some cases, they are incorporated into complex fish traps which straddle tidal heights. This variation is evident in the Northern Coast Salish term wúxwuthin ("held back at the mouth"; Lepofsky et al. 2015). The term refers to the rocks that are piled on the sides or low tide of a beach while digging for clams, as well as rock corals of the kind used in fish traps. Notably, Tla'amin Elders Les Adams and Norman Gallighar reported that fish traps and holding ponds were also valued places for harvesting clams (pers. comm. to D. Lepofsky and G. Combes, 2008).

Social–Ecological Interactions

Once a clam garden wall is substantial enough to trap silts, sands, gravels, and broken shell, this accumulation landward of the wall eventually forms the flat terraces we see today. Optical Stimulation Luminescence (OSL) dating of sediments suggest that this sediment accumulation was incremental over time as the wall increases in height (Neudorf et al. 2017). However, the specific accumulation rates must have varied locally with unique geomorphic and ocean conditions and varying cultural norms and practices surrounding sediment enhancement.

The benefits of building the wall would have varied depending on the pre-garden substrate. For instance, walls built on bedrock shelves on boulder slopes would have accrued substantial benefits simply by creating a clam habitat where there was none before. On soft sediment beaches, where clams were already thriving, we hypothesize that the building of the wall would have had an immediate ecological effect on increasing larval clam entrainment, recruitment, and post settlement survivorship. Adult clam biomass, however, would take time to increase as young cohorts of individual clams need to survive predation, competition, and desiccation to grow to larger sizes. The flattening of slope into a terrace eventually also meant that butter clams and littlenecks were accessible to people and other land predators for a significantly longer tidal window (see Figure 8.1B).

By building a clam garden, people doubled to quadrupled clam abundance, providing a reliable, accessible, and resilient source of food that fed communities nutritionally and spiritually for millennia. This structural innovation flattened the slope of clam beaches, creating a terrace landward of the wall that extended clam habitat at the intertidal height where clams grow and survive best (approximately 1.0 m above chart datum; Groesbeck et al. 2014, Jackley et al. 2016). Ecological evidence shows that clams can grow twice as fast in clam gardens compared to non-walled beaches. Clam gardens also tend to have greater densities of small juvenile clams (1–4 cm), including newly settled clam recruits (< 2 mm) (Groesbeck et al. 2014, Jackley et al. 2016). The latter is a detectable ecological effect that echoes Indigenous knowledge asserting that larval clams are more likely to be entrained and settle in clam gardens than unmodified beaches (Hul'qumi'num Treaty Group 2011). Moreover, the increase in clam biomass in clam gardens can be attributed to both the elevated sediment carbonate associated with dense accumulation of shell hash and the moderating effect of shallow sloping clam garden terraces on sediment temperature. Clam gardens maintain lower mean surface temperatures in the summer and higher minimum surface temperatures in the winter than unmodified beaches and tend to experience greater water flow (Salter 2018). Experimental transplants of clams in clam gardens provide strong evidence that these environmental conditions, sediment carbonate, and moderated temperature increase clam growth rates.

Several Indigenous knowledge holders today, including the northern and central Coast Salish, Haíłzaqv, and Kwakwak'wakw speak of the importance of creating and maintaining good quality sediment and temperature characteristics to encourage clam settlement, growth, and survival (Hul'qumi'num Treaty Group 2011; Deur et al. 2015). Some groups report adding sediment to the beach to augment the terrace with shell-rich sediments and gravel (Hul'qumi'num Treaty Group 2011; Olsen 2019; Haíłzaqv knowledge holder Davie Wilson pers. comm to A.K. Salomon, 2012), while others removed shells after harvesting (Deur et al. 2015). Our ad hoc observations of clam garden sediments at a subset of beaches suggest that a dominant component of the "shell hash" is broken barnacle plates that probably were originally attached to the rock wall or bedrock outcrops on the sides of clam garden walls and broken from wave action. It may be that the characteristic, coarse grained, carbonate rich shell hash in clam gardens, which is so important to enhancing clam growth today (Salter 2018), accumulated due to both wall construction and the direct addition of crushed shell to the terrace itself. We cannot know if shell accumulation was an intended outcome of initial wall construction, but the ancient clam cultivators undoubtedly recognized the benefits of good quality sediment characteristics in fully formed clam garden beaches.

Variation in wave exposure, sea water temperature, and salinity would have also dramatically affected the local species composition of clam gardens and thus people's interactions with these ecosystems in different places and times of year. For example, clam gardens in the southern Gulf Islands today are associated with lush fringing kelp beds that grow on the gardens' rock walls, unlike clam gardens in the more sheltered bays of Quadra Island. Intertidal sugar kelp (*Saccharina latissima)* and subtidal bull kelp (*Nereocystis luetkeana*) surround the clam gardens of the Gulf Islands only because of the rocky boulder reefs created by the clam garden wall and this region's oceanographic context (see Figure 8.2E). Here, clam garden communities experience greater wave energy, and cooler and more saline oceanographic conditions of the Strait of Georgia. As a result, a diversity of kelp-associated seafood species, in addition to clams, exist around the periphery of these gardens. This includes red rock crabs (*Cancer productus*), snails (*Nucella lamellosa, Ceratostoma foliatum*), sea cucumbers (*Cucumaria miniata*, *Apostichopus californicus*), sea urchins (*Strongylocentrotus droebachiensis*), octopus (*Enteroctopus dofleini*), chitons (*Mopalia* spp., *Tonicella* spp.), sea stars (*Dermasterias imbricata*, *Evasterias troschelii*), and a diversity of seaweeds (*Ulva* spp., *Pyropia* spp.). Consequently, these sea gardens would have been a source of a diversity of sea foods well beyond clams.

Fringing clam garden forests of kelp not only create essential fish and invertebrate habitat and entrain larvae, they also produce detrital kelp well known to fuel nearshore food webs and their productivity (Duggins et al. 1989; Salomon et al. 2008). We hypothesize that this source of kelp-derived organic carbon may in fact further boost clam growth in this region today and may have also done so in the past. It may also boost the production of clam predators, including red rock crabs, nearshore diving ducks, and terrestrial mammals such as mink and river otter – a suite of organisms that Indigenous knowledge holders have spoken of as benefiting from clam gardens (Deur et al. 2015). Local ecological observations such as these will eventually help us understand the highly local social–ecological contexts of ancient mariculture systems.

Some of the same ecological processes at play in clam gardens may have benefited clams associated with other mariculture features. For instance, beach clearings created by piling rocks to the side while digging for clams (see Figure 8.2F; Caldwell et al. 2012) would have also increased the area of suitable habitat wherein clams could grow and be harvested, as well as facilitated harvesting, sediment tilling, and improved substrate (Belchar 1998). Likewise, clams in fish holding ponds and other pools may have benefited from longer periods of time to filter and consume phytoplankton prey from the sea water and moderated temperatures.

Despite a relatively solid understanding of the ecological contexts of "fully formed" clam gardens, we lack details about how ecological benefits accrue as a clam garden developed over time. This is because our ecological experiments on the benefits of clam gardens have been based on gardens as they exist today, after the colonial disruptions to tending practices and complex traditional maricultural systems of governance. Consequently, we do not yet know whether partially formed walls, not yet built to their full heights, benefit clam recruitment, growth, and survivorship. Similarly, an important outstanding question is the degree to which partially formed walls moderate temperatures and alter sediment characteristics. Understanding these details will provide considerable insights into the short and long-term goals of ancient clam cultivators, as well as how their decisions were embedded in ever-changing social and ecological contexts. These details will also allow us to more fully and respectfully apply this ancient wisdom to current contexts.

Ancestral Governance

All mariculture features, and the now-hidden actions associated with them, were part of a larger framework of beliefs and practices. They are embedded in elaborate local and regional social systems that dictate how people should behave with each other, with other-than-human beings and landscapes, and how to modify these behaviors to adapt to changing climatic conditions (e.g., Trosper 2011; Turner 2014). The harvesting and tending of clams and the creation of clam gardens were among the many tangible and intangible actions that were enacted over the generations as people formed and were formed by their dynamic local seascapes.

Paralleling the coast-wide diversity in mariculture practices is the considerable variation in social contexts in which these practices were enacted. This is reflected in the ethnographically-documented governance systems that structured clam harvesting and cultivation. For instance, among the Kwakwakwakw, clans or lineages had proprietorship over clam beds and, according to Chief Kwaksistalla, "not only the harvesting and distribution of the clams, but also the traditional maintenance of the loxiwey itself was under the authority of the Ugwamay, or Clan Chiefs, and their designates" (Deur et al. 2015). Among other communities, families held proprietorship of the best clam beds and family heads controlled harvesting access (Moss 1993; Suttles 1951, 1990; Turner 2005). For the Lummi of northern Washington, only the beaches that were cleared were owned by the tenders (Stern 1934). As we discuss below, the variability we observe today in mariculture and governance systems is also evident in the paleoecological and archaeological records – reflecting the deep-time roots of these social–ecological systems.

Social–Ecological Variation in Clam Mariculture Through Time

We hypothesize that several social and ecological factors simultaneously and iteratively influenced peoples' decisions about harvesting and tending clams. These factors would have played out differently in different times and places (Table 8.1). We surmise that these factors resulted in nuances in why, when, and where people chose to build clam garden walls rather than simply clearing the beach; whether clam gardens were built at once to a particular tidal height or gradually through time; or even why only some groups incorporated gardens into other mariculture features. Currently, we lack sufficient temporal and spatial data to explore these ideas fully. Gaining such knowledge will eventually reveal rich details about specific place-based histories and how different peoples responded to environmental and social change.

The collective work on Quadra Island provides the most complete data set for ecological and social changes in clam harvesting and cultivation through time (Toniello et al. 2019). There, excavations into very early Holocene beach deposits (11,500–11,000 years ago) revealed butter clams that were small and slow-growing, likely because of the colder ocean temperatures and the silt-dominated sediments of the newly forming beaches during the early post-glacial time period. As ocean temperatures and beaches stabilized through to mid-Holocene (approximately 4,000 years ago), clams grew faster and were larger in size-at-death than previously.

Table 8.1 Social–ecological interactions and disturbances across time and space shaping the dynamics, resilience, and context-dependence of clam gardens and the mariculture systems in which they are embedded

Time Scale	*Spatial Scale*	*Disturbances*	*Social–Ecological Interactions*	
Daily	0.1 m–10 km	• Daily tides exposing and submerging clam beds • Thermal stress • Desiccation	• Digging, processing, and eating clams • Observing local natural history and experimenting • Learning and sharing knowledge • Rolling rocks • Weeding • Size selective harvest • Seeding, transplanting • Reducing predators and competitors • Sediment enrichment	• Variable clam recruitment rates and post recruitment survival • Filtration of phytoplankton, particulate organic matter, and bacteria by clams • Density-dependent competition among clams for food and space • Predation by red rock crabs, moon snails, shore birds, sea birds, sea stars, sea otters, river otters, and mink • Facilitation of clam recruitment, growth, and survival via reduced density dependence and high-quality sediment characteristics
Seasonally	10–100 km	• Differences in sea surface temperatures • Winter storm events • Sedimentation • Spring freshet altering aquatic transport of terrestrial and marine inputs • Occurrence and magnitude of harmful algal blooms • Overharvesting	• Preparing for winter feasts • Storage for winter • Daylight summer harvesting • Winter nighttime harvesting • Trade among Nations	• Spawning events • Changes in pelagic and benthic primary productivity • Changes in clam growth rates • Winter and summer clam mortality events

(*Continued*)

Table 8.1 (Continued)

Time Scale	*Spatial Scale*	*Disturbances*	*Social–Ecological Interactions*	
Yearly, multi-year	1–1,000 km	• Changing sea levels due to tectonic events • Disease events • Marine heat waves	• Sharing stories/knowledge intergenerationally • Demographic shifts (including cascading effects of European introduced diseases) • Conflict/warfare • Establishment and maintenance of tenure/governance systems • Initiation and maintenance of clam gardens • Potlatching (probably rare in pre-contact times)	• Clam population persistence or decline • Viability or failure of other seafood populations
Decadal	1–1,000 km	• Changing sea levels due climate change • Storms associated with El Niño–Southern Oscillation (ENSO) • Oceanographic variation associate with North Pacific Gyre Oscillation (NPGO)	• Hereditary transfer of leadership, decision-making authority and accountability via names and proprietorship over territories within clans	• Clam population persistence or decline • Viability or failure of other seafood populations
Centennial	1,000 km	• Centennial shifts in climate (e.g., Little Ice Age)	• Hereditary transfer of leadership, decision-making authority and accountability via names and proprietorship over territories within clans	• Evolutionary change in clam life history traits
Millennial	10,000 km	• End of Pleistocene Ice Age resulting in formation of beaches, establishment of clam beds, stabilization of sea levels, changes in SSTs (Neoglacial, etc.)	• Hereditary transfer of leadership, decision-making authority and accountability via names and proprietorship over territories within clans	• Evolutionary change in clam life history traits

Sometime after 4,000 years ago, people started building the first clam gardens, coincident with the initiation of several large shell-bearing settlements. New settlements continue to be established on the landscape until approximately 2000 years ago, at which time the primary expansion in human habitation was within already existing settlements. Our proxy estimate of garden ages, based on the height of rock walls relative to ancient sea levels, suggests over half of the clam garden were built after 2,000 years ago (approximately 54%; Holmes et al. 2022). The coincident timing of densified settlements and expansion of clam garden number reflects both the need to feed the increasing human population and the fact that there was a sufficiently large population to maintain the social and ecological aspects of the maricultural system. The archaeological record, however, is silent with respect to information on the governance of harvesting and tending practices, and how food was distributed and traded. For instance, while we note that clam gardens varied considerably in size and in proximity to settlements, the pattern appears to be more dictated by ecological and geomporphological opportunities and constraints than social factors.

Measurements of clams in middens on Quadra Island suggest that despite growing human populations and presumably increased human harvest rates on clams from the mid- to late Holocene, clam size and abundance were relatively stable (Foster 2021; Toniello et al. 2019). Furthermore, clam measurements indicate these cultivated clams were generally growing at least as fast as clams in the best unwalled beaches of the mid-Holocene prior to the development of clam garden technology. This pattern supports the hypothesis that clam gardens and the maricultural systems within which they were embedded were sustainable over the long-term, even despite fluctuations in sea surface and air temperatures characteristic of millennial-scale climate dynamics. In fact, it is not until the post-colonial era – with the erosion of traditional management practices, siltation of beaches from upslope logging, warming of ocean temperatures, and increasingly corrosive sea water – that clam size and growth mimic those from the unstable environmental conditions of the early Holocene (Toniello et al. 2019). Notably, the same pattern of temporally stable clam sizes in the pre-colonial era holds with clam gardens in the Broughton Island archipelago (see Figure 8.1), even where sea otter predation of clams likely competed with humans harvesting these same bivalves (Foster 2021).

Comparing the spatial pattern of clam gardens and settlements in Quadra Island with those on Northern Hunter Island on British Columbia's Central Coast further reveals the diverse social–ecological interactions embedded in ancient mariculture systems (see Figures 8.1C and 8.1D). On both Quadra and Northern Hunter, ancient settlements dot the coastline. On Quadra Island, there does not appear to be a central village or location and we cannot discern any patterning in ecological or social setting in village locations. In contrast, on northern Hunter Island, there is one centrally located village that was established some 6,000 years ago in the largest protected bay in the area. The bay offered a range of terrestrial and aquatic foods and other resources that could be managed (www.hauyat.ca/living/settlements/ancient/ancient-intro.html). Over the millennia, people continued to build on this spot, eventually creating a settlement that was at least 8 m deep and 150 m in extent. It was not until sometime after 2,000 years ago that other settlements were established around this main settlement and in neighboring bays.

Like the settlement patterns, the distribution of clam gardens is quite different in the two locations. On Quadra Island, in Waiatt and Kanish Bays, there is a clam garden on every stretch of coastline that could be transformed (i.e., excluding cliff faces; see Figure 8.1C), resulting in more than one third of the shoreline having a garden wall (Lepofsky et al. 2020). On northern Hunter Island, our pedestrian and boat survey indicated a more complex patterning of human–foreshore interactions (see Figure 8.1D) – a spatial mosaic that also exists just south in Kwakshua Channel (Jackley et al. 2016). Many areas of the shoreline are highly productive clam beaches with no apparent modifications. While some of the remaining, less naturally productive areas (e.g., bedrock shelves, rocky beaches) have a clam garden on them, others were modified only by creating small clearings in the rubble, and others still remain unmodified. There does not appear to be a relationship between the density of settlements and whether a beach is modified in some way. Thus, as with the Quadra Island case, patterning in the archaeological record of Northern Hunter does not provide insights into who had access to or was responsible for the various aspects of the ancient maricultural system. Based on current understandings and practices of Indigenous governance, we expect many of the social rules surrounding clam gardens were place- and culture-specific.

Clam Gardens Today: Re-Building Walls, Re-Building Resiliency, Reclaiming Sovereignty

Throughout the Northwest Coast today, efforts by several Indigenous groups in BC and Washington state to restore, reawaken, and reclaim clam garden technology are well underway as part of a larger movement supporting the reassertion of Indigenous governance, cultural reconnections, food sovereignty, and climate resilience. For example, Hul'q'umi'num' and W̱SÁNEĆ Coast Salish communities are leading the first experimental restoration of clam gardens in the Southern Gulf Islands of British Columbia with Parks Canada and university researchers (Hul'q'umi'num'–Gulf Islands National Park Reserve Committee 2016; Olsen 2019). Through a series of ecological surveys of prospective clam beaches and interviews with community members, the Swinomish Indian Tribal Community in the southern Salish Sea (see Figure 8.1) has assessed and chosen a site for clam garden construction as part of the tribe's climate change adaptation program (Greiner 2021). Lastly, many coastal Indigenous communities in BC and Washington have begun their unique community processes and information gathering to begin clam gardens revitalization projects of their own.

Clam gardens are important places of learning and sharing. Today, they offer adaptive strategies to increase the health of Indigenous communities in the face of climate change and other environmental changes. Specifically, they create spaces for social–ecological resilience, not just of food, but of entire food systems. Resilient Indigenous food systems are characterized by self-determination through restoration and healing activities; community connections through sharing and relationships; education by way of teachings between Elders and youth; cultural use via stewardship practices, respect, and a sense of place; and resource security via seafood quality, access, and safety (Dunatuto et al. 2020; see also Schaepe et al. 2017). Clam gardens, then, play a role in nourishing the body, the spirit, and the community.

Future opportunities lie in documenting the social–ecological effects of restoring clam gardens in the face of extreme climatic events such as marine heat waves, heat domes, atmospheric rivers, socio-political changes, and national and international market demands. Several compelling questions remain to be answered. Will restored clam gardens and their wetter sediments and reflective shell hash keep clams cooler and increase their survival through these extreme climatic events? Does this, through time, increase the production and stability of clam biomass that can be eaten and shared within and among communities? Does the enhancement of shell hash at large spatial scales buffer sea water to the extent needed to combat ocean acidification? What ancestral stewardship practices were used to adapt to sea level rise? Does kelp-derived organic carbon provide an important source of detrital food when phytoplankton concentrations are limited? How will the burgeoning international blue food movement influence the scale of clam garden resurgence? What kind of co-management arrangements will support the equitable distribution of decision-making authority, seafood, and revenue generated from sea gardens? There are many questions that remain to be answered in our quest to better understand and support the revitalization of this astonishing mariculture innovation.

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9 Ancient Knowledge, Future Wisdom

Archaeological Perspectives of Caribbean Coastal Food and Habitat Security During Times of Climate Crises

Isabel Rivera-Collazo

Introduction

Deep time perspectives shed light on what happens when environments change and what societies do to face, mitigate, or adapt to change. Archaeologists insist that their expertise can contribute to understanding the process of climate change, usually by studying instances of environmental change and climate variability at scales compatible with human experience and investigating how people survive changes (or not). However, lessons from archaeological examples are seldom present in climate change assessments (Rockman and Hritz 2020; Kohler and Rockman 2020). Archaeologists have yet to fully demonstrate, beyond descriptions of climate impacts and coincidental correspondence of possible social change, how the past is relevant to the present (Rockman 2012; Burke et al. 2021; d'Alpoim Guedes, Gonzalez, and Rivera-Collazo 2021; Douglass and Cooper 2020). Historical ecologists have made more concerted attempts to apply their research programs to questions with contemporary relevance (Oba 2014; Isendahl and Stump 2019), and some practitioners have suggested that historical–ecological methods are necessarily applied to issues of climate change (Vellend et al. 2013), resource exhaustion and management (Swetnam, Allen, and Betancourt 1999), and environmental justice (Armstrong et al. 2017).

In this chapter, I explore the ability of archaeology to address social vulnerability using interdisciplinary historical–ecological data from the northeastern Caribbean. The goal of this exercise is to go beyond the description of specific events where climate change and social response coincide, to identify lessons and wisdom from the experiences of the past that can be useful to address the challenges we face today and will face in the future.

Context: Climate and People in the Caribbean

Climate in the Caribbean is strongly modulated by the equatorial portion of the Hadley circulation, which sets the position of the Intertropical Convergence Zone (ITCZ). This is a narrow, low-pressure band that follows the hottest parts of the oceans and helps balance atmospheric energy between

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the northern and southern hemispheres (Waliser and Gautier 1993). As seasons change, the ITCZ migrates north or south following the summers of each hemisphere (Asmerom et al. 2020). Its position in the Atlantic is also influenced by the Atlantic Meridional Overturning Circulation (AMOC) and the Atlantic Multidecadal Oscillation (AMO), which track variations in Sea Surface Temperature (SST) (Warken et al. 2020; Comarazamy and González 2011; Mignot and Frankignoul 2005). The effects of the ITCZ also interact with the position of the high- and low-pressure cells in the north Atlantic, or the North Atlantic Oscillation (NAO) (Cvijanovic and Chiang 2013; Moreno-Chamarro, Marshall, and Delworth 2020). These elements influence one another – they change and dance together – in what is known as the Atlantic Multidecadal Variability (AMV) (D. Zhang et al. 2011; R. Zhang et al. 2019).

Four important features help to understand weather and climate patterns in close proximity to the ITCZ: (1) the areas right under the low pressure band receive high volumes of precipitation; (2) the areas right next to the low pressure band are drier because the moisture is being transported to the low pressure areas; (3) the sections between the high pressure cells and the ITCZ experience the constant flow of easterly winds, flowing towards the low pressure band, the intensity of which depends on the intensity of the Hadley circulation; and (4) the position of the ITCZ and the North Atlantic Oscillation, together with the El Niño–Southern Oscillation (ENSO) and other global atmospheric phenomena, also influences the path and strength of hurricanes in the Caribbean and north Atlantic storms (van Hengstum et al. 2016). When the overall amount of heat generated in Earth's system changes, so does the SST and the intensity of the Hadley circulation, and the relationship between all those phenomena therefore respond accordingly and dynamically; the AMOC and the NAO oscillate, the AMV variates, the ITCZ migrates, and the cyclone band shifts.

Rather than measuring climate, human societies living at the interface of the geosphere, atmosphere, hydrosphere, and biosphere perceive and experience weather and accumulate long-term knowledge about it within their known territories. For example, the Pleistocene–Holocene transition presented a dramatic shift from dry and cold to warm and wet climates. However, that process was not linear, but was punctuated by several peak events, such as the warm/wet Bølling/Allerød (c. 15,000 BP) followed by the cold/dry Younger Dryas (YD) (13,000–11,500 BP) (Robinson et al. 2006; Bar-Matthews et al. 1999). In the Levant, the sharp return to cold/dry conditions of the Younger Dryas has been used as explanation for the origins of agriculture and a collapse of the foraging systems (Weiss and Bradley 2001). Rosen and Rivera-Collazo (2012) re-assessed memory of subsistence behaviors in the societies living through the Pleistocene–Holocene transition and argue that the subsistence strategies of the Late Natufian groups living through the Younger Dryas are consistent with those of the Epipaleolithic groups living during the Last Glacial Maximum, suggesting the survival of social memory of how to live when it is cold and dry. While climate change impacted the diet, its influence was particularly significant over gathered resources such as nuts, fruits, seeds, and tortoises. Animal prey selection was more a function of social factors – such as territoriality – which became more complex in time as historical processes accumulated within societies. Under warmer and wetter conditions, the spectrum of gathered resources narrowed to collection (or cultivation) of highly productive protein-rich nuts or large-seeded grasses. At the same time, increased sedentism demanded a broad spectrum of prey to avoid depletion of animal resources within increasingly rigid home range boundaries. Conversely, during cool and dry episodes, the plant harvesting spectrum broadened to include small-grained grasses caused by decreased availability of woodland products, but at the same time, social and environmental conditions supported an emphasis on a lower diversity of prey animals targeted. These behaviors repeat through time, from the Last Glacial Maximum to the beginning of the Holocene, and contextualize gradual decision-making leading to a preference for more regular sedentism and agricultural practices in some groups.

While the Earth's climate has undergone change and variability over the past c. 12,000 years (the Holocene), it has remained relatively predictable and stable compared with the dramatic changes identified by paleoecologists and climate scientists in the previous Pleistocene epoch (Mayewski et al. 2004; Timmermann and Friedrich 2016; Waelbroeck et al. 2002; Lambeck et al. 2014). Normal or incremental changes and climate variability experienced by people in the Holocene have dramatically shifted in recent years (e.g., Wolverton, Chambers, and Veteto 2014). This shift, prompted by the acceleration of atmospheric greenhouse gases and the expansion of hyper-industrialized economies, has gone beyond the expected or previously recorded norms. The increased density of people, together with the intensification of land transformation and in particular the burning of fossil fuels associated with industrialization, has impacted the planet in such a way that the process of climate change is intensifying beyond previously recorded parameters. Thus, there is an important and explicit distinction between past climate variability and the current climate change crises. Puerto Rico and the northeastern Caribbean are expecting and already feeling the impacts of increased air and ocean temperatures, ocean acidification, and sea level rise – including coastal flooding and erosion – as well as changes in precipitation patterns (that is, less overall rain but more intense sudden rain events and shifts in the drought patterns), changes to water availability from runoff and aquifers, and changes in wind patterns and air quality, among others (Rudge 2021; Runkle et al. 2022). Even though the expected changes are beyond previously recorded parameters, learning from the past can help to understand the magnitude of the expected changes, and also support the recovery of ancient wisdom in responding to unexpected change (Rivera-Collazo 2021; Graves, Villano, and Cooper 2021).

The archipelago of Puerto Rico, located on the northeastern corner of the Caribbean archipelago, consists of four large islands – Borikén, Vieques,

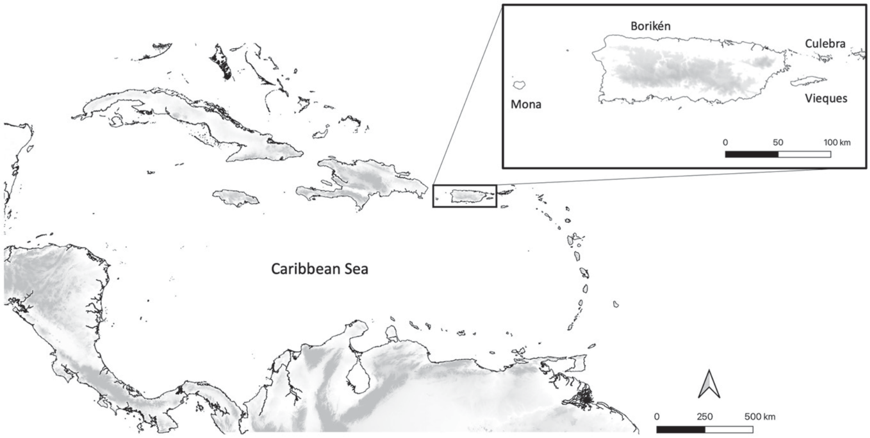

Figure 9.1 Archipelago of Puerto Rico within the context of the Greater Caribbean Region.

Culebra and Mona – and many islets and cays (see Figure 9.1). The largest island, Borikén, has rich paleoclimatic archives, such as sedimentary deposits in wetlands, mangrove peat, archaeological sites, coral reefs, and speleothems. As an island, its climate is strongly modulated by oceanic processes. Given its location, the paleoclimatic archives of Borikén should register the shifts of the North Atlantic oceanic and atmospheric phenomena explained above. Humans have lived in Puerto Rico, uninterrupted, for at least 5,000 years (Napolitano et al. 2019; Rivera-Collazo 2019). Given these potential datasets and history of occupation, Borikén is an ideal case study for exploring long-term climate variability and how inhabitants responded, changed, and adapted to punctuated changes on this oceanic sub-tropical island.

In this chapter, I use archaeological and historical–ecological methods to think about three interrelated, and often overlooked, questions related to climate change research: (1) how climate change impacts human societies, (2) how people in the past responded to climate variability, specifically changes in precipitation, and (3) what the long-term impacts of sea level rise are. I frame these questions in the contexts of lessons that might be used as a set of applied guidelines and assessable data, as we move towards an increasingly uncertain future.

Lesson 1: How to Link Climate Change and Social Vulnerability

Articulating an intersection between climate and people is not as straightforward as it might seem. Climate is a huge and complex entity and, as archaeologists, we know that human societies are extremely complicated and diverse across space and time. As such, any research attempting to integrate these two entities must coherently identify how, specifically, changes in climate variables can affect human societies and under what conditions humans perceive impacts and are vulnerable to negative effects. For example, people do not perceive climate change; they experience changes in weather patterns. Often, traditional knowledge of past weather patterns can help communities mitigate the impacts of unexpected conditions and support fast responses. However, the strongest impacts occur when high magnitude, unexpected conditions (foods, droughts, hurricanes) occur at unpredictable times and in high frequencies (Thomas et al. 2019).

Predictability is particularly important because the ability to predict environmental phenomena relies on highly localized and situated knowledge. This traditional knowledge is an extensive corpus of cultural data, accumulated over generations of observation and experience, of people living in the same place for a long time. Western scientific methods registering climate tend to be relatively very short: in Puerto Rico these extend to maybe 50 years (e.g., Keellings and Hernández Ayala 2019). However, people have been living on the island two orders of magnitude more than that, at least 5,000 years. Traditional knowledge, history, ecology, and archaeology can contribute to an extended record of climate variability and improve our understanding of the magnitude, predictability, and frequency of climate drivers, and the effect that their change has on the islands and on the communities.

Climate change is a global, large-scale process, well beyond individual experience, but the weather phenomena it triggers can occur within single lifetime frames. We must therefore focus on processes that are compatible with both the lifecycles of people and their non-human relatives (see also Reyes-García et al. 2016). Historical–ecologists have been especially critical about the use of controlled and rigorous temporal datasets. For example, environmental scientists attempting to examine historical land-use activities and attendant impacts often poorly integrate (or ignore outright) historical and temporal range and variation (Lane 2019; Bender 2002). This is especially problematic given that concepts of resilience and sustainability are inherently temporal in their application (Thomas et al. 2019), or, as Lane points out, operating at different rhythms and amplitudes (Lane 2019: 64). When looking at the past, we must make sure that the phenomena we are studying are contemporaneous within a relevant temporal margin of error. For example, paleoclimatic records such as those from speleothems (Winter et al. 2011; 2020; Oster et al. 2019; González and Gómez 2002) can provide data about ancient precipitation at annual or sub annual resolution. However, in Caribbean archaeology, most cultural chronologies are built using relative classifications of pottery styles, which group social contexts in broad multi-century scale blocks with huge margins of error and imprecise beginning and end dates (Napolitano et al. 2019; Agorsah 1993). Changes in pottery styles interpreted as social change cannot be correlated to changes in climate. Analyses of climate change impacts to ancient societies, such as droughts or hurricane events, need to identify and measure relevant variables that relate social decision-making to changes in weather and climate. We must also improve the resolution of reconstructed social processes within sites. It is poor practice to articulate high resolution climate data (less than 10 years) with low resolution cultural data (more than 300 years) and use that to build explanatory correlations.

On their own, few of the changing climate phenomena impact humans directly. Heat and severe events do pose direct risks to human life, as heat waves can and do cause increased mortality (Méndez-Lázaro et al. 2015; Méndez-Lázaro et al. 2018), as do catastrophic events triggering landslides, floods, or other structural collapses (Noji 2000; Santos-Burgoa et al. 2018; Kishore et al. 2018). Other changes impact people indirectly or disproportionately. For example, sea level is an important climate change variable, but mostly for people that live on the coast and less so for those that live in continental settings. In addition to this, the impacts that climate change causes can exacerbate discriminations and oppression already imbedded within a society (Nishime and Williams 2018; Thomas et al. 2019). Sea level rise has already and will continue to create unavoidable impacts for people that live on coastlines and cannot relocate, but it will be perceived as a less urgent issue for affluent individuals for whom coastal settings are second or vacation homes. Climate drivers affect people most intensely when the climate event occurs where people conduct their daily activities. That is, individuals living in areas that are not affected by a specific heat wave or a high magnitude cyclone, or those with the means to mitigate how those impacts affect their life, will feel the change differently from those directly on the path of the event or without means to mitigate it. Therefore, members of societies are not all equally vulnerable: we have differential vulnerabilities to climate change (Thomas et al. 2019).

Archaeologists identify separate cultures based on differences or discontinuities in specific variables in the archaeological record – the traditional ways of making utilitarian vessels, the techniques for making tools, how and where people build their houses, where people choose to live, and how they interact with others. Among these, the most conservative variables, those cultural characteristics that persist even when there is change in others, are the cultural priorities tied to food and habitat: what people eat and how are meals prepared, where people live and what their settlements look like. We have all experienced this in person. We remember the places we live in, the scents, the colors, the light; they are part of who we are. In archaeology, we attempt to reconstruct at least some of these phenomena by analyzing plant and animal remains, as well as settlement patterns and intra-site structure. Food and habitat are defined by and characterize culture. Livelihood security is the ability of people to continue those traditions: to eat in a culturally significant way, and to live in culturally significant places. Therefore, when thinking about how to tie climate and people, we need to focus on the climate drivers that can impact components of human food and habitat security, especially those that directly threaten human health and well-being.

Changing climate drivers can affect the life cycles of plants and animals that support traditional foodways and therefore will impact whether people feel safe and supported in their homelands, those places where some people have lived traditionally for millennia. However, humans are not static or agentless recipients of impact. Humans define their cultural patterns or "our ways of doing" (Martin and Mirraboopa 2003). Communities can decide to change their diet or to live somewhere else, and, if those changes are culturally acceptable, they maintain their cultural identity. Climate change is catastrophic for societies when the adaptation measures augment elements of oppression and colonialism and, in turn, terminate traditional cultural identity. Taken together, as archaeologists and historical ecologists seek to link aspects of climate research with social impacts and discussions of vulnerability, there needs to be a more seamless integration of people over spatial and temporal scales. This means working with traditional and residential communities and centering on their needs to be better at understanding how climate change affects people within culturally relevant ways.

Lesson 2: Downscaling Climate Data and Human Adaptation Strategies

The end of the mid-Holocene (4,200 years ago) (Walker et al. 2019) in the Caribbean coincided with the end of a period of intense solar forcing that triggered overall higher SSTs in summer and larger land-sea contrast during winter (Hodell et al. 1991). This influenced the ITCZ to migrate further north, reaching the Greater Antilles during summer in the mid-Holocene (Pollock et al. 2016; Braconnot 2000; Gyllencreutz et al. 2010; Wanner et al. 2008; 2008). The convection band of the ITCZ also widened, affecting a larger area and depositing a further 2–4 mm of rain per day compared to modern conditions (Braconnot et al. 2007). This meant that the Greater Antilles saw wetter wet seasons and dryer dry seasons (Greer and Swart 2006). At this time, the archaeological record demonstrates the presence of permanent settlements along the coasts of societies that migrated to the Caribbean islands from the South American mainland (Rivera-Collazo 2019). These societies had narrow subsistence ranges, which means that they sourced their food from ecosystems immediately around their settlements, including coastal forests, mangrove and coastal wetlands, estuaries, reefs, rivers, and sandy beaches. They also brought domestic plants with them and cultivated plants in the immediacy of the settlements (Rivera-Collazo and Sánchez-Morales 2018).

To investigate how broad climate shifts are reflected in Puerto Rico specifically, we analyzed a speleothem from the Palco cave to reconstruct local precipitation ranges that could affect surface runoff, wetland expansion, and aquifer recharge, and thus habitat security (Rivera-Collazo et al. 2015).

Our analysis revealed a growth phase in the speleothem that lasted around 800 years, between 3,900 and 3,100 years ago. This event fits between two northern hemisphere cold events at 4,100 and 3,200 years ago, and probably represents a brief return of the ITCZ to a northern position, with local precipitation at an average of 50–70 mm/year. It also occurred at the same time as the Archipelago of Puerto Rico presents evidence of many settlements with material remains associated to what is generally known as the Archaic tradition or Archaic period. The higher precipitation period started after habitation was established at three important archaeological sites – Maruca, Angostura, and Paso del Indio – and ended before the end of that initial period. This coincidence of environmental change within the lifespan of what seems to be a single culture makes this long-lived event a good example for which to consider the human response. Angostura is located at the foothills of the limestone karst system where the coastal plain begins, next to what would have been a coastal lagoon at the time of occupation. Paso del Indio is located on the floodplain of a narrow gorge of the karst system on the Cibuco River, and Maruca is located on the southern coastal plain, adjacent to mangrove wetlands at the time of occupation. During the time of higher precipitation, Angostura and Maruca show evidence of groundwater surfacing, and Paso del Indio presents a shift from a stable to a depositional environment with periodic overbank flow.

Both Maruca and Paso del Indio seem to have been abandoned during the wet period when the Palco speleothem was growing, but occupation continued immediately after. In Maruca, a returned occupation after the period of higher precipitation includes the presence of burials mounds, suggesting stronger identification and fidelity with the land. Microcharcoal evidence from the coastal plain just north of Paso del Indio suggests that people could have relocated to the coast or other areas away from the floods and instability of the river, but that the landscape was not abandoned. Stable occupation at Paso del Indio is evidenced after the period of floodplain instability. Angostura was also not abandoned. The inhabitants responded rapidly to increased moisture by creating shell layers over the natural clay soils and limestone outcrops of the forest (Rivera-Collazo et al. 2015; Rivera-Collazo and Sánchez-Morales 2018; Rivera-Collazo 2011). These layers were then covered with additional sediment to create habitation spaces, raising living surfaces above the periodically flooding forest floor because of groundwater surfacing.

This case study presents two lessons. First, that people respond to the changes they perceive based on their lived and learned experiences. The fact that the ITCZ migrated south prior to 3,500 years ago in Puerto Rico does not mean that the period was dry as would have been expected. The local data reveals that Borikén experienced a localized time of higher precipitation and that people responded to it and not to the migration of the ITCZ. Therefore, we cannot use broad climatic parameters to understand human processes. We need to scale them down to regions or territories if we want to understand the human experience of climate. Second, different communities and groups, even within the same society or culture, respond differently to their experience of climate. Maruca, Paso del Indio, and Angostura show that people will develop adaptation strategies that fit their own needs, even if that means responding differently to the same environmental phenomenon. Therefore, in the present, it is unwise to propose one-size-fit all adaptation strategies, especially when using data that is not downscaled to relevant human variables affecting the localities where the relevant communities are living.

Lesson 3: Effects of Sea Level Rise Over Coastal Communities

The previous example focused on a specific point in time: the transition from the mid- to the late-Holocene. In this example, I look at long-term change through time. Sea level rise is at the top of people's minds when referring to climate change. Rapid melting of the ice sheets at the end of the Pleistocene triggered massive amounts of meltwater to return to the oceans and this led to incredibly fast sea level rise between 25,000 and 5,000 years ago (Khan et al. 2017; Ashe et al. 2019). This process triggered significant restructuring and reshuffling of landscapes everywhere, especially on shallow continental and insular shelves (Flemming 2021; Harff et al. 2017; Rivera-Collazo 2019) (see Figure 9.2). Even though the sea level reached modern levels around 2,000 years ago (with broad margin of errors due to relative adjustments), sedimentological processes have continued adjusting and responding since then. Therefore, the landscapes we experience today are not the same ones that people experienced in the past.

Punta Candelero is a highly important settlement where peoples made and used Saladoid and Huecoid pottery. Radiocarbon dates suggest that the site was active at least between 480 and 1100 AD. The site is located on the coastal plain of the Candelero River basin. The geomorphology presents an alluvial sequence with eroded loams over weather bedrock at the headwaters, and smaller grain sizes towards the coast, ending with sand dunes at the shoreline. The settlement itself is located on what geomorphologists have identified as a cuspate foreland, which is a type of headland that forms when currents clash and drop their load, depositing it seaward. To better understand the context contemporaneous to human habitation, as well as the response to the local geomorphology to sea level rise and stabilization, we analyzed geoarchaeological samples from within and around Punta Candelero, as well as its topography and bathymetry (Rivera-Collazo et al. 2021).

The interpretation of Candelero as a symmetrical cuspate foreland suggests harsh and challenging environments for inhabitants, with ocean waves of similar transport energies from opposing locations clashing at the site and creating a transport current seward from the foreland's tip. Cuspate forelands tend to be unstable, as they can fully erode or accumulate depending on the oceanographic conditions (Miyahara, Uda, and Serizawa 2017). Thus, living on one would create added risks for any permanent settlements. The lithological analysis from the headwaters to the coast suggests that Punta

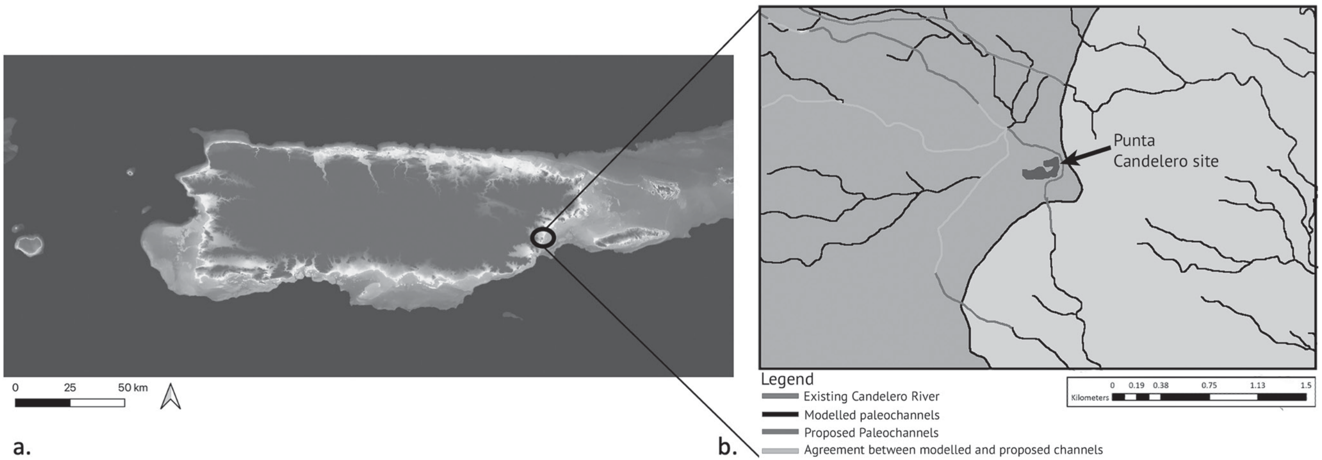

Figure 9.2A–B Landscape transformation after post-Pleistocene sea level rise. Part A: the archipelago of Puerto Rico showing in light blue the areas of the insular shelf that would have been dry land during times of lower sea level. Part B: the location of Punta Candelero site on the east side of Borikén. The analysis of the local topography and bathymetry demonstrate the existence of paleochannels that extend under water and suggest that this landscape today is dramatically different from the one experienced by the inhabitants of Candelero between 480 and 1100 AD.

Candelero is not a cuspate foreland but a delta at the head of a coastal plain scarred by paleochannels (Rivera-Collazo et al. 2021) (see Figure 9.2B).

One of these channels flowed into Candelero's foreland and drained towards the sea with a curved sand bar at the beach. The continuation of these channels underwater suggests that this drainage system had been active since the Late Pleistocene, when the sea level was lower. This paleoenvironmental reconstruction shows a complex and ecologically rich ancient setting that allowed access to a wide variety of highly ranked ecosystems from a single location. As an alluvial setting, the foreland has rich soils with agricultural potential that would have been available within the settlement and immediately around it. These soils could have supported rich production of cassava (*Manihot esculenta*), a staple food for Caribbean cuisine (Bates 2014: 350). Aside from immediate access to prime soils, the setting also allowed access to estuarine and reef species, all key to the traditional subsistence patterns observed on the site (Rivera-Collazo 2010). In addition to fishing activities, the delta would have had an inlet behind the mouth's sand bar, which would have been ideal as safe shelter for canoes, protected from wave action. All these allowed Punta Candelero to be a prime location for peoples' food, livelihoods, and commerce. It presents an excellent viewshed, access to navigation routes, and highly diverse and valuable resources, including rainforests, alluvial plains and clay, silt, and rock outcrops.

Rethinking the sedimentological origin of the foreland invites us to think about its future. A delta is formed when sediments flow into water bodies. In the case of Candelero, the origin was the Candelero River, but this river was canalized at some point before the 1940s to a location further north. Development during the 20th and 21st centuries has modified the landscape significantly, thus impeding the natural sedimentary budget to reach the river mouth. Today, the foreland is severely threatened by erosion, which has seen a landward migration of the shoreline of over 50 m since 2014. The northward movement of the river, together with decreased sediment input, rising sea level, and increased frequency and magnitude of storms, will continue transforming this coastal landscape. Development near the shoreline and the use of hard structures will further threaten it by reducing even more the sediment budget transported in coastal currents.

This analysis brings forth three lessons. The first is that we cannot assume modern geomorphology will reflect or be a blueprint for past geomorphological patterns and processes. People live in areas that are attractive for their own social priorities, and they will try to continue living in them as long as it makes sense to them. Second, the interplay between geomorphological processes and long-term human modification of landscapes is central for the understanding of hazards and hazard evaluation in the present and the future. Third, the assessment and mitigation of the risks posed to human life and infrastructure must take into account past and present human geography because modern geomorphological processes are the product of very long-term dynamics.

Closing Thoughts

The scenarios for the future are dire. As this chapter is being written, world leaders, powerful stakeholders, and thousands of observers gathered in Glasgow for the 26th meeting of the Committee of the Parties, or COP26. At that international level, and at national and local levels too, the efforts towards preparing for what will happen circle around better understanding of climate drivers, improving climate science, downscaling forecasts, better identification of risks, mapping potential impacts, and suggesting risk management or adaptation measures. However, we are still missing an equally sensitive and intensive effort to understand people. Natural scientists insist on the urgency and the seriousness of the dire scenarios that we are facing, and repeatedly call for action to mitigate change and to increase resilience. However, there is a gap between the calls for action and the real effects on the ground. The wider narratives about climate change, telling us about the expected worsening conditions in 2050 or 2100, give us a false sense of security, as if change will happen in the future, not yet. This perception keeps that gap open, with scientists on one hand talking about the future and about often unrealistic mitigation plans, and people on the other hand carrying the burden of changing weather and real disasters, facing real threats to their livelihood security and to their identity.

Global and national efforts need a better understanding and integration of people for navigating the scale and complexity of the climate crisis. By partnering with local communities, we can help move our conversation towards action. Local communities are more than simple receivers of information, providers of local knowledge, or volunteers for data collection. They are experts on their homelands, which scientists are often only visiting for a small window of fieldwork. Integrating traditional and local knowledges with coastal and ocean sciences requires recognizing historical–ecological relationships and land-based heritage, stepping down from the white marble towers, and establishing respectful horizontal partnerships.

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10 Whose Climate Change Is It?

A Thousand-Year Example of Kali'na Responses to Shifting Coastal Landscapes in the Lower Maroni River

Marquisar Jean-Jacques, Marianne Palisse, Martijn M. van den Bel, Antoine Gardel, and Edward J. Anthony

Introduction

> *Climate change, climate change – everything is because of climate change according to these white people today. But me, I have already experienced coastal flooding and erosion in the past. But then the erosion stopped and things stabilized. My parents, their parents, and so on experienced that too. In the past when things got too difficult, it didn't matter the reason, Kali'na moved places. So I'm not worried, because the same thing is happening again with the beach. I'm not worried, we'll find solutions and I don't think the erosion will continue, it's just a cycle.*
>
> (76- year- old man, Yalimapo, 2018)[1]

Sitting under his carbet[2] in the town of Awala-Yalimapo, this elder recounted the continuous coastal changes that he and his ancestors have experienced over generations. Kali'na people have long resided in the coastal regions of French Guiana and eastern Suriname, which forms part of their broader territory ranging from northeastern Amapa state, Brazil, to northeastern Venezuela (Collomb, 2003). This man evoked Kali'na traditions of mobility to explain how his people have adapted to environmental and geological changes on the coast. This conversation highlights the fact that the perception of climate change as something self-evident and ongoing might not always be shared or perceived as a useful way to understand environmental changes experienced by local people.

Climate change is widely understood as one of the biggest collective challenges of our century. The IPCC and other multi-disciplinary and multi-lateral groups have utilized cutting-edge scientific assessments to project future climate scenarios for our planet. At the same time, the entrance of climate change into public discourse has allowed a variety of media and political interests to reinterpret the concept in relation to their own interests (Fernández-Llamazares et al. 2015). While impressive scientific

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developments have accelerated the rate and precision with which objective climate data can be gathered and analyzed, the meanings and interpretations that emerge from those cumulative data are filtered through social and cultural experiences of individuals and groups (Junqueira et al. 2021; Veteto and Carlson 2014). This can create tension between scientific understandings of climate change, which are touted as objective, impersonal, and apolitical, and the lived experience of local communities, which are socially, geographically, and historically situated (Jasanoff, 2010; Cameron et al. 2021). At the same time, the recognition of the utility of local communities' environmental knowledge for understanding climate change has offered them the opportunity to play a role in the world debate by asserting their own place-based experiences of climate change (Gill and Lantz 2014; Reid et al. 2014).

In this chapter, we present an analysis of Kali'na people's historical and contemporary experiences of environmental and socio-cultural change in the Lower Maroni River. We demonstrate the limitations of the climate change concept in this context, which arise from differences in temporal scales, the dynamic adaptive capacity and strategies of the people, and their deeply personal and sensitive experiences of environmental change. Using a chronological approach as an analytical tool to understand the stages of social–ecological change, we combine ethnographic, archaeological, and historical data to problematize local ideations of climate change. We argue that, as a scholarly phenomenon, climate change distorts temporal and spatial scales. When a global concept like climate change is brought to bear on a local community, it can create ambiguity that does not come from an inability to assimilate the scientific theory of climate change, but rather from the fact that scientific representations of time and space are at odds with Kali'na (or other local communities') ontology. We outline the history of continuous human occupation and geomorphological change in the Lower Maroni River region over the past thousand years and explain how Kali'na people situate themselves today in relation to this history and to the climate change discourse.

Chronicles of a Singular Coastal Region on the Northeastern Edge of Amazonia

The 612 km-long Maroni River is one of the longest rivers of the Guiana shield and forms a large stretch of the border between French Guiana and Suriname. Its estuary opens onto the largest muddy coast in the world, which extends between the deltas of the Amazon and the Orinoco Rivers. The high dynamism of this coast is due to the huge amount of fine sediment (about 800 million tons/year) dumped into the sea by the Amazon River. A part of this sediment is transported northwest along the shore as migrating mudbanks, which are deposited on certain portions of coast and rapidly colonized by mangroves. In areas where mudbanks are lacking, erosion leads to the disappearance of mangroves accompanied by shoreline retreat rates of tens of meters to several kilometers over periods of a few months to a few years (Anthony et al. 2010; Toorman et al. 2018). These cycles of erosion and deposition have formed the young Holocene coastal plain of the Guianas, which is composed of sand ridges (*cheniers*) supplied by the Maroni River and separated by marshes (Augustinus, 1978; Wong et al. 2009).

The human occupation of sand ridges in the Maroni region is attested to by archeological remains (ceramics, earth ovens, quartz debitage, *terra preta*), with the oldest sites found on the Pleistocene white sand formations and the Holocene river terraces (van den Bel 2015). Awala and Yalimapo villages are located on a Holocene chenier, whose formation has been dated to between 2000 and 1300 years BP (Brunier et al. 2022). The majority of the archeological sites of this region date from approximately 1000 BP onward and have been attributed to the Late Ceramic Age (Cornette 1987; Coutet 2014; van den Bel 2015, 2018). The former inhabitants of this region built raised fields in the savannas for agricultural purposes as a component of a complex subsistence system, similar to many historical processes of landscape transformation practiced by Indigenous societies throughout Amazonia (Balée 2013). These earthworks were created by the Arauquinoid cultures during their eastward migration from the Orinoco region along the Guianese coast between 650 and 1650 AD (McKey et al. 2010; Stier et al. 2020).

Another coastal culture known as Koriabo began just before the first Europeans arrived in the Americas (Barreto et al. 2020). The first descriptions of the "New World," which simply speak of "good" and "bad" inhabitants or describe Arawaks and Caribs, fail to account for the possible diversity of people that inhabited the area. The Guianas were considered unattractive by the Spanish colonists compared to other regions of the Americas that held more valuable resources (gold, silver). Also, the coast was inhabited by many "savages," hence the name *Wild Coast* or *Wilde Kust* used by English and Dutch colonists. Nevertheless, there is very little historical documentation from the region in the 16th century, and what exists is heavily colored by colonial ideas and interpretations. It was only near the end of the 16th century that Indigenous toponyms of the Guianese coast were documented due to the growing interest of the English, Dutch, and French, which eventually led to encroachment in the region (Collomb and van den Bel 2014).

The Maroni River became important for Europeans because of its theoretical potential to provide access to *Manoa*, the mythic city of *El Dorado* (Raleigh 1596). The English captain Lawrence Keymis was sent to search for passages to Manoa, and at the mouth of the *Amonna* (Mana) River he found a "very great" town called "*Iaremappo*" (Yalimapo) inhabited by "*Charibes*" (Keymis 1596). At the mouth of the "*Marawini*" (Maroni) River, Keymis encountered Paracuttos (see Figure 10.2). About 15 years after Keymis' voyage, the Maroni River was visited by Unton Fisher and Humfrey

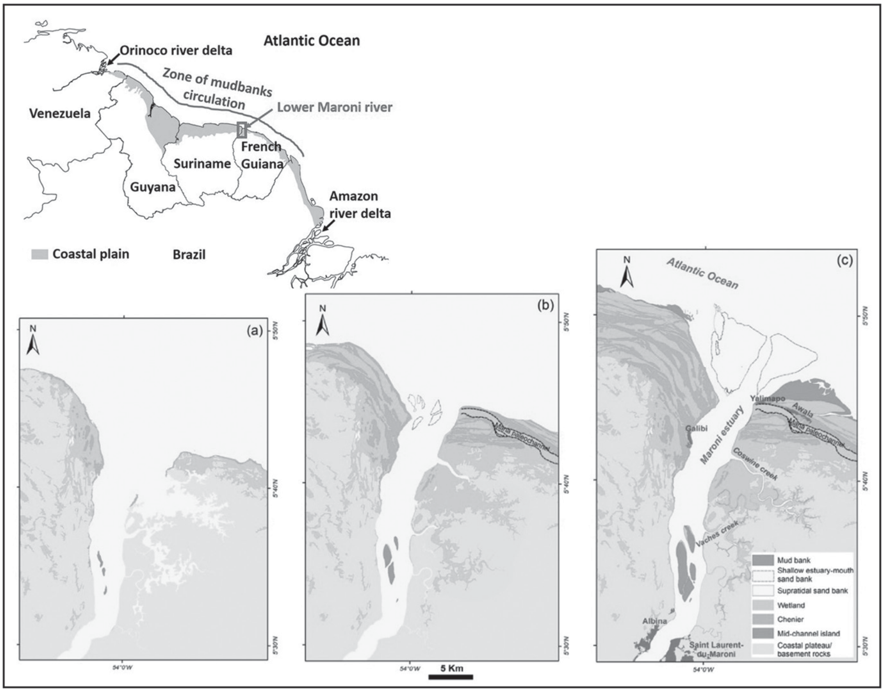

Figure 10.1A–C Schematic three-stage evolution of the Maroni estuary following the Holocene sea level rise. Part A: Young flooded estuary after sea level stabilization and formation of first cheniers. Part B: Median stage of estuarine development showing the increasing development of cheniers and coastal deposition. Part C: Present stage with mud bank settlement and transition to delta associated with Maroni River sand supply (A–C: Gardel et al. 2021; upper left map adapted from Allison and Lee 2004).

Croxton, who mentioned that "*Paragotos, Yaios, Charibs, Arwac*" nations were now inhabiting the lower part (Harcourt 1613).

There is hardly any detailed data for the first two centuries after contact except for a few mentions in logbooks or journals such as those attributed to Jesse de Forest (1625) and David Pietersz de Vries (1634), who also confirmed that various Indigenous groups lived on the lower reaches of the Maroni River. At the end of the 17th century, the Maroni River became a frontier after the Dutch captured Suriname from the English (van den Bel and Collomb 2021), and military outposts were built on both sides.

During the late 18th century, European colonists' maps represent possible movements of people along the coast, especially for the region between the Mana and Maroni estuaries. Other maps have been used by the geomorphologists Plaziat and Augustinus (2004) to outline the geological

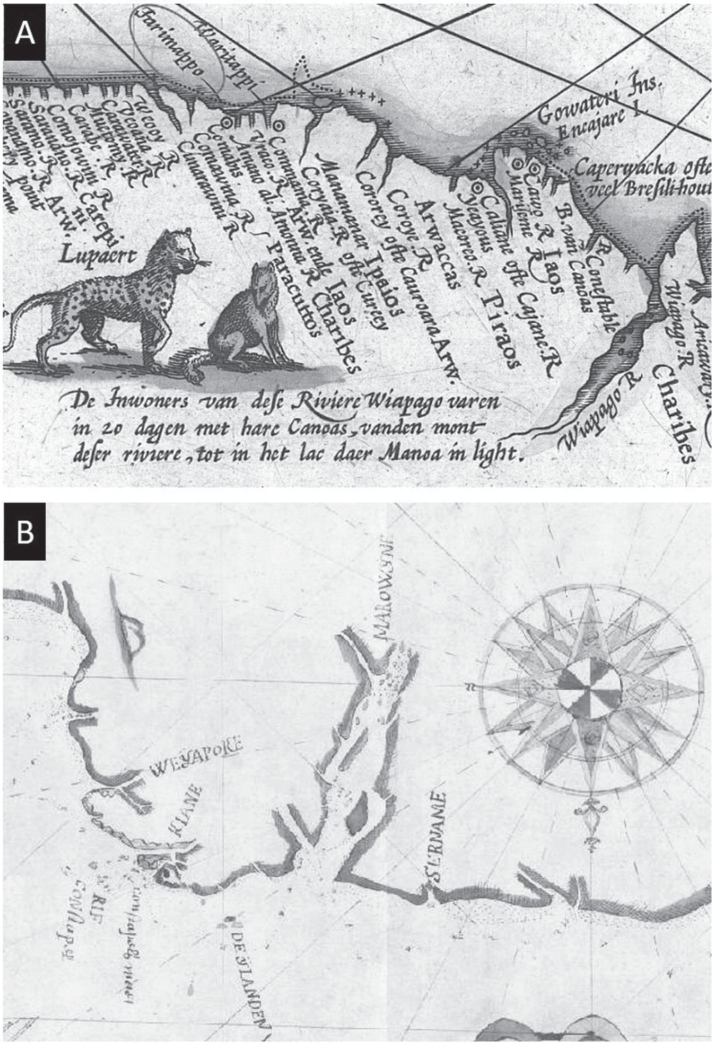

Figure 10.2A–B Part A: The coast of French Guiana at the end of the 16th century showing Iarimappo circled in red. Extract of a map by Jodocus Hondius called Nieuwe Caerte, 1599 (© Collection of maps, HB-KZL 104.05.04, Allard Pierson, Universiteit van Amsterdam). Part B: The mouth of the Maroni River. ©Nationaal Archief, Extract of Map of the Guiana coast between Demerary and the Amazone river by Joos Bastiansen, 1627. Facsimilated in Great Atlas of the West India Company part I p. 143. Archive inventory number : 650. File name : NL-HaNA 4.VEL_650.

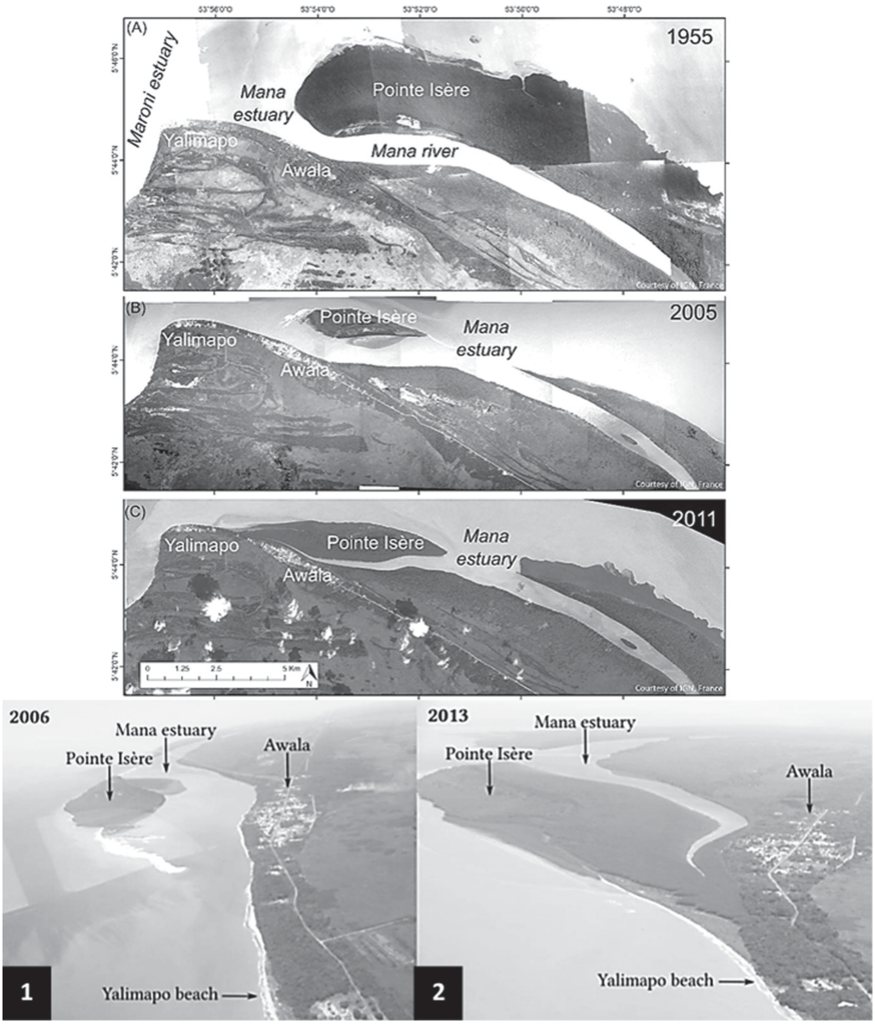

Figure 10.3A–C Parts A and B: Rapid shoreline changes associated with erosion of the mud cape of Pointe Isère between 1955 and 2013. Part C: The progressive closure of the former mouth of the Mana River between Awala and Yalimapo by shore-welded mangrove-colonized mud that has isolated the beach at Awala from the sea (Jolivet et al. 2019a). Part 1: The welding of Pointe Isère to the shoreline. Part 2: The colonization of the shore-welded mudbank by mangroves causing the closure of the mouth of the Mana River (photo credit: Daniel Payeur) (Jolivet et al. 2019b). Reproduced and modified with permission from the Coastal Education and Research Foundation, Inc.

evolution of the coast during the colonial period in French Guiana. During that time, the main geophysical change between the Maroni and Mana rivers was the development of a sandy cape, later named Pointe Isère, and the transformation of the Mana river mouth into an estuary. In the mid-19th century, Kali'na people settled on Pointe Isère after displacement due to the expansion of prison camps around Saint-Laurent-du-Maroni in areas previously used by Indigenous people for subsistence activities (Donet-Vincent 2003). During this same period, the Surinamese town Albina was founded on the site of a previous Carib village called *Kumaka* (Kloos 1971), leading Kali'na people to maintain distance with these new colonial settlements. In the 1850s, Point Isère was subjected to repeated phases of erosion and growth, but significantly extended toward the Maroni river mouth until the 1940s.

The Lower-Maroni Region Since the 1950s: A New Era of Changes?

In the early 1950s, an intense episode of erosion began to affect Pointe Isère, where Kali'na and Creole villages coexisted (Lohier 1972). This episode led Kali'na families to move onto the continental coast where the villages of Aoura[3] and Yalimapo were founded. Mobility continued to make it possible to cope with the morphological and ecological coastal changes. In the late 1950s, mobility was still central to peoples' livelihoods: "*Many young people move from one bank to the other when they get married, and entire villages sometimes emigrate from Surinam to French Guiana and vice versa.*" (Hurault, 1963: 146). This erosion period also coincided in the late 1950s with the closure of the penitentiaries, which made some land available once again for Kali'na use. In the early 1960s, the French government started to group Kali'na families in fixed villages near Creole towns and to educate children in "pensionaries" in order to assure their assimilation (Armanville 2012; Guyon 2013). This period gradually brought them into the labor economy, giving men access to wage markets and families access to social assistance that comes with French citizenship (Collomb and Jolivet 2008). At the same time that some Kali'na used the relocation program to take greater control of their socioeconomic circumstances, these social changes slowly coerced them to sedentarize along the coast. Despite this, the traditional strategy of mobility has continued to be employed for coping with coastal change as well as to meet the necessities of social life. For example, between the 1980s and 1990s, Awala inhabitants experienced a phase of erosion that swept away sections of roads, a football field, and a school. The response of some families living on the shore was to move further inland as soon as the flooding reached their homes – which in general marks for them the "right time" to leave. Their displacement was self-organizing, relied on intra- and inter-family solidarity, and was facilitated by the lightweight building materials of their homes.

In 2011, the old mouth of the Mana River was sealed off and a new one slowly formed from a breach on Pointe Isère (Palisse et al. 2022). The beach in front of Awala village was then completely cut off from the sea as mangroves grew over the offshore mudbank (see Figure 10.1). Awala's shore has remained stable until today, whereas Yalimapo's coast recently began to change. The arrival of a mudbank in 2016 and the formation of a sandy spit at the mouth of the Maroni River perpendicular to Yalimapo beach reversed the direction of offshore currents, intensifying the rate of erosion. Since 2019, the beach at Yalimapo has continued to experience significant erosion.

Among all these coastal change, Pointe Isère continues to mark the collective memory since it has been significantly eroded over the last fifty years (Jolivet et al. 2019a). Kali'na people's experiences of the constantly alternating advance and retreat of the coastline is primarily perceived through human time scales and culturally-defined perspectives of time.

Environmental Changes Seen Through the Lens of Local Temporalities

Studies on climate change with local communities often start with observations of local environmental changes, which are then interpreted in light of global climate change (Funatsu et al. 2019). This approach risks simplifying or mischaracterizing how people experience and deal with change in their lived environments, and results from the temporal and spatial differences that often exist between local and global perceptions of environmental change. Climate change and ongoing natural climate variability do not occur at the temporal scale of human experience, and what researchers record "*includes perceptions of environmental change, which is either attributed to global climate change impacts, to local weather patterns, or simply unrecognized as impactful*" (Wolverton et al. 2014: 274). The concept of climate change inscribed in a distant future is confronted with that of a near future experienced every day by people (Rosengren 2018). Within the scientific temporal framework, climate change is presented in terms of a linear conception of time comprising a series of geological eras, which culminate in the current Holocene (or recently proposed Anthropocene) epoch (Bonneuil and Fressoz 2016).

However, in other time perceptions, like those of Buddhism and Hinduism (which believe in a circular universal cycle of destruction and creation) and for many Indigenous peoples, the relation to time is defined by nonlinear temporalities (Wander 2021; Wright et al. 2020). For these groups, time is relational, linking present experiences with historical and ancestral pasts, and embodied across varied spaces, places, and bodies (Chisholm Hatfield et al. 2018; Whyte 2017). The transformation of the relationship to time in the context of climate change can be influenced by local populations' appropriation of knowledge originating within the framework of climate change awareness campaigns (Hulme 2009). But in many cases, the difficulties of the climate change discourse on a local level lie in the projection of a new and distant global temporality which may not match local people's temporalities (Döring et al. 2022).

In Kali'na language and culture, temporality is not entirely commensurate with geophysical prescriptions of time in the age of climate change. A bio-circular temporality is represented by natural cycles of seasons, days, months, and human lifespans (birth, growing old, death). This place-based temporality is then linked with a symbolic cosmogenealogy based on meaningful historical events (usually recorded in myths and related to individual and collective social experiences), including colonial memories (e.g., travel to France for exposure at the human zoo Jardins d'Acclimatation at the end of the 19th century, religious missions, first contacts with the European colonists, etc.). An asynchronous temporality represented and reachable through dreams and spiritual journeys also exists and has consequences for lived experiences of environmental change. Like in other Amazonian Indigenous societies, the oral tradition is also for Kali'na people a conservatory of geographical knowledge, songs, myths, and stories that are used to teach skills, transmit cultural values, convey news, record family and community histories, and explain the world (Santos-Granero 1998; see also Virtanen et al.'s chapter in this volume). In this sense, the relation to and transmission of history is based on orality (Kloos 1971), and the elders have a role as transmitters to pass it down to the next generation.

People's Perceptions of Environmental Change and Their Responses in Awala-Yalimapo

When people in Awala-Yalimapo notice changes in their environment, they explain and analyze these changes within their own framework of time and in relation to a long history of environmental dynamism. Most individuals challenge linear narratives of a dreadful future of climate destabilization by offering their own accounts of history that highlight resilience in the face of constant change and global uncertainty (Sachdeva 2016). Others challenge science's claims to objectivity by pointing out that measuring is not the same as understanding change:

> *They said it is the Amazon River, they make projections that it will reopen in a few years, that some mudbanks will move down shore a few kilometers, et cetera. But they are not God, things can happen differently, nobody knows!*
>
> (43-year-old man, Awala, 2018)

> *They like to do a lot of studies on the beach evolution. I don't remember how many scientists came to Awala-Yalimapo to study the environment, certainly too many. But what I can say is that their studies don't bring anything useful because we continue to have the same problems that are*

not solved. I am a man of action, and for the type of coastal constraints we face here, we have to act quickly and move just like our parents used to do in the past. They don't need to spend money on studies to know that the sea can be a danger if we stay here, they should rather use this money to help us build up somewhere else before it's too late.

(52-year-old man, Yalimapo, 2021)

This last quote also clearly illustrates one of the key problems with the climate change concept for Kali'na people: since it unfolds on a vast spatial and temporal scale, mitigative action is too slow, out of step with their intimate knowledge and experience of constant coastal change. For this man, the reality of the impacts of coastal change are, in effect, too fast and too relevant for climate change rhetoric to be of use.

An important episode of flooding occurred during the rainy season of March 2022, during which the two main coastal roads were cut off by overflowing rivers and swamps. The floods were heavily covered by the media and roads were closed for several days. The western part of French Guiana, including Saint-Laurent-du-Maroni, was isolated while the Mayor of Mana declared a state of emergency. Awala-Yalimapo, located 20 km from Mana, was not directly affected by the floods; however, the people were worried. In this context, most inhabitants expressed astonishment without mentioning climate change:

I never saw such floods before on this road section, it's impressive!

(53-year-old man, Awala, 2022)

Other inhabitants expressed their surprise at the extent of the flooding, adding that it must be caused by climate change:

Yeah, it's climate change! It's unusual, normally we have a little calm period in March before it starts to rain hard again.

(53-year-old woman, Awala, 2022)

Conversely, another inhabitant stated that there was nothing unusual about the event during the rainy season, and that, rather, the issue was not climate change – it was the defective infrastructure of French Guiana:

For me, all of these floods happening now are normal, it's the rainy season, and it already happened before. I don't know why people react each year the same way when they should know what happens during the rainy season. I don't think it is climate change. The problem is the roads are not adapted and well-built to support heavy rains.

(61-year-old man, Awala, 2022)

The ways that coastal change is understood to be related to climate change differ among different generations of inhabitants:

> *Maybe it's because of climate change, maybe not, I don't know. But what I see every day is that the sea is getting a little bit closer to our houses.*
> (55-year-old man, Yalimapo, 2018)

> *I think the coastal changes and risks we encounter might be related to climate change since they say it has an influence on sea level rise, and that some weather phenomena will become more frequent in the future. But maybe it's not climate change, who knows, I'm not a specialist.*
> (24-year-old man, Yalimapo, 2018)

This man expresses the ambiguity associated with the drivers of climate phenomena. Climate change may or may not be touted as an explanatory cause of an observed phenomenon. Also, power relations shape his discourse: "*I'm not a specialist.*" It shows that sometimes some locals may adopt or be persuaded by scientific discourses, disregarding their own reasoning, place-based knowledge, or oral traditions (Geniusz 2009; Rosengren 2018; Whitaker 2020).

In relation to this recent event, as well as for other episodes of environmental change, the positions expressed by locals might effectively be divided among those who "support" or acknowledge climate change and those who are skeptical and object to it. Depending on the context, people might use climate change as a justification for exceptional events, while others, like in the quote above, point to other causal factors of environmental change. In some cases, neither justification nor rejection of climate change was apparent – some preferred to remain silent. The questions raised by the climate change discourse are further compounded by the media, where complex data and scientific discourses are framed and filtered through emotive and affective language and imagery (Hulme 2009). The diffusion of pictures and videos on TV and social media and the level of education in Awala and Yalimapo play a role in some inhabitants' reception of the climate change discourse. Some seem to know what climate change is and its consequences, but at the same time they express skepticism and uncertainty about its influence on their local level, and they often do not label natural hazards as disasters.

Even after severe coastal flooding in 2019, most inhabitants remained skeptical about climate change and coastal risks (see Figure 10.4).

Furthermore, inhabitants do not perceive coastal and ecological changes as phenomena profoundly compromising their way of life. Conversely, they see them more as natural constraints that they cannot fight against but can respond to by adapting their social practices. Mobility was and still is a form of response, although it may be seen as insufficient or as doing nothing by people external to the community. Adjusting how livelihood activities are practiced is another response. Today, sea access for Awala's fishermen is mainly dependent on empirical observations of tidal dynamics, sandbank movements, and daily weather conditions in order to navigate safely through the estuary to the sea. When there are shortages of high-value large

Figure 10.4 Rapid erosion on Yalimapo beach and beach overwash.

species, fishermen buy new nets to target smaller but still profitable fish while waiting for a return of preferred species. This management of fisheries shows inhabitants' capacity to cope with ecological change on an individual level. Regardless of what responses to environmental change people call upon, their awareness of natural constraints does not lead to radical changes in their behavior (Jean-Jacques 2018).

However, how natural constraints or environmental change are understood differs significantly between the inhabitants who experience them directly and those involved in managing and studying them. For older generations, disasters and risks are often experienced from a spiritual perspective. For them, it is the transgression of social and cultural prohibitions, for example the presence of menstruating or pregnant women on the beach, which offends *palanakɨlɨ*[4] (the spirit of the sea), who then causes coastal erosion or the disappearance of beaches under mudbanks and mangroves. The youngest generations, on the other hand, evoke the explanations of scientists and catalogue these phenomena as natural processes. The choice to speak or not speak about spiritual explanations reveals again that conversations between environmental or risk "specialists" and the public are driven as much by the personal experiences and values of participants as they are by scientific knowledge. In conversations about climate change and coastal risks, inhabitants share or hide their beliefs and values based on whether the expert knowledge of the scientist is resistant or sympathetic to such personal viewpoints. The words, statistics, and visual devices used by scientists to convey complex ideas about future climate scenarios may or may not find traction with the listening public. In some cases, inhabitants may feel judged by outsiders – or even stigmatized by other community members – for sharing a shamanic worldview, especially since some inhabitants are being converted to monotheistic religions which demonize shamanic beliefs and interven tions by *pɨyai* (shaman).

Although most inhabitants consider coastal changes from the perspective of their own daily reality, the municipality officials have to deal with coastal risks on an administrative level and must apply the French state's temporal framework to make future planning projections. This makes displacement more complicated than in the past. As a French municipality, Awala-Yalimapo is subject to highly restrictive land management rules that are poorly adapted to local realities. In France, every coastal town has a "*coastal risk prevention plan*" that regulates spatial occupation and takes into account climate change, especially predictions about sea level rise. In accordance with this risk prevention plan, the mayor of Awala-Yalimapo recently issued a municipal decree to relocate the inhabitants of Yalimapo because, legally, he must apply the plan as a matter of security. However, although this seems to be a way that French rules can support the Kali'na tradition of mobility, according to the mayor, the decree did not lead to a consensus among the inhabitants, who reacted with incomprehension, further complicating relations between them and elected officials:

> *When Awala was undergoing intense erosion, the inhabitants reacted only when they saw that the sea was too close to their homes. Today in Yalimapo, I'm not surprised they react the same way to the same phenomenon. The old generation's experience of the cyclical process of erosion and deposition gives some credibility to their assumption that the phenomenon won't go further. And the younger generation, because they never really experienced that before, they observe it but don't really have an opinion on it and rely on the experience of the elders, who don't worry.*
>
> (Jean-Paul Fereira, Mayor of Awala-Yalimapo, 2022)

Conclusion

We have shown that the Kali'na have a millennia-long history of responding to social and environmental change primarily through mobility, a response attested to in the literature concerning other Indigenous groups in Amazonia (Alexiades 2009). For most Kali'na people, environmental changes in the lower Maroni River region are related to natural ecological processes and also to human influences through inappropriate behavior toward spiritual entities (see also chapters by Virtanen et al. and Whitaker in this volume). They do not necessarily perceive the actual environmental change as exceptional or linked to broader patterns of "climate change."

In fact, French Guiana's coast, while a little bit urbanized, is still well preserved in contrast to neighboring Guyana and Suriname, where the coastline and coastal space (more densely populated) has experienced significant transformation since the 17th and 18th centuries (Nijbroek 2012; Vaughn 2018). Coastal dynamics specific to the Guianas, with the movement of mudbanks and associated mangroves, may indeed be impacted by climate change. An acceleration in mudbank migration rates has been observed, increasing from 1 km/year to 2 km/year (Gardel and Gratiot 2005; Abascal Zorilla et al. 2018). In French Guiana, observations by Météo France show an increase in the average sea level of 3.5 mm/year between 1993 and 2012. With sea level rise, storm swells would generate more surges, aggravating the risks of coastal flooding and coastal erosion. However, despite increasing insight into these coastal dynamics, many of the complex mechanisms are still poorly understood. Overall, geomorphologists recognize the unpredictability of shoreline change on the Amazon–Orinoco coast (Jolivet et al. 2019b), as do the Kali'na people.

But the discourse around environmental transformation has been shaped by a positivist standpoint where humans are often perceived as being locked in a struggle for domination with nature, and thus must attempt to control it. The dualistic separation of humans and nature continues to underlie the conceptualization and management of socio-ecological systems. This point of view is present in international calls for collective efforts to reduce greenhouse gas emissions, as if the product of centuries of development could be solved simply by reversing a trend and negotiating with time. With climate change, the idea propagated by the media, political parties, and private companies is that we have already created change in one direction and that through our actions we will be able to limit the damage of this change. This approach reinforces the belief in the superior power of human action over nature, which is reassuring for humanity.

The concept of climate change embodies spatial and temporal scales that are different from those experienced by local people. It is therefore misleading on the part of some scientists and governments to assume that local communities, because they are subject to changes in shoreline mobility similar to those purportedly induced by climate change, will react to these changes in the same way and have the same reactions to the challenges of climate change as scientists and governments themselves. Experiences and reactions to such changes will rather be unique for each community. It should be recognized that an unambiguous vision of climate change by local populations does not exist, since perceptions are influenced by a large number of factors and phenomena that are expressed in different ways (Worliczek 2013).

A critical anthropological approach to temporality recognizes that time is constructed, embodied, implemented, and memorialized differently in each context. Therefore, the purposes of employing the climate change concept in different time-space contexts, especially when it reproduces a different understanding of time, should be questioned. As is sadly often the case with sustainable development, the climate change narrative can also serve as a new injunction, a disguised means of ecological interference with local communities (Hartnett 2021). Thus, the neocolonial potential of climate change discourse and the top-down management that sometimes follows it can enable the maintenance of unequal power relations and the application of ideologies of environmental dominance (Collins 2020), even when local communities are clearly not responsible for the causes of climate change (Whyte 2017).

Notes

1 All quotations were translated from French conversations with inhabitants of Awala and Yalimapo. Inhabitants expressed their will to be anonymized and chose to give only their gender and age.
2 Wooden shelter, usually with a roof of (woven) palm leaves propped up by wooden stakes and without walls.
3 Ancient French name of contemporary Awala.
4 This is according to the official Kali'na spelling in French Guiana (Renault-Lescure 2008).

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11 Long-Term Ecological and Climate Changes Through Amazonian Indigenous Oral Histories

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Introduction

Stories, story work, and storying reflect deep embodied experience of intimate, long-term relationships with landscapes, animals, plants, and other more-than-humans (Blaser 2014; Haraway 2016). Because of this, stories allow investigation of deep layers of historical time and imagining, and often encode detailed information on historical relationships with the land that might not be recorded in other ways (Cruikshank 1994; Archibald 2008). Amazonian Indigenous stories, as with diverse forms of Indigenous arts and rituals, describe and teach about the relationships which make beings exist, but they are also active ways of making beings and personhood, and creating historical consciousness, and, thus, are a highly creative activity (Hill 1989, 1993; Lagrou 2007; Cesarino 2011). In addition, by recounting connections to particular landscapes, stories convey the historical and spiritual meanings of cultural keystone places (Cuerrier et al. 2015). Through stories, people have made sense of the world, the self, relations between beings and communities, and individual and collective lived experiences, meanwhile teaching about the desired outcomes of actions (Lévi-Strauss 1964; Fisher 1984).

Furthermore, stories often recount historically important events, as knowledge holders pass down knowledge of ecological changes and social memories of the landscape through storytelling. Among other memories, those of floods and deluge in lowland South America are pervasive in Indigenous oral histories and creation stories (e.g., Gow 2011). North American Klamath peoples' stories include collective memory of the volcanic eruption of Mount Mazama that took place more than 7,000 years ago (Barber and Barber 2004), while the stories of various Pacific Island societies describe ecological events that occurred as long as 700 years ago (Janif et al. 2016). Such collective biocultural memory is increasingly recognized as a source of social-ecological resilience, directly influencing local agency in terms of adaptation to the impacts of global environmental change, including climate change (Sakakibara 2008). The importance of stories for land-based stewardship and conservation efforts have consequently been noted (Davidson-Hunt and Berkes 2003; Fernández-Llamazares and Cabeza 2018), and new research is

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also showing the immense value that these stories have for disciplines such as ethnobiology and historical ecology (e.g., Crate 2017; Fernández-Llamazares and Lepofsky 2019). As a case in point, on the northwest coast of North America, the sharing of Kwakwaka'wakw stories and songs about clam gardens with academic researchers in 2002 opened the door to understanding this ancient form of Indigenous mariculture and prompted a surge of scholarly writings shaped by their deep cultural knowledge (e.g., Deur et al. 2015; Lepofsky et al. 2015).

In this chapter, we examine recent environmental and climatic changes in the story work of Southwestern Amazon. The burning of the rainforest and large-scale deforestation for farmlands and cattle pasture have changed the Amazon, earlier characterized as a humid region with constant and periodic rains but now hotter than ever before, with increased droughts, on the one hand, and floods, on the other (Andersson et al. 2018; Aragão et al. 2018). Clearing the forest makes the environment ever more fragile and prone to fires and biodiversity loss; the *varzea* (floodplain areas) and their ecosystems are especially vulnerable to climate changes, while the Amazon as a whole may even transform from a net carbon sink to a carbon emitter (Cardil et al. 2020; da Silva et al. 2021). As pointed out by Francisco Sarmento Tukano (2017), the effects of these recent changes are materially felt at local levels in the Indigenous economy, river transport, food sources, and the irregular flowering of plants and fish reproduction, which impact and are connected to the spiritual level.

How are these changes experienced and addressed in the long-term in the story work of knowledge holders and elders? Amazonian Indigenous oral histories reflect the dynamics of relations among more-than-humans and between diverse groups of human beings. Thus, they are valuable for ecological studies (see also Jacques et al.'s chapter in this volume). The stories are an effective prism that brings into focus the long-term changes in the Amazon at local levels, and how the ecological changes are connected to the well-being of humans and more-than-humans. In this chapter, we look at the traditional narratives of two Arawakan-speaking peoples, the Apurinã and Tsimane', and how they explain the current climatic and environmental changes in their biocultural contexts (Figure 11.1).

Based on our ongoing ethnographic engagements with these societies in the southwestern Amazon region, our cases show that the oral histories of these societies have some remarkable similarities, as they point out that environmental changes are a result of impacts on beings' relations, especially those with the guardian spirits that protect specific biocultural places, ecosystems, and life-supporting biodiversity. They reveal relational values and responsibilities (Whyte 2013), as well as desired relations between beings, but also the kinds of actions that lead to disasters. The chapter, thus, underlines the important potential of stories to cast light on the long-term underpinnings of relations, changes in them, and their significant potential to guide the actions that should be taken in order to protect keystone

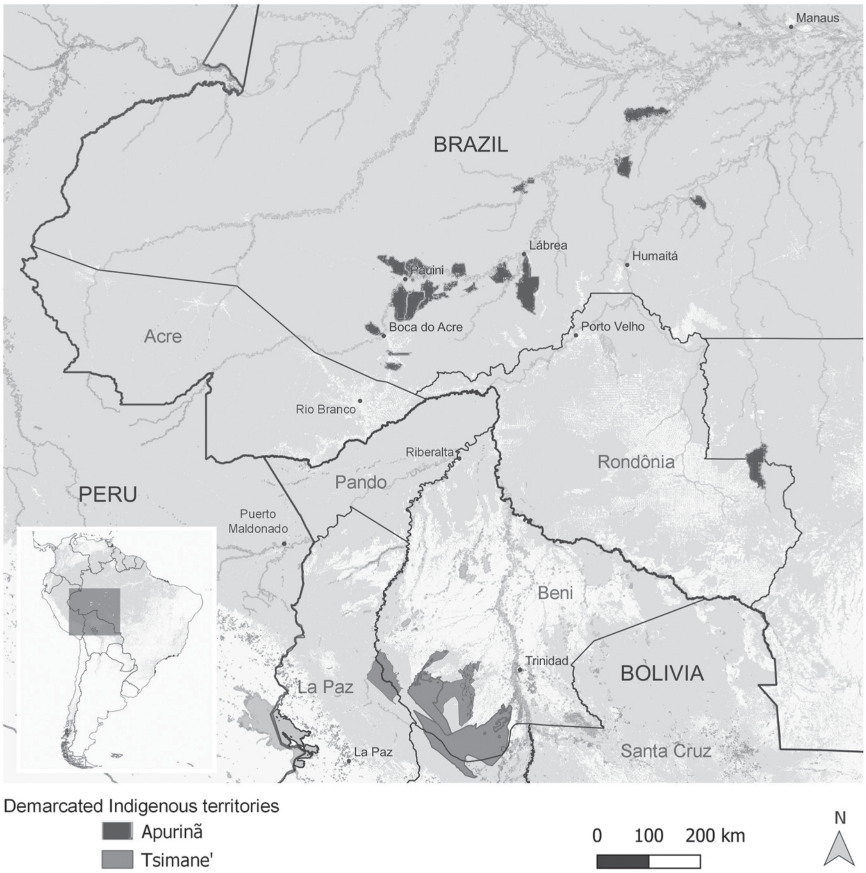

Figure 11.1 Map of Apurinã and Tsimane' lands in current-day Brazil and Bolivia.

biocultural places for the overall well-being and relations of humans and more-than-humans.

Relationality with More-Than-Human Beings

For several Amazonian Indigenous societies, the world is inhabited both by humans and diverse more-than-human beings, including spirit agencies, which means that humans are entangled in a cosmic web with other animated life forms (e.g., Descola 2005; Fausto 2008): inter-connected, mutually interdependent, and intra-dependent (Virtanen 2022). Spirit beings include guardians and caretakers, and are responsible for specific life forms, such as trees, animals, water bodies, or animal breeding grounds. Rather than representing hierarchical relations and ownership in the Western sense, however, guardian spirits are considered to be involved in the co-protection and co-production of life with humans (Fernández-Llamazares & Virtanen 2020), as are other kin and more-than-humans. This is clearly demonstrated in a note by Katãwiry, a late Apurinã knowledge holder from the Upper Purus Region:

> *We Apurinã have been on the land since the beginning of the world, as my father told me, as my grandfather had told him, as my great-grandfather told my grandfather . . . Tsura* [Apurinã cultural hero], *our creator, gave life to the different beings that exist: those who live on the land, those who live in water, those who live in the air, and even those who live in the heaven, in the world of the enchanted, and in the world under the earth. Since then, we have learned to take care of the things that he* [Tsura] *left us from the first day, taking from the land only the necessary, as he taught us, respecting his creation, because even animals speak to us and deserve respect. Many of these animals are our own relatives. Tsura also gave the Apurinã the knowledge that allows us to know which are the animals that we can kill to eat, and when we should respect them as our kin. Therefore, everything that harms the land also harms Tsura's teachings.*
>
> (2018)

Thus, while guardian spirits have often been described as master and owner spirits, they can rather be understood as being in reciprocal relations (see also Whitaker 2020; Garcia 2021; Whitaker's chapter in this volume). The co-dependence and co-living between them and humans are realized in ideas of respect for the different beings that exist and limitations on excessive behavior. Yet when the guardian spirits are not interacted with, protected, and cared for, but disrespected, they are considered to react in diverse ways, causing lack of subsistence resources, illness, and even death (Virtanen 2015; Sarmento 2017; Apurinã 2019).

Among many Amazonian Indigenous peoples, the places associated with guardian spirits and ancestral beings are considered the source of food resources, health, and knowledge; for many, locations with important historical and spiritual meaning are also the basis of the Indigenous sense of place and landscape (Lewis and Sheppard 2005; Nabokov 2006). Such places and their beings, and their explicit communication reflecting the relations to other beings, are also at the core of this chapter, as the Apurinã and Tsimane' stories of ecological changes place special emphasis on the places of guardian spirits.

Apurinã Traditional Knowledge Holders Storying Ecological Change

The Arawakan-speaking Apurinã (Pupỹkary) inhabit the Purus River Basin and number some 10,000 people. They live in over 20 Indigenous territories, and additionally several Apurinã territories in the process of demarcation.

A large population lives in the state of Amazonas, including its urban areas, as well as in the states of Acre and Rondônia. The Apurinã living at a distance from urban centers practice swidden agriculture and are hunter-gatherers that rely on a diverse range of species, while those living in ancestral Apurinã areas that have been deforested only continue their traditional subsistence on a small scale, participating to a greater degree in the cash economy.

Discussing changes in the climate, several Apurinã noted that the temperature is felt to be high earlier than in the past, meaning that after eight am people can no longer remain in the sun. In the Central Purus River area, an Apurinã man explained that ecological and climate changes are a result of deforestation and a consequent lack of trees and vegetation, the agencies that purify water. The leaves and roots are considered to lower the temperature, and without them, rain falls directly onto the land and the water remains unpurified; some trees are also regarded as crucial agents in the circulation of water and the avoidance and control of floods and droughts. Furthermore, he explained that when the trees are gone, there is nothing left to provide oxygen for humans. Therefore, they are not separated from human bodies, nor from Apurinã social space, and are actually addressed by kin terms.

According to the Apurinã knowledge holders, human acts that impact the land are considered to affect the spirit and cosmic beings in the Apurinã biocultural landscape directly. A large area of the Purus region is looked on as Apurinã ancestral lands and home to guardian spirits and deceased shamans (*myyty/kusanaty*), who have transformed to inhabit specific transformative places called *kymyrury*, and specific trees (such as *kynhary*, *Mauritia flexuosa*) among others. Discussing the ancestral shamans living the Apurinã lands, Katãwiry explained in 2017:

> *The spirit of* kusanaty *lives where there is* kynhary [moriche palms], *because where there is* kynhary*, there is a spirit of the enchanted . . . But the* kusanaty *also live in other places: they like lakes, rivers, and streams.* [In the past] *when they were about to leave, they asked to be buried in a* [ceramic] *pot with a hole to facilitate their exit . . . My father told that some days before my great-grandfather was leaving, he had the designs of the snake on his body. Each* kusanaty *owns a lake, a curve of the river, and a stream. There are always fish there, and never a shortage. But if* kusanaty *leaves, the fish go with them.*

The ecological and climate changes people are experiencing are caused by the controlling guardians of different spaces and the past shamans living in the land – because they are offended by exploration, invasions, and excessive use of forest resources. The spirit agencies consider that these actions display insulting, disrespectful ignorance of their presence, and in turn they cause environmental crises and shortages of game and fish, floods and droughts, and also landslides, earthquakes, and tsunamis in other parts of the planet.

Their moods and well-being is crucial for the Apurinã, as these are also the auxiliary spirits of the contemporary shamans.

In the Upper Purus region, Makana Kataty, an Apurinã female elder and knowledge holder, told a long story about how and where these changes actually take place. Makana lives in Apurinã territory which is traversed by a highway, yet has not managed to establish its own school despite the efforts of its leaders. The language shift from Apurinã to Portuguese has been radical in the area, as has the introduction of new livelihoods. The territory is surrounded by cattle farms and new roads that have given direct and fast access to the more distant areas of the demarcated territory, which the Apurinã have protected for their crucial resources.

Also situated in the area are clay licks, regionally known as *barreiros*; these are ecosystems, rich in game animals, that are often associated with spirit agencies in diverse Amazonian local views (Aparicio 2015; Albuquerque and Shepard 2017). The Apurinã knowledge holders narrate long stories about the *barreiros* (mimitu) and their owners, who let the animals go out [of the clay licks]. They tell that, contrary to the past when people hunted sustainably, today people hunt large quantities, especially the non-Apurinã who enter the demarcated ancestral area. In addition, they leave remains of the animals to rot in the clay lick, which is thought to make the chief spirits of the barreiro very angry, thus recently they have been noticed no longer to let the game animals to go out to eat. Makana's story describes the violation of the clay lick, with which her ancestors have long interacted:

> *In the past, at the time of my grand-grand-father and grandparents, people killed tapirs in that clay lick, and to clean it, they would pull her out to distance so they didn't leave the skin, bones, legs, head* [inside the barreiro]. *The spirit owner* [of the barreiro] *doesn't like dirt in the clay lick. I always heard my grandfather and grand-grand-father talking about it. Now, there is no longer respect. People throw skin and guts into the clay lick, they throw the bones* [of the animals they kill inside the barreiro]. *They even walk across the* kymyrury [natural fields, sacred place] *and there is no longer respect. It* [the barreiro] *will end. Because the kin and the White people* [kariwa], *who want to pass there, do not respect. All that is there in the clay lick is taken care by spirit owners.*
>
> *That's why, me the oldest, at 81 years, I never forget the advice I received from my father and my parents. Today I still respect. Every time I arrive at the barreiro, I say,* 'Atha way apaka nynyrymane' [My kin, I came here now to seek]. *I am telling the owners of the clay lick that the family of my father and my grandfather have arrived there, but nowadays the others who arrive there say nothing. They go away and say nothing. They arrive there and say nothing.*
>
> *That's why today the clay lick is all closed by vegetation, and the owner spirit is already hiding his game. In the past, our clay lick were full of game, with many tapirs that passed there, but nowadays, there are only*

few tapirs, it's already losing. (…) Now the owner of the clay lick is only releasing the black tapirs, which are not good. A really good tapir, the owners only release at midnight, fat tapir. They go out at midnight. My grandfather, my father used to say that a good, fat tapir only came out at midnight. That's when the owners release them, it makes a big noise. The noise is similar to when the farmer also opens the door for his cattle. So the guardian spirit opens his door with that noise, he opens the door of his tapirs. Bad tapirs go out early, around 10 and 10:30 o'clock, skinny tapirs. But the fat ones, the owner is no longer releasing. Because people want just to do things in their ways, the owners are hiding [the game]. *It is like when you are taking care of good cattle, you do not want to kill excessively them just to spoil it. If so, you will be punished. In the same way it is at the clay lick. My grandparents knew the guardian spirits of the clay lick* [by proper names]. *(…) The guardian spirits, who take care of the clay lick, they never die like us.*

Today us, when we arrive there [at the place of the barreiro], *we ask* [permission] *speaking in Apurinã. But today, they say in Portuguese, 'My uncles, my grandfather, my brother, give us a tapir for us to kill and eat.' And, they'll release them, because it's a kin who's asking for it. And they will give a good tapir for us. The White people enter without asking the owner. That's why I say to my grandchildren that some time from here, there will be nothing. The clay lick will be finished, because there is no more shaman to fix the clay licks. Today the tapirs' drinking fountains are all crooked and there is no forested land* [around]. *There was a shaman who used to go there to fix the drinking fountains of the animals, but he already died. He was the strongest shaman.*

My late father-in-law took him there. He said 'Let's fix the clay lick. There were no longer tapirs passing on them, all already closing. It is like the land of White people: if there are no cattle walking around every day, the place starts to close. In the same way with the clay lick: when the tapirs and other animals walk around, it doesn't close. He [the late shaman] *said, I will go. Before leaving they* [all] *took snuff* [awiri], *and he said let's go.*

As they were leaving the shaman said to the [kin] *in the village, 'When it is midnight you will hear a big noise, a bang, and all kinds of tapirs will go out, the owner will release* [them]. *And when it was midnight, there was* Teeeeei!'. *'The next day, in the morning, you go. Don't kill skinny tapirs, but you choose* [fat ones] *to kill.' My late father and grandfather killed. When they got there, all the tapirs were together, like cattle in the pasture. They chose a fat one.* 'Tuuuuum*!' And the other person,* 'Tuuuuum!' *And they said, 'Ok, it's fine, only this.' There is a limit to killing, you don't kill too much. But today, if there is more, they will kill* [all the tapirs]. *But it's not like that.*

When we get to the clay lick, we see those places where they [animals] *drink water, but for animals they are like vine of pineapple, banana, cassava. My grandfather told that he killed a tapir, and when he left it to treat*

> *it, he found the fresh skin of a pineapple inside of it. Pineapple! Pineapple from where? From the clay lick. It is a good tapir, which goes out only at midnight.*
>
> *Today these younger ones don't know how to respect the clay licks, they enter there in all ways; they pee there, they poop close to the clay lick, but in the past not, all at distance. Even when they were going to roast the game killed, they did it very far away from the clay lick to take care of that place and not leave dirt, and the owner* [spirit] *was releasing* [game]. *But if one leaves garbage, bones, skin inside the clay lick, the owner will hide. Because the owner doesn't want excessive use. He gives that amount that he gives. There are people who go and want to kill more. I think to myself inside my heart I say it is not in, in that way as you want it. There it's how the owners want it to be, they're the ones who run that place. There is an owner who rules there. (…)*
>
> *Everything has its chief. There is a chief of the fish, the chief of the* deers, *the chief of the peccaries, the chief of tapir – everything has an owner and a chief* that dominates. *(…)*
>
> *Never at the time of my grandfather and father, people were waiting at the clay licks all night, because there are many things at night. There is the chief of the clay lick, and today the people no longer respect him. They make a mess in the clay lick. They kill a tapir, and still stay there. (…)*
>
> *When the owner releases the game, their food is already there. There is food for them, there is vine, and they take the vine made from pineapple, banana, corn. All that mud is their food.* Every hole in that mud, is their vine. *And they eat, and they return. We, who die, see it as mud. But it's not, it's their food. There are different types of vine, pineapple, banana, corn, all different types. They say, 'let's go out and eat.' (…)*
>
> *There are people who don't know, people who do not want to know. They don't want to know about Tsura, but all animals have a chief. It was from the largest of our clay licks that Tsura left, but today, today, none respects it.*"

The story offers good examples of communication, of the creation of relations with specific biocultural places, and of perspectivism (Viveiros de Castro 1998), but, crucially, it also points out the key role of the Apurinã ecosystem and the environmental values and norms attached to it. Humans are expected to keep the clay licks clean, control the noise they make within them, approach them calmly, and hunt sustainably, thereby not excessively impacting places vital for the local ecosystem. The story also makes sense of the recent changes that have occurred due to the increased use of natural resources, their commercialization, invasions by non-Apurinã, and the lack of traditional education for young Apurinã. Earlier, these places were not valued for their monetary value, but rather for relational values and even aesthetics as they are felt in bodies at a sensorial level. In contrast, the new private actors in Apurinã lands neither consult the Apurinã nor reflect on the importance of the clay licks in relation to larger ecological systems and their vulnerability, only accessing them for the purposes of maximum capture, exploitation, and extraction of natural resources for monetary purposes and personal pleasure.

Tsimane' Oral Histories in Relation to Landscape Change

The Tsimane' is an Indigenous society in the Bolivian Amazon numbering approximately 14,000 people. Tsimane' settlements are nowadays scattered across an array of land tenure systems as a result of different policies deployed in successive laws and agrarian and forestry reforms (see Reyes-García et al. 2014). In this area, we mostly consider communities within the Tsimane' Indigenous Territory, established in 1990. In the past, the Tsimane' were hunter-gatherers and fishers, but nowadays they also practice small-scale shifting agriculture and, especially when they live close to urban areas, are starting to engage in cash-generating activities, such as cash cropping, sale of non-timber forest products, and wage labor. Despite these new sources of income and livelihood, forests continue to provide an essential basis for Tsimane' subsistence (Fernández-Llamazares et al. 2017).

As with other Indigenous peoples, the oral histories of the Tsimane' highlight the interdependence among human beings, animals, plants, and their spiritual worlds, and describe the forest as an extended web of social relations (Riester 1978; Ellis, 1996; Fernández-Llamazares and Cabeza 2018). As is typical of other Amazonian Indigenous peoples, the Tsimane' consider animals to have previously been humans, transforming into their "animal forms" and becoming prey for humans as a result of acts by spirits (Huanca 2008). Because of the similarity between humans and more-than-humans, specific forms of communication and relations need to be established with the animal spirits of the forest that include asking for permission before hunting and showing gratitude to the spirits after a successful hunt (Ellis 1996; Riu-Bosoms et al. 2015). Additionally, there are complex culturally established rituals and customary practices for establishing reciprocal relationships with the diverse life forms inhabiting the forest (Luz 2013).

Hilly areas (*mucú*) and rocky outcrops are among the specific locations in the biocultural landscape that have great spiritual significance. Ellis (1996) reports that stones, boulders, and large rock formations are associated with animal guardians and other non-human beings among the Tsimane', and are thus considered portals to power. The dwellings of spiritual agencies are believed to be located in hilly areas, uninhabited by humans, deep inside the hills (*mucu'can*). The Tsimane' use the generic term jäjäbä to refer to all animal guardians, although specific guardians associated with certain animals have other names. Jäjäbä is described as a cattle rancher who owns a large corral with a well-guarded enclosure in the hills where he keeps, feeds, breeds, and herds wild animals.

Jäjäbä can allow animals to roam freely outside his corral by letting them exit through doorways (*chui'dye'*), which are believed to be certain holes found in specific prominent rocky outcrops in the forest. He frees his herds of animals in the forest with a shepherd, the jaguar (*itsiquij*), who guides the herds to sources of water and places where palm fruits are abundant. For the Tsimane', game-keeping spirits are simultaneously generous and dangerous. Jäjäbä is pleased if harvested meat is properly smoked, brought to households, and consumed by Tsimane' with happiness and gratitude. Consequently, if not provoked, jäjäbä will gladly allow a steady stream of game to leave his enclosure in order to be seen and hunted by humans. Rocky outcrops tend to be surrounded by healthy, undisturbed forests, as the Tsimane' tend the larger areas, which are respected for their animated more-than-human actors. These spirit-embedded sites are highly valued by the Tsimane' and there are specific rules regulating human behavior when accessing or using them. Many Tsimane' hunters avoid the sites inhabited by malevolent or dangerous spirits while hunting. Similarly, when boulders are found near Tsimane settlements or when prominent rocky outcrops are encountered on travels, they are usually commented upon, often with awe if not fear (Ellis 1996).

Over the years, however, outsiders have deliberately destroyed some Tsimane' biocultural places, such as the Pa'tsene salt licks located on the upper part of the Maniqui River (Hissink 1955). Oral histories describe Pa'tsene as being a spiritually charged location associated with Dojity, Tsimane' creator spirit of the universe (Huanca 2008). Pa'tsene was the place where Dojity's wife gave birth to humanity, with the amniotic fluid turning into a salt lick. The site was demarcated by sacred petroglyphs of vulvas, hooks, and anthropomorphic figures, which held ancestral importance and memory for the Tsimane' community (see Figure 11.2). The vulva carvings indicated the precise location where Dojity's wife had labor. Every time the Tsimane' visited this place, they thoroughly cleaned the rocks and drawings, believing that this would allow them to obtain plenty of salt from a nearby salt lick. As Huanca (2008) perceptively notes, "People going up the Pa'tsene had to observe *muyejjoi*' (a strong cultural law) if they wanted to have salt." The petroglyphs mark a traditional route called *Jeni-sii majmiji* ("Father's way", Daillant 1997).

The opening up of a road by the logging company SERIMA in 1996 completely destroyed the culturally and spiritually important petroglyph sites of Pa'tsene (Daillant 1997). To our knowledge, the only graphic records available of the now-extinct petroglyphs are a set of original photographs taken by Albert Hahn in 1952 (two of which are reproduced in this chapter with permission from Frobenius-Institut). In 1996, the representatives of the Gran Consejo Tsimane' (the legitimate political institution of the Tsimane' people) wrote a letter of complaint to the National Director of Anthropology and Archaeology at the Vice-Ministry of Culture of Bolivia, but this never

Figure 11.2A–B The Pa'tsene salt springs, located on the upper part of the Maniqui River, were one of the most important sacred sites in the Tsimane' worldview and were demarcated by sacred petroglyphs. The original picture was taken by Albert Hahn in 1952 (reproduced with permission from Frobenius-Institut, Frankfurt am Main, Germany).

received any formal response, and the perpetrators of the site's destruction were never officially prosecuted (Strecker et al. 2015).

Some Tsimane' attribute current patterns of defaunation in the area to punishments by the spirits for the disrespectful conduct that led to the desecration of this important cultural keystone place. The case represents a vivid example of how relational values (e.g., holding certain sites to be sacred as well as other forms of spirituality) are often undermined and/or destroyed by the expansion of extractive land-use policies, and how the destruction of these heritage sites impinges negatively on people's spiritual well-being. Despite the destruction of its petroglyphs, the site of Pa'tsene still holds cultural and spiritual importance today, because of the shared memory, wisdom, and history embedded in the site. As such, Pa'tsene fits the definition of a "persistent place" (Schlanger 1992), and is still a symbol and archive of the complex bundles of relations that the Tsimane' have established with their lands and the more-than-human actors with whom they share these lands.

Diverse actions addressed to the spirit beings clearly exemplify the importance of relational values in wildlife stewardship. Indeed, Tsimane' fish and game spirit keepers provide an interesting illustration of the environmental impacts of this storied and embodied socio-cosmology.

Teaching Relational Values

As we have seen, Apurinã and Tsimane' stories point to long-term processes of ancestral rules, restrictions, practices, customs, and taboos, which have established multispecies interactions and reciprocal behavioral structures. Stories recount how the humans in caring relations with animated more-than-humans who do not interfere too much with their places guarantee the abundance of natural resources, thus being relationally responsible (cf. Whyte 2013). The stories examined in this chapter highlight the key places in Amazonian ecosystems and biodiversity, such as the clay licks and specific trees (Apurinã) and certain hills and rocks (Tsimane'), which have been associated with game animals and are crucial to the significant ecosystems. Thus, it is not only storying the places and their beings, but also place-specific customs and rules that indicate the ways to relate to focal points of spiritual life and their more-than-human actors. Stories express memory and traditional environmental knowledge that draws from long-term interactions and experiences with the land (Nazarea 2006).

A further similarity between Tsimane' and Apurinã stories is that the availability of animals and other resources is not a given; rather, they appear only when humans control their behavior and also consider more-than-humans as moral actors. Traditional forms of Apurinã and Tsimane' environmental education and instruction taught the younger generations to interact with and respect the gamekeepers and acknowledge their places when moving through the forest (Virtanen 2015; Fernández-Llamazares and Virtanen 2020), as both are able to make moral decisions. By regulating human behavior in the complex web of relations with more-than-humans, certain ecosystems are created with different kinds of beings. In contrast, extractive actors who disturb the places of spirit beings with noise, smells, and trash, or leave the remains of animals after hunting them, are considered uneducated and immoral, causing ruptures and unhealthy changes in ecological relations which eventually lead to environmental catastrophes.

The spiritual and sacred sites are places of material and also immaterial cultural heritage. They reference previous generations, and perform memories and affect people at the sensory level, all important parts of storying and teaching relational values, as the stories themselves demonstrate (Virtanen 2022). Besides the Apurinã and Tsimane' oral histories, their artwork, with its geometric designs, and songs play a critical role in this regard, revealing kinship relations and reciprocity between humans and more-than-humans while encoding a strong philosophy of wildlife stewardship (see also Lawrence and Paige 2016; Fernández-Llamazares and Lepofsky 2019). These themes can be traced to pre-colonial times at some of the archaeological sites in the Amazon (Virtanen and Saunaluoma 2017 on geometric earthwork landscapes of the Upper Purus), which bear evidence of time-honored relational values, reflecting societies in which more-than-humans have been crucial social actors.

Conclusions

The highly detailed Apurinã and Tsimane' stories examined in this chapter highlight the collective cosmocentric caring of diverse beings and long-term relationships within specific biocultural places of deep spiritual significance. They are also cultural keystone places, to use a term coined by Cuerrier et al. (2015) that builds on the earlier concept of ecological keystone species. Furthermore, our study has clearly shown that the existence and ontological value of guardian spirits is analogous to that of cultural keystone species, as they are necessary for the existence of other beings, and shape in major ways the social systems and cultural identities of Amazonian Indigenous societies. Both the Apurinã and the Tsimane' assign particular importance to specific earth formations, rocky outcrops, and places preferred by game animals that bear evidence of millennia-old stewardship systems. The oral stories compiled here provide a wealth of information about long-term relations with biocultural and cultural keystone places, and the spiritual agencies that are considered to inhabit such sites. The moral guidance of these oral histories and their records of environmental change are considered in terms of more-than-human beings, not just as top-down anthropocentric acts. Oral histories educate humans on how beings are formed and emerge in relations, and how they should interact with more-than-human beings, ensuring respect and reverence towards these entities and the sites they inhabit.

As stories partake in creating realities and "storying otherwise" (Haraway 2016), they play an important role in determining the adoption of management practices that govern and navigate the complex challenges imposed by rapid environmental change, meanwhile offering crucial keys for understanding the social memory of local biocultural landscapes (Mathez-Stiefel et al. 2007). Such storying is of utmost importance because it also shapes to a large extent how people might respond to impending social-ecological changes (Whyte 2018). Thus, on the one hand, the stories and storytelling practices describe changes that have occurred, thereby offering a richer picture and understanding of the vulnerability of biocultural landscapes, and, on the other, present potential routes to recovery.

Storying is also important for guiding resistance to colonial forces and Indigenous erasure (Sium and Ritskes 2013; Whiteduck 2013), although the Apurinã and Tsimane' oral stories mostly point to the urgency of safeguarding specific biocultural spaces within their lands. Our results thus highlight the enormous power of oral histories to affirm and mobilize Indigenous stewardship and their long-term connections to their lands and waters as part of an active relationship of engagement and immaterial and material communication; thus, they have immense value for the discipline of historical ecology. Several researchers have emphasized that Indigenous landscapes in the Amazon cannot be understood without taking into account their spiritual dimensions (e.g., Gilmore et al. 2010; Riu-Bosoms et al. 2015). Considering that in many Indigenous societies, the spiritual meanings of places are largely handed down through stories (Nabokov 2006), storytelling should be considered central to the field of historical ecology. Although the use of oral histories has a relatively long tradition in historical ecology (e.g., Szabó 2014; Lepofsky et al. 2017), we believe that the field would benefit from approaching such stories as "ontological assertions" (Watson and Huntington 2008: 269) rather than as contextual evidence complementing other forms of hard data. We contend that such stories still have an untapped potential for understanding the complexities of human-environment relations, as well as for the identification, documentation, and effective protection of place-based biocultural heritage embedded in the landscape.

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12 Owning Climate Change Among the Makushi and Akawaio

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Despite a slow start, anthropologists in recent decades have contributed foundational studies of Indigenous encounters with climate change through ethnographic engagements (Baer and Singer 2018; Batterbury 2008; Crate and Nuttall 2009, 2016; see Brown 1999; Rayner 1989). Many Indigenous peoples are at-risk for the negative impacts of flooding, drought, and related climatic phenomena. These impacts are often connected with land-based subsistence practices, as well as past and present colonization and marginalization (see also Vaughn 2022). Although Indigenous encounters with climate change are increasingly being documented by anthropologists, many depictions of these encounters still tend to center around standard Western discourses of climate change. However, ethnological literature exists concerning spiritual ideas and practices about weather in Amazonia (Wilbert 1996) and recent research has explored broader ontologies regarding weather and related phenomena associated with climate change among Indigenous peoples in the region (Rosengren 2018, 2021; Whitaker 2020a, 2020b; see Killick 2015). This resonates with work on Indigenous perceptions, knowledge, and knowledge production concerning climate change, which shows the divergence of many Indigenous perspectives on climate change from Western views (Barnes and Dove 2015; Byg and Salick 2009; Crate 2011, 2021; Cruikshank 2005; Sillitoe 2021; Strauss and Orlove 2003; Vedwan and Rhoades 2001; Welch-Devine et al. 2020; see also Jean-Jacques et al.'s chapter in this volume). Focusing on Indigenous lived-realities, which are often centered around local landscapes and related subsistence practices, such work is crucial to supporting communities undergoing negative climatic impacts and to understanding ontological alterities surrounding the concept of climate change itself.

This chapter will examine perceptions and ontologies related to climate change among Makushi and Akawaio villagers in Guyana. It is based on fieldwork in the Makushi villages of Surama (2012–2020) and Yupukari (2021) and the Akawaio village of Kamarang/Warawatta (2021). It is based on a combination of semi-structured interviews and participant observation. Most people in these three villages have some familiarity with the concepts

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and terminology used in Western discourses of climate change, and some now refer to climate change when speaking of various weather-related phenomena. However, climate change is mostly an outside concept recently introduced (primarily by Westerners) among Makushi and Akawaio groups. Neither language has an exact term for "climate" (see also Rosengren 2018, 2021). In recent years, climate change language and narratives have been exogenously introduced through villagers' interactions with outsiders in contexts of education, governance, and eco-tourism. Knowledge of climate change varies among villagers and previous research has indicated that many use the concept in ways that vary from those of Western scientists (Whitaker 2020a). However, although the concept itself is introduced, many are keenly aware of alterations in weather-related patterns that are negatively impacting them. Although villagers sometimes speak of climate change, local ontologies underpinning climate-related weather phenomena reveal alterities that center around relational frameworks involving the historical–ecological landscape and the non-human beings within it.

Despite sharing similar ontological concepts, Kamarang/Warawatta, Surama, and Yupukari represent different landscapes with heterogeneous demographic, environmental, and geological features. Surama is a mostly Makushi village of around 314 people that is located in the northern Rupununi region of Guyana. It lies in a savanna zone, which is surrounded by forest and located close to the Burro-Burro River. Although many villagers continue to rely on shifting agriculture (centered around cassava), the village is heavily involved in eco-tourism. Yupukari is a Makushi village of 648 people that is located in the middle Rupununi region of Guyana. It lies in a less forested savanna zone between the Rupununi River and a large lake. Villagers rely heavily on cassava farming in remote areas that are accessible by boat. Eco-tourism is present to a smaller extent there. Kamarang/Warawatta is an Akawaio village except for the government compound area where many non-Indigenous Guyanese reside. It is located in the upper Mazaruni region of Guyana in a mountainous and fluvial landscape. Cassava farming is common, but mining is the economic mainstay. Travel to farms and across the village is mostly by boat and tourism is rare. Despite these differences, all three villages report similar accounts of altered weather patterns and similar weather-related ontologies.

The fieldwork for this chapter was primarily conducted in 2021 in Yupukari and Kamarang/Warawatta and coincided with unprecedented levels of flooding in Guyana (see also Vaughn 2022). The flooding severely impacted cassava agriculture in both villages and reportedly destroyed houses in nearby communities. Several villagers readily attributed this flooding to climate change as a generalized phenomenon. Villagers often described changes in local weather and environmental conditions. Although reports were wide-ranging, accounts mostly centered around changes in the rainy and dry seasons, environmental disturbances (e.g., floods), and alterations in villagers' livelihood practices due to weather and temperature.

This chapter explores the implications of ontologies related to weather among Makushi and Akawaio people in Guyana with an emphasis on historical ecology (Balée 1998, 2006; Balée and Erickson 2006). It will examine recent local experiences with "climate change" and how people describe and perceive these encounters within their landscapes. This chapter shows how climate change is situated in Makushi and Akawaio ontologies within the context of ongoing relations between humans and non-humans, for example, "owner" or "master" beings who dwell within "cultural forests" (Balée 2013). These interactions involve back-and-forth exchanges that implicate villagers in ongoing relations with beings who control, protect, and nurture aspects of the landscape, which includes in this sense plants, animals, forest, savanna, and even weather phenomena. In the case of Surama, as previously described (Whitaker 2020a, 2020b), these ontological relations have partially shifted to non-reciprocal giving relations with what is sometimes called "Mother Earth," although notions of "Mother Earth" are apparently much less common in Yupukari and Kamarang/Warawatta. Regarding the historical–ecological landscape, contemporary climatic and weather-related disturbances occur due to breakages in normative relations with non-human entities that were managed in the past by shamanic practitioners. Such breakages have become more common as "development" – whether eco-tourism, mining, or other forms – displaces traditional ecological management in local landscapes (see Rival 2009). These breakages are associated with the declining prevalence of shamanic practices of managing relations within the landscape.

Perceptions of Changing Weather Among the Makushi

Some of the clearest descriptions of weather changes in Surama and Yupukari concern alterations in the rainy and dry seasons (Whitaker 2020a; see Betts et al. 2008; Butt Colson and Armellada 2001; Wilbert 1996). Villagers report that the long rainy season typically starts around April or May and continues into late July or August when the long dry season begins. Villagers in Yupukari said that the later stages of the rainy season are indexed to sequential constellations of stars. The rising of *Tamï'kan*, according to villagers in Yupukari (in contrast to other sources) refers only to the Seven Stars or Pleiades and corresponds with the heavy rains, preceding the rise of *Pebung* (locally identified as Orion) (see Butt Colson 2009; Butt Colson and Armellada 2001; Daly 2015; Grund 2017). Tamï'kan is also associated with mastery/ownership over fish in some regional cosmologies (Butt Colson 2009; Butt Colson and Armellada 2001). Referring to a "leg" constellation, Pebung was described as separate from Tamï'kan and marks the final stormy rains (with thunder and lightning) of the rainy season. However, the rainy season is now observed to last longer than before – that is, both starting earlier and ending later – in both villages.

There is a short rainy season that occurs between December and January, after which short dry season conditions return in February and continue until around April or May. People in both Surama and Yupukari often indicate that rain sometimes now continues sporadically into the dry seasons, which complicates agriculture, and that even the long dry seasons have shortened. Villagers also indicate that the rainy seasons in some years are drier than normal and that the boundaries of seasonality have become unpredictable (Whitaker 2020a).

These changes in weather have led to several problems regarding local land-use and livelihood strategies. First, it has become difficult for villagers to know when to cut and burn sections of forest and bush for planting cassava. Both activities are generally done at the end of the now unpredictable dry seasons. Secondly, it has become difficult to know exactly where to plant cassava given that planting locations are decided, in part, on (now unpredictable) weather conditions. When expecting dry conditions, cassava is planted in low, wet, and flood-prone areas. These are often located in proximity to Ité palms (*Mauritia flexuosa* L.f.), which are said to be refuge areas in times of drought.

For rainy conditions, cassava is planted on higher ground to avoid flooding. Many in Yupukari mentioned the severe flooding of 2021, which went beyond usual seasonal inundations and destroyed farms due to subsequent root rot in cassava plants.

In response to this severe flooding, some cassava farms were relocated to higher ground in Yupukari. However, for many villagers, lowland cassava farms were already ruined by floods, which meant farmers had to re-plant their crops. For villagers in Yupukari, the relocation of crop fields is not a new strategy and is linked to past efforts to survive periods of extreme weather. Although reportedly less frequent today, drought was identified by many in Yupukari as a major problem in the past (see Rival 2009). Several villagers described a severe drought that occurred during the early 1980s that they had experienced or heard about from elders. This drought resulted in a major crop failure and food and water shortages. During times of drought, Makushi people traditionally relocate temporarily to areas near Ité palms in the wet lowlands and use what villagers call "ground provisions" – particularly, naturally occurring yams (*Dioscorea* spp.) and *eddoe* (a mix of Colocasia and *Xanthosoma* spp.) – and other foods when available (Rival 2009; Whitaker 2020a). For Makushi people, these untended yams and eddoe are occasionally used foods that can be relied upon in times when cassava is scarce. They are particularly prevalent around the settlement of Quatata, which is a satellite village of Yupukari, and the nearby village of Nappi. In contrast to these traditional strategies for drought, survival strategies for flooding (beyond merely planting cassava on higher ground) were much less frequently mentioned. Although droughts present different problems than floods, villagers in Yupukari indicated that severe flooding is a more recent concern, while droughts are now relatively uncommon.

In relation to ecological changes, many in Yupukari describe recent weather-related alterations in which the savannas have expanded and the high forest has receded to the central areas around the village. Some villagers attribute these changes to anthropogenic activities like savanna burning and the relocation of some cassava farms into nearby savannas. Others see such changes as part of a broader pattern linked to changes in rainfall and rising temperatures. In contrast, some villagers in Surama, where burning is more restricted, suggested in 2019–2020 that their savannas are shrinking. In both villages, people note that traditional phenological signs of rainfall – observations tied to animals and plant life histories – are now out of rhythm (Rival 2009; Whitaker 2020a: 851).

Villagers in Surama and Yupukari gave various accounts (some anthropogenic and others non-anthropogenic) regarding recent changes in the weather, the temperature, and the broader landscape. Concerning the temperature, many claim that it is hotter today than in the past. Some villagers suggest that increased logging of trees near the village has contributed to the rising temperatures. Others attribute the increasing heat to "climate change" as a more general phenomenon. The changes in forest cover, for example, the expansion of savanna in Yupukari, and the elevated temperatures are often described as interrelated. Other anthropogenic causes associated with temperature and weather center around logging, mining, modern technologies, and declines in traditional practices and beliefs. There are claims in both villages that recent weather-related changes are associated with unsustainable uses of gasoline around the world. However, many specifically point to deforestation as a major causal factor concerning weather-related changes (Whitaker 2020a; see Betts et al. 2008). Burning of savannas and changes in agricultural practices (particularly the location of cassava farms in savanna) are also mentioned. Concerning responses to recent changes, some in Yupukari spoke of pushes by village leadership to reduce savanna burning (similar to in Surama) and to relocate cassava farms further away from the village. However, these efforts do not seem to be fully implemented at present.

Despite some villagers using climate change discourses as explanatory or interpretive frameworks for observed changes in weather and ecological processes, concepts of climate change are widely perceived in both villages as associated with outsiders (see also Moore 2016; Rudiak-Gould 2016). In Yupukari, many who know about climate change indicate that they first heard about it either in school, through workshops, or in meetings involving the North Rupununi District Development Board (NRDDB). The NRDDB is located relatively far from Yupukari, but villagers in Surama actively participate in the organization since it is closer to them. Villagers in Yupukari often say that people in Annai and surrounding communities (e.g., Surama) are the ones who "really know" about climate change. In Surama, climate change is more often associated with Europeans, North Americans, and

NGOs (Whitaker 2020a). In both villages, people express anxieties about what climate change entails and the impacts that it will continue to have on them.

Ontologies of Weather Among the Makushi

Many Indigenous groups across Amazonia speak of "owners" or "masters" who control and lead other beings within the landscape (Costa 2017; Fausto 2012). Such entities emerge in accounts from Surama and Yupukari and are sometimes thought to influence certain adverse weather events. In the present, traditional notions of ownership are often described by villagers using contemporary discourses of conservation and ecological management. Within this framework, some suggest that past shamans maintained strategic relations with owner-beings as a way of managing and conserving the local landscape. These relations are central to local ontologies and are situated within the broader historical ecology of the Makushi in Guyana.

Ownership and mastery relations extend across several domains that include kinship, interactions between certain outsiders, and human relations with non-humans (Costa 2017; Erikson 2005; Whitaker 2021b). In Makushi, such owners are called *putorï* (sometimes pronounced *padlru*), *pa-tamona* (different from Patamona people), or *mogo* (referencing a grandfather); in some cases, such as cassava, fishes, and peccaries (wild hogs), they are called "mamas" (Daly 2015; Grund 2017; Whitaker 2016; see also Butt Colson and Armellada 2001). These owners are particularly associated with game animals, fish, and forested areas where cassava farms are often located. The *putorï* controls and protects his or her wards. In Surama, for example, it is sometimes said that peccaries are led through the forest by a bird-like being (see Butt Colson and Armellada 2001) and that one howler monkey leads the others. Shamans maintain strategic relations with owners, but non-shamans also normatively offer them tobacco before hunting or harvesting their wards (Whitaker 2020a, 2020b). Such relations combine mutualistic exchanges, such as giving tobacco and receiving game, with the potential for asymmetric predation, such as taking without giving (see Descola 2013).

Makushi notions of ownership entail that hunting, fishing, and other practical engagements with the landscape are positioned within a relational context between humans, plants, animals, and spirits. Failure to maintain normative relations of mutuality, for example, by overharvesting, overhunting, or excessive mining, may result in reprisals involving sickness and sometimes weather disruptions. Ownership can extend to weather phenomena such as thunder and lightning, and can be associated with certain astronomical formations (Butt Colson and Armellada 2001; Grund 2017; Koch-Grünberg 1979–1982). In some Makushi accounts, peoples' actions are therefore causally implicated in events like violent storms and floods. For example, thunder (*uranhi* or *wuranhapi*) is understood by some Makushi as controlled by the *uranhimï* in the sky (see Butt Colson and Armellada 2001; Daly 2015). Villagers in Yupukari claim that it is important during the corn season not to let roasting corn pop loudly because it frightens the children of the *uranhimï*. The *uranhimï* perceive this as gun-like, become angry, and fire back with thunder in order to scare the offender's children in retaliation. Running loud mechanical engines can also antagonize the *uranhimï* and lead to retaliatory thunder. To stop the thundering and lightning, according to villagers in Surama, one must aim the hole of a cassava squeezer (*matapi*) at it. One man in Yupukari said that one might similarly aim one's anus instead. Both responses would imply that one was threatening to "fire back" at the *uranhimï*. As such, thunder and lightning are ontologically situated within a relational context centered around reciprocal interactions (see also Wilbert 1996).

Makushi people often speak of owners in rivers and lakes. Although reportedly more common in the past, these beings are said to live in deep water holes that never dry out even during severe droughts. They can cause violent storms and boat-sinking waves when certain restrictions are violated, such as by: (1) dropping hot peppers into particular rivers or lakes, (2) going to a river or lake soon after a close family member's death, or (3) visiting a river or lake during menstruation. Each implies a break in normative relations with a river or lake owner and may result in sickness or the offender being taken underwater. Many accounts also associate events like rain, storms, and sometimes flooding with such owners and their potential acts of retaliation and negative reciprocity. In the past, elders could apotropaically stop these storms by using *taren* (a form of magical spell) (see Carneiro de Carvalho 2015; Daly 2015; Whitaker 2016; see also Wilbert 1996) while throwing burning wood into the water. This wood was possibly from a *Virola* species (Butt Colson and Armellada 2001; see also Wilbert 1996). Similar to "firing back" at the *uranhimï*, preventing or turning back storms involves a retaliatory act of reciprocation.

In Yupukari, there is a story about an underwater owner called Pragwa who lived at the bottom of a whirlpool and caused storms and waves to sink boats until he was removed by a *pia'san* who willfully allowed his boat to sink into the whirlpool. Once underwater, the *pia'san* caused the boat to explode (using gasoline from sunken ships). This dislodged the Pragwa who subsequently relocated to Brazil where he reportedly remains today. In this case, instead of burning firewood, an exploding boat was used to send a reprisal for the adverse weather and to end the negative exchange within the landscape. In other stories, underwater or forest-dwelling owners are tied up or chained by a *pia'san* to prevent them from causing further sickness or weather-related problems. Sometimes owners are said to be relocated to mountains. Although maintaining relations with owners is often useful for ensuring provisions of game, fish, and so on, they are sometimes seen as overly predatory, and the relationship is ended (sometimes temporarily) by the *pia'san* through relocation or constraint.

The concept of tying or chaining owners connects to ontological notions concerning adverse weather. One villager in Yupukari associated the regional flooding in 2021 with owners and suggested the following:

> *what I have heard a little bit is like how we start to get flood. And then them* pia'san *did tie them* [owners] *up with their head up so they not making no more trouble. But we believe that when the young girls start to get their health and go bathe . . . And the chain that the* piaiman *tie them* [owners] *with get rotten then. And some say that may be why we get flood.*

When asked for clarification, she explained:

> *The owner of the waters. They are dangerous. He tie* [sic] *them for them to make trouble no more. But the tie that he used must be start to rottening* [sic]. *And that is why they must be coming back like before. It happening now.*

Similarly, another villager from Yupukari suggested that a dragon-like owner had once been locked up in a nearby mountain and that it caused earthquakes when it awakened from sleep. The problems of managing relations with owners are complicated today because neither village has a *piaiman* to manage these relations. Adverse weather-related phenomena are reportedly emerging (at least partially) because past strategies for shamanic management of the landscape through normative relations with owners have fallen into desuetude. As such, recent flooding is a result of breakages in historical–ecological relations within the landscape.

Perceptions of Weather Changes Among the Akawaio

Akawaio villagers in Kamarang/Warawatta and visitors from neighboring villages, which include Jawalla, Kako, Philippi, and Waramadung, described similar changes in weather patterns as Makushi villagers in Surama and Yupukari. They claim that the rainy season now lasts longer, and that the length of rainy and dry seasons is more variable and unpredictable than in the past. Akawaio villagers also point to phenological signs from stars (especially the "seven stars" or Pleiades), plants (e.g., *Mora* species), and birds (e.g., Alcedinidae genera) that are traditionally used to predict the starting and ending points of the seasons. However, these signs are reportedly no longer reliable indicators given that they are sometimes now out of sync with the seasons.

As in Surama and Yupukari, changes in weather patterns in Kamarang/Warawatta have caused difficulties for cassava farmers. Unpredictable weather conditions have complicated applications of traditional knowledge. In particular, it is now difficult to know when to prepare farms. The cutting down of forest or bush areas prior to burning fields in preparation to plant cassava must be carefully timed to allow for sufficient dryness for burning before regrowth occurs. This was observed firsthand during September and October of 2021 as rain sporadically fell every day or two. This prevented successful burning of forest and bush areas for planting. Many villagers reportedly now cut forest and bush and prepare land for farming at varying times, which sometimes even changes from one year to the next. Farmers sometimes now have to cut forest and bush for their farms more than once. This difficulty is due to rain continuing after the initial cutting. The other major difficulty for villagers in the Upper Mazaruni has been an increase in the intensity of flooding, which causes even greater disruption to local farming, housing, and livelihood. Villagers in Kamarang/Warawatta showed pictures from 2021 that illustrated extreme flooding conditions. In addition to cassava farms, some houses were partially flooded. In the nearby Akawaio village of Jawalla, floods reportedly destroyed several houses. Parts of these houses subsequently floated downriver. Although several respondents acknowledged that some seasonal flooding occurred annually, many claimed that the level of flooding and destruction in 2021 were unprecedented and record-breaking.

In contrast with Surama and Yupukari, villagers in Kamarang/Warawatta often said that there is little they can do to avoid or prevent destruction to cassava farms during severe flooding episodes. Although villagers' accounts varied, most said that flooding in the Upper Mazaruni affects both the highland and lowland areas, so relocating farms to higher areas would only help marginally. However, some villagers mentioned that a few farmers are now planting one cassava crop on high land and another on low land to hedge against the heightened risk of flood damage. In contrast with flooding, drought was generally not considered a significant problem in the fluvial setting of the village, although some people did remember drought episodes that had caused difficulties in the past. Unlike Surama and Yupukari, many villagers in Kamarang/Warawatta claimed that they had few strategies for surviving periods of drought or flooding. No reports were heard concerning "survival foods" or refuge areas during times of extreme weather. Many suggested that they would survive such episodes (especially flood-related crop failure) by receiving food from the government, purchasing food from shops, and intensifying employment in mining for money to make such purchases. The unreliability of seasonal weather and flooding has also reportedly increased youth participation in mining due to frustrations with farming. Mining is seen as providing more reliable and faster returns relative to the risks of farming.

Villagers in Kamarang/Warawatta often reported that they perceived the general temperature to be hotter now than it was in the past and especially during the dry season. Combined with the unpredictability of seasonal changes and rainfall, the increased temperature has complicated work schedules and made life more difficult. In response to the heat, many people try to avoid doing physical work during the hottest times of the day. Some have reportedly lost crops due to rising temperatures and there are accounts of heat-related reductions in game animals in the forest, large die-offs of fish in ponds, and disrupted fruiting cycles. However, compared to Surama and Yupukari, hunting and fishing are somewhat less significant sources of food in Kamarang/Warawatta. Increased temperatures have also reportedly exacerbated dryland conditions and receding forests. In contrast with Yupukari, many in Kamarang/Warawatta attribute forest contraction to increased heat and not to anthropogenic burning near the village. Increased temperatures have reportedly contributed to natural fires in some cases. Nevertheless, the overall temperature in the Upper Mazaruni is considerably cooler than in the Rupununi savannas due to the higher elevation.

Some villagers in Kamarang/Warawatta pointed to climate change as a cause of increased temperatures. However, they pointed to multiple culprits, and accounts differed in relation to whether or not such changes are anthropogenic. They also variously suggested that deforestation, foreign industry, gasoline usage, and overuse of the forest were causal factors in the changing temperatures. Some villagers said that the increases were because of "nature" while others suggested that they were the work of God and a sign that the world was coming to an end. Also, as will be described in more detail below, some respondents drew connections between recent weather-related changes and the mining taking place across the region.

Knowledge of climate change in Kamarang/Warawatta remains associated with outsiders and is not a common topic of conversation. Most villagers interviewed indicated that they first heard about it in school or through activities involving outsiders. This is again similar to Surama and Yupukari. Government workshops were frequently mentioned in this regard. Many said that they did not fully understand climate change. A few (mostly elderly) villagers claimed not to know about it other than that it somehow meant that things were changing. Overall, there is much concern about the drastic changes to weather and seasonality that are negatively affecting villagers across the region.

Ontologies and Weather Among the Akawaio

Although Akawaio villagers in Kamarang/Warawatta did not mention owner-beings becoming "unchained" or "untied," there were accounts concerning "owners" or "masters" influencing adverse weather events as a result of broken relations within the landscape. Akawaio villagers in Kamarang/Warawatta sometimes use the term *poido'ma* to refer to owners or masters (cf. Butt Colson and Armellada 2001). At other times, Akawaio groups use different terms, such as *siwon* (Cooper 2020), *esak*, or *potori* (similar to the Makushi term *putori*) to refer to them (Butt Colson 2009). The basic ontological contour of ownership relations in Kamarang/Warawatta, as well as among visiting Akawaio people from neighboring villages nearby Kamarang/Warawatta, is generally similar to those in Surama and Yupukari. As owners, sometimes in the form of stones, *poido'ma* are associated with control over game animals, fish, and remote areas of the landscape. There is an emphasis in the Upper Mazaruni on ownership in relation to mining – *poido'ma* are said to control gold and diamonds underground. Although similar ideas were occasionally mentioned by Makushi in Surama and Yupukari, mining is much more common in the Upper Mazaruni than in the Rupununi and "ownership" of precious stones and minerals is more salient. Similar to hunting game and fishing, extraction of minerals in the region requires maintenance of normative relations with *poido'ma*. Excessive mining results in a breakdown of normative relations with owners and causes reprisals, such as severe storms and sickness.

Many identified *poido'ma* as sometimes creating adverse weather conditions similar to those associated with climate change. Similar to accounts in Surama and Yupukari, adverse weather and sickness are often said to result from violations of restrictions in relation to bodies of water. This includes visits to lakes or rivers by menstruating women (see also Wilbert 1996) or people in mourning, as well as dropping pepper in lakes or rivers. Some said that deaths in general could cause rains or storms. A local prophetic leader said that severe weather would result only from the death of a baptized man or prophet. This was especially the case if the man died through drowning. Furthermore, he claimed that the flooding in 2021 coincided with the death of a major prophetic leader in another village. Rains, storms, and flooding are also said sometimes to occur when strangers (typically non-Amerindian outsiders) visit "sacred sites" near Akawaio villages. Sickness and storms also reportedly result from forest fires, which are said to kill the owners' children. For example, one man suggested that the Covid-19 pandemic resulted from the fires in Australia in 2020. As such, adverse weather can variously be centered (directly or indirectly) around owners.

Although there are parallels between Akawaio and Makushi ontologies, Akawaio accounts in Kamarang/Warawatta draw unique conclusions concerning climate change. Among the Akawaio, water spirits are generically called *laado* (similar to Makushi *rato*). This is the underwater equivalent of *poido'ma* and can refer to a number of different kinds of related beings. For example, one kind of *laado* is called *panagaru*, which is related to the Makushi term *prankru*. Both terms refer to water spirits. However, *panagaru* is also sometimes associated with white people (particularly Western Europeans and North Americans) (see Whitaker 2020c). For example, one man stated in Kamarang/Warawatta in 2021 that:

> *Old people used to tell us that when white people coming then that is laado. That is a belief. They say that white person going to come and carry you* [away] *and* [you] *might think they boyfriend. And it is a big snake* [associated with underwater beings].

The Makushi term *prankru* is a shortened form of the term *paranaghiri* (a cognate term of the Akawaio *panagaru*). *Paranaghiri* is found directly and indirectly in colonial era documents dating from the 17th through the 19th centuries (Edmundson 1904; Rivière 2006). The term in Makushi combines *prana* (meaning sea) with a term *kru* or *kuru* (referring to people from the sea) (Schomburgk 1923; Whitaker 2020c). Since most white people historically arrived in Guyana by sea, they are *prankru* (Makushi) or *panagaru* (Akawaio) (Whitaker 2020c). With these connotations, white people are associated with non-human owners relevant to weather and are linked to adverse weather events (see also Wilbert 1996). As among the Makushi (Whitaker 2020a; Whitaker 2020b), notions of ownership serve as frameworks through which relations with outsiders are conceptualized.

One Akawaio leader suggested that villagers sometimes associate *laado* (as underwater owners) with weather phenomena linked to climate change, but that this association can go beyond interactions involving lakes and ponds. He said that white people (as *panagaru*) are also seen as a type of *laado*. In other words, there is a connection between ontological notions concerning local weather phenomena caused by "owners" and the responsibility of people in the Global North for high levels of carbon emission and resulting changes to local weather and climate. This elucidates Akawaio associations between climate change and foreign industrialism (see also Rosengren 2018). The association highlights Akawaio understandings of weather disruptions as resulting from failures to manage normative (although not necessarily reciprocal for the Akawio) relations involving "others" in the landscape or beyond. Akawaio people point to a failure of whites to maintain normative relations with non-human beings in the landscape in Guyana and abroad. Excessive resource extraction, mistreating non-humans, and abusing the landscape have angered the non-human owners and incurred weather changes that now threaten Akawaio people. As such, disruptions to weather and climate emerge again as the result of breakages in relations within the landscape.

Conclusion

This chapter has examined weather-related alterations associated with climatic changes from the perspectives of Makushi and Akawaio villagers in Guyana. Although some interpret these changes through Western discourses of "climate change" as recently introduced by outsiders, the ontological underpinnings of these phenomena traditionally center around animistic notions of non-human ownership. This chapter's goal has not been to evaluate the Western-focused "scientific accuracy" of these accounts or the underlying physical causes of related phenomena. For example, villagers rarely mentioned the El Niño and La Niña cycles highlighted by Western scientists in relation to periodic drought and flooding throughout the region (see Rival 2009). Instead, this chapter elucidates the importance of local accounts in their own right. Emphasizing a relational landscape centered around animism, such accounts may help scientists to examine blind spots in their own theories.

Of course, ontologies concerning weather can change. For example, villagers often expressed uncertainty about the kinds of astronomical seasonal markers described by Butt Colson and Armellada (2001), although a few mentioned Orion (identified as *kaiwonok*), the Pleiades (identified as *chirikö pupai*), and *tumön*. Some said that traditional signs (both cosmic and ecological) are now out of sync with seasonal and ecological cycles. Although such knowledge may have been partially lost in Surama, Yupukari, and Kamarang/Warawatta in recent decades, there is also a shifting emphasis towards ownership within the landscape and less focus on astral ownership. Even traditional knowledge can change over time.

Nevertheless, many Makushi and Akawaio people continue to associate experiences regarding irregular weather with ontologies concerning non-human ownership. Although evincing degrees of totemism and naturalism (Whitaker 2021b), these ontologies are primarily animist (Bird-David 1999; Descola 2013; Rosengren 2018, 2021). This supports Rival's (2009) suspicion:

> *that further ethnographic research would show that, for the Makushi, the best way to deal with weather vagaries is not so different from the way one "cultures" the land so that manioc can grow, or tames wild spirits so that the ill can be cured.*

Weather, agriculture, fishing, and hunting implicate shamanic ontologies of ownership that require management of normative relations involving back-and-forth interactions within the landscape. These ontologies also influence "cultural forests" and facilitate landscape management (Balée 2013). As such, they are part of local historical ecologies (Balée 1998, 2006) and are central to local perspectives on climate change. As historical–ecological phenomena, climatic change and variation emerge ontologically as the results of broken relationships with the landscape and its owners. Stemming from a current absence of resident *piaimen*, as arbiters of traditional knowledge and managers of relations within the landscape, there are uncertainties about how to rectify emerging problems with weather and seasonality in Surama, Yupukari, and Kamarang/Warawatta. Like people around the world, local villagers are unsure how to "tie" or "chain" the forces now wreaking havoc on their climate and broader landscape.

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Postface

Climatic and Ecological Change in the Americas: A Perspective from Historical Ecology

Victoria Reyes-García and André Braga Junqueira

Introduction

Global environmental change, including changes in the functioning of the atmospheric and the biophysical systems, is a phenomenon affecting all ecosystems and societies around the world. Nevertheless, the way in which atmospheric and environmental changes impact each ecosystem and each society are distinctively different, being shaped both by the specific biophysical environment in which they occur (IPCC 2022) and also by the socio-cultural and historical contexts that form societies as we know them today (Adger et al. 2013; Crate 2011; de Souza et al. 2019). Since historical ecology recognizes at its core both the place-specific interactions between landscapes and people and the large-scale and long-term processes that shape local contexts in unique ways (Balée 1998; Dayton et al. 1998; Odonne and Molino 2021; Crumley 2017; Balée and Erickson 2006; Crumley, Westin, and Lennartsson 2017), this approach provides a well-suited theoretical and methodological framework for understanding how long-term patterns and current processes of change interact in their impacts on specific social–ecological systems.

This book examines different climate change experiences across the Americas using historical ecology as a structuring framework for understanding climatic and environmental change across space and through time. Overall, the contributions presented add to current scholarship in historical ecology in the context of climatic and ecological change by significantly advancing three emerging topics: (1) the intertwined character of climatic and environmental change impacts; (2) the importance of values, ontologies, and governance systems to explain beneficial impacts of long term landscape management; and (3) the importance of engaged research. In this postface, we elaborate on how chapters in this book advance these important emerging topics.

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Climate Change and Environmental Change are Intertwined and Their Impacts are Situated in Specific Socio-Cultural Contexts

One of the first important emerging topics that permeates several chapters in this volume is the idea that climate change and environmental change are intertwined and situated in specific socio-cultural contexts. Hence, the way such changes impact people and people's responses to them cannot be understood without considering these connections and contexts. Indeed, since the 1970s, several scholars have focused on ancient climatic oscillations as a factor affecting landscapes and cultures (e.g., Meggers 1979). However, scientists increasingly recognize that – because ecological and anthropogenic forces have long interacted in complex ways – climate change impacts should be considered in the ecological and cultural context in which they occur (e.g., Hans-Otto Pörtner et al. 2021). In other words, current scholarship is increasingly embracing the idea that, while climate change is a global phenomenon, it is expressed and experienced at a local scale, which requires considering the synergistic effects between climate change and other direct and indirect drivers of environmental change (e.g., land use change and pollution), as well as the social context in which climate change operates (e.g., colonial history, differences in access and control of resources, presence of development and extractive projects) (e.g., Junqueira et al. 2021; de Souza et al. 2019).

Drawing on theoretical praxes and postulates of historical ecology, which reject environmental determinism and emphasize historical contexts (Balée 2006), several chapters in this volume emphasize the importance of looking at the climate–biodiversity–society nexus to understand the complex network that results in climatic and ecological change in the Americas. For example, in Chapter 1, Rostain and de Souza argue that the drier period accompanying the Medieval Climatic Anomaly (950–700 BP) most likely affected demographic and settlement patterns in Amazonian populations. Importantly, while some cultures flourished, others collapsed or moved to nearby locations, suggesting that responses to climate change impacts were highly culture-specific (see also de Souza et al. 2019). In Chapter 2, Ford argues that climatic changes (particularly an overall drying trend) in the Maya region (beginning 4,000 years ago) coincide with the emergence of permanent settlements and with an increase in landscape management, leading to substantial changes in forest composition. In Chapter 4, Mueller shows how Indigenous peoples in eastern North America prevented ecological changes associated with climatic impacts and preserved prairies and pyrophytic forests through ecological management that mimicked past climate conditions. Similarly, in discussing the importance of fire as a key component of dry conifer forests in western North America, Roos and colleagues argue in Chapter 5 that Indigenous fire management strategies (involving small, frequent patch burning) fundamentally increased forest fire resilience (see also Coop et al. 2020; Savage and Mast 2005), which again shows how climate change impacts on ecosystems can be palliated through social and cultural practices, such as long term landscape management.

The climate–biodiversity–society nexus is equally emphasized in chapters looking at current climatic and ecological impacts. An important argument being made in several chapters in this book is that these impacts are particularly exacerbated in communities where long-term histories of excessive resource extraction coupled with colonial legacies and recent development pressures (such as land-use change) have increased vulnerability. In that sense, Rostain and de Souza in Chapter 1 state that "*climate change is not the first danger to the Amerindians.* [. . .] *Western socio-technological change is by far the most dangerous threat.*" In a similar vein, Ladio and dos Reis in Chapter 6 argue that current threats to the conservation of *Araucaria araucana*, a species of key cultural and economic importance to the Pewenche and other Indigenous groups in Argentina and Chile, increases their situation of vulnerability. In Chapter 10, Jean-Jacques and colleagues analyze how current coastal landscape and settlement patterns of Kali'na Indigenous peoples in the Maroni River result from both historical and contemporary social–ecological processes, including contexts of colonization and the intrinsic river mobility and environmental responses of local populations. In Chapter 12, Whitaker shows how Indigenous communities understand flooding, drought, and related climatic phenomena through ontological frameworks and within contexts of past and present colonization and marginalization.

Values, Ontologies, and Governance Systems Explain Beneficial Impacts of Historical Forms of Landscape Management

A signature contribution of the historical ecology framework is that, over millennia, societies have transformed (or "domesticated") their landscapes to obtain beneficial social impacts, or to increase the contributions that nature provides to people (Crumley 2017; Rostain 2010; Graham 2006; Clement 1999). Some well-known examples of these long-term modifications resulting in landscapes that are more "productive and congenial for humans" (Clement 1999) include earthworks such as raised fields or forest islands (Rostain 2010; Lombardo et al. 2020; de Souza et al. 2019, fish weirs (Blatrix et al. 2018), anthropogenic forests with concentrations of useful and domesticated species (Maezumi et al. 2018; Levis et al. 2017; Armstrong 2021), landscape-scale water, forest, and fire management (Lentz, Dunning, and Scarborough 2015; Anderson 2005), or the creation of anthropogenic soils (Iriarte et al. 2020). Several of the chapters in this volume continue this line of thinking. For example, three chapters of this book discuss how Indigenous peoples have manipulated landscapes (e.g., by preserving prairies and pyrophytic forests) to improve fire resilience and thus reduce severe risks from wildfires. Together, the chapters herein by Rick and colleagues, Mueller, and Roos and colleagues show how landscapes "domesticated" through the skillful use of fire not only reduced risks from severe wildfires, but also supported plants and animals that could help in meeting the challenges of severe droughts. In a similar line, in Chapter 8, Lepofsky and Salomon provide another example of how – amidst climatic and ecological changes spanning millennia – Indigenous peoples in coastal British Columbia, Canada, constructed and managed intertidal rock-walled terraces to favor clam growth, thus providing a strong basis for local economies.

However, while postulates for historical–ecological research suggest that all ecosystems on Earth might have been, to some degree, affected by human societies, they also emphasize that there is no "pre-programmed" direction regarding whether landscape manipulations would result in beneficial or detrimental impacts in species diversity or other environmental parameters (Balée 2006). So, the question remains: What are the underlying conditions that allow landscape manipulations to result in long-term, simultaneous, and beneficial social and ecological impacts? In response to that question, an important emerging topic that permeates several chapters in this volume is the critical role that values, ontologies, and governance have in understanding impacts generated by historical forms of landscape management.

In that sense, several of the works presented in this volume go beyond descriptions of landscape management practices and propose relational frameworks that emphasize how values, ontologies, and governance systems underpinning historical landscape management strategies mediate the sustainability and resilience of social–ecological systems. For example, Rostain and Souza in Chapter 1 emphasize that Native people of the Northwest Amazon associate climate change with human activities, acknowledging also their own role in driving the observed changes. In a similar vein, in Chapter 2, Ford emphasizes that the limited understanding of forest value brought by Spanish conquerors undermined the Maya flexible and resilient strategies and practices of forest management, ultimately affecting ecosystem resilience as a whole. In Chapter 6, Ladio and dos Reis use the concept of "relational models" to analyze the spatio-temporal pattern of the Pewen landscape use in Argentina and Chile. Their framework analyzes the preferences, principles, and virtues that explain the degree of responsibility towards non-human beings developed by different cultural groups interacting with the forest. The authors show that, against the extractive model of colonizing societies, the mutual nurturing model developed by Pewenche communities builds resilience in contexts of socio-environmental change, demonstrating the importance of Indigenous cosmologies and governance systems in forest conservation. With a focus on local ontologies, in Chapter 12, Whitaker highlights how understandings of weather phenomena among the Makushi and Akawaio people in Guyana often center around notions of ownership in the historical–ecological landscape, which implicate non-human beings. The author makes the argument that for these Indigenous groups, climate change is understood as part of ongoing relations between humans and non-humans (particularly "owner" or "master" beings) who dwell within the "cultural forest" and broader landscape. These interactions involve back-and-forth exchanges and relational management, for which contemporary climatic and weather-related disturbances are understood to occur due to breakages in normative relations with non-human entities.

Overall, these contributions bring to light the localized community histories, customary laws, cosmologies, and governance structures that explain long-term landscape management beyond its technical and biophysical aspects. The approach is important because it honors placed-based knowledge, identities, and histories as they have developed over generations and as they are reflected in local governance protocols, laws, religious practices, and other cultural constructs (Trosper 2011; Turner 2014; Anderson 2005). The approach also emphasizes how intangible elements underpin observable landscape management and are inseparable from landscape material features (whether those are ecological parameters or infrastructure development) (see Nadasdy 2005; Johnson 2010 for a similar argument).

Importantly, by advancing this emerging topic, this book contributes to the move of historical ecology research away from the positivist standpoint that (by conceptualizing humans as mere ecosystem managers) separates them from nature. In a way, this new development responds to a recent call to "*consider how various ontological perspectives and worldviews can confront the dominant and controlling nature of human relationships to the environment – the same dominant relationship that is espoused by 'technofixers' as the answer to climate change*" (Armstrong and Junqueira 2020). Notably, the emphasis on how intangible elements underpin and are inseparable from observable landscape management is much in line with the latest IPCC assessment report (IPCC 2022) and with the IPBES conceptual framework (Díaz et al. 2015), both of which have suggested that technological fixes are insufficient to deal with the current climatic and environmental crises, and that we need a larger focus on changing values, preferences, and the ways through which we relate to non-humans. Implicit in this way of thinking is that attempts to look to the past to guide the future of resilient and equitable landscapes amid changing social–ecological conditions should go beyond the study of material features and dig into the relational logics (including worldviews, ontologies, values, and governance systems) that put those landscape management systems in place.

A Call for Engaged Research

A final important topic emerging from chapters in this book relates to the importance of engaged research, particularly attending to current demands of Indigenous peoples and local communities to be able to continue managing the landscapes and territories they have traditionally managed. Applied work is not new in historical ecology (e.g., Swetnam, Allen, and Betancourt 1999). Indeed, a hallmark of historical ecology is the diversity of methods and knowledge systems used to better understand the past, evaluate present conditions, and inform future decisions (e.g., Pauly 1995; Egan and Howell

2001). By focusing on people's historical relations with landscapes, scholars working with the approach of historical ecology have done more than broaden research engagements with peoples' responses to climatic and ecological vulnerabilities; they have also often engaged with changing landscapes and with applications of Indigenous and local knowledge (Crumley 2017).

Nevertheless, different authors adopt different approaches in applying knowledge derived from historical ecology research. Some authors adopt a pragmatic approach. For example, in Chapter 5, after demonstrating that Native American fire management favored ecosystem resilience in Southern USA, Roos and colleagues suggest that similar strategies could be applied today to reduce the risk of future high-severity fires (see also Lake et al. 2017). Similarly, in Chapter 9, Rivera-Collazo explores food and habitat security during times of environmental change in the ancient Caribbean (between c. 2000BC–1500AD) and discusses ways in which past responses to various environmental crises (e.g., hurricanes, floods, sea level rise, and ocean warming) can inform current climate mitigation strategies. Overall, this pragmatic approach explores how lessons learned from historical ecology research can be useful as inspirations for improving resource management systems and addressing the current environmental crises.

Other authors emphasize how unveiling long-term sustainable landscape management through historical ecology research constitutes an empirical basis to support local communities' demands for territorial and/or other stewardship rights. For example, in Chapter 3, after analyzing North Coastal Indigenous communities' land management in California, including traditional burning practices and fisheries and wildlife conservation efforts, Rick and colleagues argue that colonialism exacerbated climate impacts, as colonial policies displaced people from their ancestral lands, denied them access to coastal and other resources, and caused major upheavals, resulting in a dramatic reorganization of California's ecosystems. Based on these findings, the authors call for the restoration of Indigenous connections to their ancestral land and seascapes as a way to restore functioning ecosystems. In that way, authors in this chapter use findings from historical ecology research to support the claims of descendant communities seeking to assert resource title and sovereignty to reclaim land-based livelihoods. Similarly, the integrated historical–ecological perspective presented by Armstrong and colleagues in Chapter 7 shows how historical Indigenous stewardship and management of their homelands created beneficial ecological legacies on the Northwest Coast of Canada. According to the authors, such a long-term perspective allows identifying the contribution of different societies to environmental degradation and/or regeneration, which might be useful in the development of just climate change mitigation strategies. Similarly, in Chapter 8, Lepofsky and Salomon show how the interplay between social and environmental variables across time and space has shaped practices related to the building, maintenance, and use of intertidal rock-walled terraces to favor the growth of clams. Here, according to the authors, the assessment of such long-term practices constitutes an important basis for the reconnection to and reclamation of ancestral clam gardens by current Indigenous populations.

All in all, these chapters indicate a contemporary tendency of applied historical ecology to learn from the past and apply this knowledge not only to improving ecosystem management, but also to restoring the rights of communities to the landscapes they have historically managed.

Conclusion

In its relatively short life as an academic multidisciplinary framework, historical ecology has contributed to showing several ways in which landscape management can result in beneficial effects to societies. This book adds to this body of research in three main ways. First, chapters in this volume emphasize the many ways in which climate change and environmental change are intertwined and how their impacts are situated in specific socio-cultural contexts. This implies that attempts to understand historical processes of change and how they impact current social–ecological systems need to consider the climate–biodiversity–society nexus. Second, because landscape management occurs in specific socio-cultural contexts, attempts to inform the future also need to consider the values, ontologies, and governance systems that underpinned specific management techniques. Third, several chapters in this volume demonstrate how historical ecology research can engage with the demands, claims, and understandings of landscape stewards, thus contributing to maintaining or restoring functioning social–ecological systems. In sum, as we learn from this volume, future works in historical ecology should systematically consider the broader social contexts in which landscape management took place and – where appropriated – consider how research results can support the rights of the populations that have domesticated landscapes to maintain their ecological functioning while providing beneficial impacts to societies.

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Index

Note: Page numbers in *italics* indicate figures and in **bold** indicate tables on the corresponding pages.