THE POWER OF NATURE

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Archaeology and Human-Environmental Dynamics

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UNIVERSITY PRESS OF COLORADO
Denver

Published by University Press of Colorado
1624 Market Street, Suite 226
PMB 39883
Denver, Colorado 80202

The University Press of Colorado is a proud member of
the Association of University Presses.

The University Press of Colorado is a cooperative publishing enterprise supported, in part, by Adams State University, Colorado State University, Fort Lewis College, Metropolitan State University of Denver, University of Alaska Fairbanks, University of Colorado, University of Denver, University of Northern Colorado, University of Wyoming, Utah State University, and Western Colorado University.

∞ This paper meets the requirements of the ANSI/NISO Z39.48-1992 (Permanence of Paper).

ISBN: 978-1-64642-351-4 (hardcover)
ISBN: 978-1-64642-352-1 (ebook)
https://doi.org/10.5876/9781646423521

Library of Congress Cataloging-in-Publication Data

Names: Smith, Monica L., 1964– editor.
Title: The power of nature : archaeology and human-environmental dynamics / edited by Monica L. Smith.
Description: Louisville : University Press of Colorado, [2022] | Includes bibliographical references and index.
Identifiers: LCCN 2022052924 (print) | LCCN 2022052925 (ebook) | ISBN 9781646423514 (hardcover) | ISBN 9781646423521 (epub)
Subjects: LCSH: Environmental archaeology—Case studies. | Human beings—Effect of environment on. | Human beings—Effect of climate on. | Natural disasters—Social aspects. | Climatic changes—Social aspects. | Epidemics—Social aspects. | Nature—Effect of human beings on.
Classification: LCC CC81 .P69 2022 (print) | LCC CC81 (ebook) | DDC 930.1028/6—dc23/eng/20221103
LC record available at https://lccn.loc.gov/2022052924
LC ebook record available at https://lccn.loc.gov/2022052925

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Preface

MONICA L. SMITH

Rarely does the backstory of an edited volume become part of the finished product, beyond a perfunctory mention of the conference or the confrérie of its inception. Typically, the months and years between the initiation of a group project and its fruition are dissipated through hazy memories of time lines, streams of correspondence, and the more firmly recalled moments of completion punctuated by helpful intervention from publishers, copyeditors, and layout designers. But the fact that the work on this particular volume straddles the time before, during, and, it is hoped, after the global pandemic gives us a particular philosophical vantage point worth marking. This is especially so because the subject of the book is an inquiry on the "power of nature" to shape and disrupt human lives. The premise, which seemed compelling enough when this project initially began, has become our collective lived experience in the interim.

This volume carries within its pages the Before Times of the merry company of handshakes and carefree crowding that we enjoyed at the Society for American Archaeology (SAA) conferences before the global Covid-19 pandemic and lands at the doorstep of what will come after it, the "New Normal" times that—as of this writing—we are not yet experiencing. As an authorial group, we want to recognize the isolation, loss, and unsettling uncertainties that permeated the incubation period of this volume. Most of the chapters were initially presented at the SAA meetings held in Washington, DC. By the time the finished offerings were ready for submission, the world had shut down in ways that sparked new, ongoing

https://doi.org/10.5876/9781646423521.c000

conversations among the authors and the commentators. Accordingly, the authors updated their manuscripts and kept in mind the internalized acknowledgment that the nature-culture interface is one in which humans often look on helplessly as Mother Nature deals the upper hand. In integrating new content that directly addressed the pandemic, we also were fortunate in securing contributions from Sara Juengst and colleagues and from John Robb as commentator.

Throughout the volume's period of creation and beyond the archaeological subject matter of our initial focus, we recognized the many ways humans perceive the consequences of their interactions with the world around them. Perception itself is filtered by individual experience and personal philosophies, as well as by larger grouped effects of cultural expectations and the amplifying echo chambers of discourse within households, among communities, and at the level of the nation-state. As academics, we should not want to return to a pre-pandemic lassitude of simply accepting that there was a long human trajectory to the present; instead, we have been handed a once-in-an-epoch opportunity to recraft our understanding of humans' place in the world. Conferences that are capitalizing on the forward momentum of our era are recognizing that human-nature interactions are dynamic, iterative, sometimes mutually constructive, and often mutually destructive. These include recent global conversations such as the "Archaeologies of Deltaic Ecology: Relevant Methods and Techniques for Engaging with Human and Non-Human Interaction in the Southwestern Part of Bangladesh," organized by the Department of Archaeology of the Government of Bangladesh and Jehangirnagar University; and "Asia and the Anthropocene: Visions of Being Human in a More-than-Human World," organized by the East-West Center of the University of Hawai'i.

None of us writing this volume, and none of you reading it, will be quite the same people or inhabit quite the same social world. Our volume's offerings about humans' creative tenacity against the elements show that regardless of the time and place, our species' effects on the planet are a work in progress and that the power of nature is (nearly) comforting in its assured continuity.

THE POWER OF NATURE

1

Nature as Agent

Mass-Event, Incremental, and Biotic Perspectives

Monica L. Smith

ABSTRACT

The concept of the Anthropocene is based on the premise that humans have had a profound and increasing impact on our environments. Yet many environmental conditions (earthquakes, storms, tsunamis, fire, disease, and other dramatic natural phenomena) can easily overpower human capacities and result in significant change. Incremental processes such as soil creep, vegetation growth, oxidation, and material fatigue similarly act against human intentionality by causing deterioration and decay whose denouement is unpredictable in timing and magnitude. The sentient world of animals, in which behavioral patterns have evolved for viability in a diverse world of predators and reproduction strategies, similarly presents challenges when managed under the assumption that humans are the primary determinant of comportment. In this volume, we consider the agentive effects of natural phenomena to which the direct human response is primarily reactive. The objective is twofold: to highlight that even within the "Anthropocene," not all natural phenomena can be anticipated, much less controlled, by humans; and second, to critically evaluate the variety of past human responses to natural and biological entities as seen through the archaeological record.

The archaeological study of human-environmental dynamics has been heavily weighted on the "human" side of the equation. In recent years, that focus has been augmented by an increasingly pointed indictment of the way human activities can

https://doi.org/10.5876/9781646423521.c001

not only alter local environments but can also collectively push the entire planet into new physiological configurations. The development of the "Anthropocene" as a distinct geologic era, added to a century's worth of scholarly discussion about the role of humans in their ecosystems, has further solidified an interpretive view of humans as prime mover. In this volume, we challenge the interpretation of human centrality by focusing on the force and impact of nature relative to human knowledge, action, and volition. We identify the ways natural entities, ranging in size from viruses to mega-storms, have presented our species with dynamic conditions that overwhelm human capacities. Using an archaeological perspective, we illustrate and analyze the many ways in which people do *not* control their environments.

The dynamic world of nature is so large and complex that cause and effect are rarely the result of dyadic interactions but instead encompass synergies among multiple entities and along multiple timescales (e.g., Cordova and Porter 2015; Doughty et al. 2013:4; Wright 2017). An ecosystems perspective is the only way to evaluate physical forces as parameters for human activities in both the past and the present; the goal is not to identify causalities and prime movers as much as to document the generative and mutually implicated relationships among entities that include static factors such as latitude and longitude as well as dynamic factors of climate change, plant and animal species, and biochemical shifts (Wright 2017:2, 4). Mutually generative relationships also include human actions, in which people respond proactively and reactively to their surroundings, thereby contributing to the complexity of ecosystems.

Our species came into existence within a framework of powerful natural forces, evolving in an environment that included the vagaries of sunlight, wind, water, weather, fire, magma, quicksand, tides, gravity, seasonal cycles of temperature, and plate tectonics. Humans could recognize the effects of those natural processes but could rarely control or even predict their onset, amplitude, duration, and frequency. Everyday actions related to food, energy expenditure, living spaces, and mates were conditioned by ecosystems inhabited by hundreds of other species. Early in our evolutionary trajectory, however, humans became more than just another mesopredator. Starting a million or more years ago, our ancestors began to use tools to leverage individual actions in ways that impacted larger and larger portions of the surrounding environment. They not only utilized fire to serve individual and household needs by altering the taste and texture of food but also modified entire local ecosystems by increasing the periodicity of fires beyond natural frequency, intensity, and seasonality. People consumed plants and animals disproportionately to their natural population distributions and, in selectively targeting prime animals instead of weak ones, exercised strategies of culling that were different from any other carnivore. This modification further intensified when humans undertook the genetic manipulation of plant and animal populations through the process of domestication and through the terraforming of the natural landscape to facilitate agriculture and enhance aesthetics.

In modifying their environments, our species remained subservient to the forces of nature that continue to provide both gentle and terrifying parameters for human actions. The resultant fraught and complex relationship between people and their surrounding landscapes has long been the subject of philosophical commentary. Ancient Greek writers, starting with Homer in the first millennium BCE, poetically articulated widespread cultural recognitions of the power of nature over human intentions. In the *Iliad* and the *Odyssey*, the elements of wind, water, and tide thwarted even the most determined of ships' captains sailing to Troy and the most determined of heroes trying to return home afterward. Hesiod's *Works and Days*, written a few centuries later, provided wisdom to farmers as they faced endlessly cycling seasons of agricultural opportunity and risk punctuated by frost, rain, and scorching sun.

Religious and literary traditions from around the world likewise have noted the power of nature to destroy human creations. The Hebrew Bible, for example, is replete with natural assaults including plagues, locusts, and the Flood; devastating inundations also make their appearance in narratives from Australia, sub-Saharan Africa, the Indian subcontinent, Polynesia, and North America (Witzel 2010). Volcanoes, strung along fault lines globally and concentrated around the Pacific Ring of Fire, are worrying both when they are active and when they are dormant; they are the subject of continual vigilance and appreciation, as in New Zealand where "good and bad outcomes from volcanism are part of long-term cycles of reciprocity and equilibrium that link modern Maori to their ancestors" (Cashman and Cronin 2008:407). Other natural phenomena—storms, plagues, earthquakes—are measured and memorialized by their impact on human volition and human creations.

THE ANTHROPOCENE

Since the mid-1800s, philosophers and scientists have devised new terms to describe human-environmental dynamics in ways that increasingly implicate our species as prime movers in a "human domination of earth's ecosystems" (Vitousek et al. 1997:494). These terms have included the "Anthrocene" (Revkin 1992), the "Anthropozoic" and the "noösphere" (see Erlandson and Braje 2013:2), and the most popular current neologism: the "Anthropocene." Over the brief twenty years since the first published appearance of the term, the definition of the "Anthropocene" has increasingly emphasized human culpability. In their original formulation, Paul J. Crutzen and Eugene F. Stoermer (2000:17) proposed that the Anthropocene defined a time when "the global effects of human activities have become clearly noticeable." More recent definitions have highlighted the way human activities are "outcompeting natural processes" (Crutzen 2006:13) and "overwhelming the great forces of nature" (Steffen et al. 2007:614). The Anthropocene is now being considered as a formal epoch and as a successor to the Holocene in the International Chronostratigraphic Chart, a move that has generated considerable controversy given the "lithologically thin" geological record and the perceptions of a strong political impetus to the designation of a human-focused geological era (Zalasiewicz et al. 2017).

The chronology as well as the impact of the Anthropocene have been subject to debate. Many ecologists suggest a formal inception that corresponds with significant human technological innovations or intensifications, such as fossil fuels beginning around 1800 CE (Steffen et al. 2007) or atomic detonations starting in the mid-twentieth century (see Barnosky et al. 2014:226; Zalasiewicz et al. 2017:207). Archaeologists have argued for much earlier starting dates, noting that the human impact on the environment can be materially demonstrated long before the fossil-fuel era. Jon M. Erlandson and Todd J. Braje (2013:1) propose that the Anthropocene started 10,000 years ago, concomitant with the domestication of plants and animals, a time that David K. Wright (2017:6) suggests could be termed the "long Anthropocene" and that Lucas Stephens and coauthors (2020) call the "deep Anthropocene." Applied in this way, the Anthropocene would thus overwrite (and eliminate) the Holocene as a geological era. Christopher E. Doughty and colleagues (2013:4) roll the clock back even earlier, to the pre-agricultural demise of the mammoths ca. 14,000 years ago. Stephen F. Foley and coauthors (2013:84) propose the most generous allocation of all, defining a Paleoanthropocene coincident with the emergence of the genus *Homo* around 1.8 million years ago, a term that recognizes humans' distinct effects on the environment while reserving a formally defined Anthropocene for the very recent past.

Regardless of the proposed starting date, the appellation of the Anthropocene or any of its cognate labels implies that as soon as humans appear in a landscape, they instigate change. This emphasis on the (largely destructive) effects of our species endows us with a special focal point that we may not wholly deserve and does so in a manner that dissipates and underemphasizes the forces of nature that still exist even in the modern, fossil-fuel era. Geologists share this discomfiture about pivoting to a cultural rather than physiological threshold for defining geologic eras; in an elegant move that sidesteps the question of the Anthropocene, the International Union of Geological Sciences (IUGS) has divided the Holocene into three parts marked by global-scale and objectively measurable climate anomalies at 8.2 kya and 4.2 kya (Walker et al. 2019). The third of the three divisions in particular hammers home the fact that culture is subservient to nature: naming the 4.2 kya event the

Meghalayan, the IUGS acknowledges that the era of drought toppled many well-known Old World Bronze Age civilizations.

In our view, calls to affix the start of the "Anthropocene" with premodern archaeological cases seem to distract from a much more interesting question: how do humans respond to and plan for the power of nature? As an alternative to the geological cause-and-effect rhetoric of the Anthropocene, we embrace the more holistic, mutualistic notion of the "anthroposcape" as a description of the ways humans have physically altered the physical environment through the selective consumption of plants and animals and the modification of terrestrial slope, gradient, hardscapes, watercourses, and vegetation regimes. The term *anthroposcape* has already been used in the philosophical sense that encompasses the concept of agency and being-in-the-world, with an initial definition offered by Bee Scherer (2014:1) as "the landscape of our embodied experiences." A materialized, archaeological use of the term enables us to counter the visible effects of human actions with and within the powerful counterbalance of the natural world, in which agency and (re)animation is encompassed within both sentient and non-sentient components of the Earth.

The use of an anthroposcape perspective incorporates the recognition of the long history of human interactions with the remainder of the natural world and extends the impact of humans to the first tool-using australopithecines 3.3 million years ago, (cf. Harmand et al. 2015), far earlier than even the most generous-minded proponents of the Anthropocene concept would generally accept. Given the controversies of the Anthropocene as a marker of compelling human control of the environment, the use of anthroposcape is a politically neutral and nonjudgmental term that measures the impact, rather than the morality, of human and natural mutualism. The term also provides a sense of the complex responses humans have developed as recipients of natural actions and how our collective past provides the inescapable background for both the present and the future and helps us identify the range of individual and collective responses of the type that would make archaeological investigations truly relevant to modern life.

The scale and impact of the human-nature dialectic as an anthroposcape can be approached in productive ways using iterative perspectives borrowed from linguistics. One avenue for the assessment of natural and human interactions can be found in frame analysis, as developed by the theoretician Erving Goffman. Frames, also termed frames of reference, constitute "schemata of interpretation" for the input of new information and actions (Goffman 1974:21), resulting in realities that are measurable and physically evident. Frame analysis need not be limited to entities capable of intentional or sentient actions but can be viewed as the constituent quality of inanimate collectives (e.g., Snow et al. 1986, 2014) in which frames are literal or figurative "sedimented histories of particular ways of understanding and engaging with the world" (Jepson

2010:314). Although the majority of his development of frame analysis (as well as others' use of the concept) focuses on the relationships within and among social groups, Goffman (1974:23) emphasized the necessary coexistence of non-sentient natural entities and sentient human capacities in the frame-creation process.

For nature, frames of reference are encoded through repetitive events: successive volcanic eruptions pile lava flows one on another; successive rainstorms fill lakebeds; successive drought seasons transform shallow lakes into desert. Human frames of reference make use of these naturally iterative processes and the cultural processes of new knowledge and innovation, as well as memories of successful past attempts and the physical entities created by human hands. The generative impact of human actions is scalable (from an individual lighting a fire, weeding a field, or cutting down a tree to collective groups engaged in dam construction or cooperative hunting). The process of reassessment and renegotiation at both the individual and the group level results in the ongoing trial and error that characterizes human approaches to a dynamic environment, in which participation in a course of action is "subject to frequent reassessment and renegotiation" (Snow et al. 1986:467). But the concept of frames also permits natural entities to engage in actions that are similarly of the moment yet subject to preexisting conditions: a sudden storm can spread out its waters as a thin wash across a plain or can deeply gouge the landscape's surface through incipient or existing channels, whether those channels are natural or human-made.

In addition to the concept of framing that can be identified through the archaeological and paleontological records, the dynamics of iteration can be evaluated through the concept of "conversation analysis" in which dialogue is understood to be recursive, situational, and cumulative because of the memory of past utterances and actions (Ahearn 2001; Sacks et al. 1974; Schegloff 2006). Conversation analysis takes as a given the existence of interlocutors' prior experiences that are brought with them into any new conversation, in which linguistic expectations about grammar and the meanings of words provide the scaffolding for each new interaction. Although non-sentient natural elements transfer energy through actions rather than through independence of volition and communication, the concept of a "dialogue" as a process that involves back-and-forth iterations provides a way of thinking about the dynamic interlocution of natural and human forces in which each action carries forward into the "conversation." For example, clear-cutting of forests provides both farmland and fuel and may alleviate risks of fire or predator ambush. Such actions also render benefits to humans along a long timescale, including the opening up of habitats that favor grasses and the ruminants that feed on them. At the same time, clear-cutting leaves newly exposed areas vulnerable to erosion and nutrient depletion, reduces habitat for some desired species such as birds, and entails additional costs of resource collection once the felled trees are used up.

Both conversation analysis and frame theory support an anthroposcape concept, in which there is a mutualism of natural and human actions. Archaeologists have discussed the dynamism of human-material engagement as a relationship that is not only recursive but incrementally additive such that each interaction results in a slightly new configuration, in which the return to an "original" state is impossible. Severin Fowles and Jimmy Arterberry (2013:69) have discussed this phenomenon as one in which object "agency" is encompassed within "recursive networks and alliances between people and things that are irreducible to anything else." In other words, the mutualisms of interaction not only are impossible to reverse but cannot be pulled apart at all once they have started down the path of synergy. Mutualisms are materially evident at every scale archaeologists investigate, from the site to the landscape and even to the level of an entire planet. These observations help us recognize that unambiguous archaeological explanations are difficult to achieve because of the many different responses humans can use to counter objectively measurable phenomena such as climate, biodiversity, or tectonics.

Eliciting explanations about human-nature mutualisms requires the support of evidence from both large-scale and microscopic perspectives. The most salient and archaeologically discoverable locus for the articulation of human-natural mutualism is the human settlement. Settlements, constituted of sociably organized human dwellings, provide physical places of investment in architecture, possessions, foodstuffs, and cooking equipment that reflect everyday needs of biological and social subsistence (cf. Smith 2010). The settlement is a scalable concept that includes every size of habitation, from the spare collection of forest foragers' huts to the most densely occupied cities. Any settlement also has a temporal component that crosscuts the concept of scale. Short-term encampments can be small if occupied by forager groups, but they also can be large when encampments are places of pilgrimage or refuge in ways that accelerate human impacts on the surrounding landscape. As a physical locale and the focus of quotidian human investment, the settlement can thus be identified as the prime locus of action and a hinge between natural actions and the actions that materialize as the result of human memory, volition, and response.

Although settlements are conceptualized as parts of "giving" environments because humans gravitate toward places of natural abundance of some desired aesthetic or material condition (Moore and Schmidt 2017, drawing from Ingold 2000), it is clear that settlements of all sizes can also induce, harbor, and accelerate natural effects. Settlements can prove to be particularly resilient to storms through sturdy construction and mutual aid or can be particularly vulnerable to domino effects of flooding and wind brought by inclement weather (e.g., Liao 2019; Rodríguez et al. 2006). Settlements provide conditions for unintended mutualisms between diurnal people and nocturnal commensals such as rodents. Concentrations of people result in concentrations of invisible viruses and bacteria as well as visible disease vectors, such as feral animals attracted by human waste accumulations. The effects of human activities radiate beyond the boundaries of collective living quarters into the surrounding areas that serve as the spatial locales of interaction and constitute the support networks for water, food, and fuel. In between settlements as intensely manipulated environments and the greater wilderness in which there is successively less impact, there exist catchment zones of opportunistic mutualisms brought about by human action. Agricultural fields provide attractive foliage for browsing animals with the risk to them of garden hunting; impounded water for agricultural irrigation provides environments for populations of species that would not otherwise be found, including captives (fish) and free-ranging (mammalian and avian) species. The advent of arboriculture (and its oscillating opposite, timber harvesting for fuel and construction material) alters the landscape of birds, which, in turn, affects their availability for human food, feathers, and soundscapes.

AGENCY

The study of agency as a foundational component of human social engagement has been a focal point of anthropological and archaeological theory for the past twenty years. Seminal works of this genre included the edited volume *Agency in Archaeology* (Dobres and Robb 2000) and the influential articles "Language and Agency" (Ahearn 2001) and "Agency and Archaeology" (Dornan 2002). These writings considered the meaning and intentionality of human actions in the past, as reflected in artifacts and architecture and encompassed within a tradition of material theory. These works were followed nearly ten years later by a broader perspective on the subject titled *Material Agency: Towards a Non-Anthropocentric Approach* (Knappett and Malafouris 2008), which focused primarily on memory, material objects, and text—all of which are exclusively human domains of initiation and reflexivity in which objects "speak" because they are invested with human intent in their creation. A continuation of this important line of thought about the mediating effects of artifacts in the creation and manifestation of human agency is found in the volume *Relational Identities and Other-than-Human Agency in Archaeology* (Harrison-Buck and Hendon 2018).

In this volume, we eschew the consideration of intentionality and human efforts as prime movers of physical change, focusing instead on the physically measurable effects of action rather than considering animacy, intentionality, or personhood. Instead, we focus on agency as a measurable initiator of cause and effect and adhere to the clearly delineated causality proposed in Stephanie Spengler and colleagues'

(2009:290) definition of agency: "was it me or was it you?" In our chapters, the dialogic back and forth of causality between natural actions that occur without reference to human beings, and the human attempts to survive and thrive within those natural parameters, provides the opportunity to evaluate human-nature dynamics beyond the rubric of an "Anthropocene" in which human actions take center stage. We thus turn to the agency of natural phenomena at multiple spatial and temporal timescales and within the anthroposcape through three categories: mass event, incremental, and biotic phenomena.

Mass-Event Natural Phenomena

Mass-event occurrences include weather phenomena such as storms (hurricanes, typhoons, tornadoes), earthquakes (and their follow-on effects such as tsunamis), and volcanic eruptions. Natural events on this scale provide some of the most dramatic changes to the landscape; to this day, hurricanes, typhoons, volcanic eruptions, and tsunamis can affect continental-size portions of the earth. By comparison, single-event destructive attempts by humans—even the atomic bomb—are puny analogs to the forces of wind and water that can destroy hundreds of thousands of square km of habitable land within a matter of hours or days. Other natural events such as earthquakes can be more localized and their debris fields more limited, perceived by humans through the effects on settlements but holding great potential for change in topography and waterways. Seasonality is a factor in some natural mass-event activities, lending some predictability to the timing of events such as sandstorms, dust storms, and monsoons even though their duration and amplitude are unknown except in retrospect.

Human perceptions and responses to mass events are characterized by distinct stages of reaction: a sudden impact followed by a heroic phase, a disillusionment phase, and a rebuilding and restoration phase.[1] If local inhabitants interpret a mass event as destructive, they may flee the area. But people also may perceive a benefit from a mass event, such as the clearance of land that makes available new locations for settlement and increases the potential for agricultural productivity. When interpreted as an opportunity (e.g., an act of divine retribution that supports the further development of a millennial movement or a rationale for large-scale reorganization that has long been desired but for which there was no proximate impetus), then a mass event becomes a generative turning point in human-environmental dynamics.

In this volume, we term large-scale natural occurrences as "mass events" rather than "catastrophes" because the latter is a value judgment assessed within the frame of reference of the people who experience the event and its aftermath and who move forward from that experience through subsequent actions. When resilience is built into the process of human landscape use, mass events take on diminished cultural significance. An example comes from the North American Great Plains, where a 1950s drought was climatologically more significant than the one that produced the 1930s Dust Bowl phenomenon; although the 1950s event was potentially more destructive, "catastrophe" was averted through multiple human activities that had been emplaced because of knowledge gained from the Dust Bowl days: some of the responses to the later drought were slow and incremental (conservation practices such as the conversion to grasslands and the construction of erosion dams) and some were circumstantial (the increased use of irrigation from the Ogallala aquifer; Cordova and Porter 2015).

Incremental Natural Phenomena

In contrast to mass events, processes of incremental change are often so subtle that they elude direct notice. Incremental physical changes such as chemical reactions, crystallization, and oxidation are continually active, often on a microscopic scale imperceptible to humans. Some processes are extremely active in nature, such as dry rot that facilitates forest growth and regeneration but also attacks human architectural timbers. Some processes are latent in nature but become aggressive agents disproportionately on human creations, such as salt effluorescence on pottery and in agricultural fields (cf. Redman 1999). Some incremental changes (whether visible in the form of oxidation or invisible in the form of microstructural change) can eventually result in sudden-onset failure (Lehner 2018). This has interesting implications not only for individual-use artifacts ("Grandpa's bronze sword isn't good for battle anymore") but also for large-scale configurations such as infrastructure and other monumental constructions, which can in a single day be transformed from a functioning utilitarian necessity to a disruptive failure.

To what extent would ancient people have seen, worried about, or mitigated the risks of incremental change, whether in the purely natural realm or as applied to wood, cloth, basketry, and other artifacts and architecture made of organic materials? Human settlements increased the canvas on which incremental natural actions could take place because of the propensity of humans to accumulate utilitarian and decorative objects. Humans also provided the opportunity for otherwise latent natural processes to manifest themselves through the creation of anthropogenic materials such as bronze, which immediately upon its invention provided a new substance for oxidation (Lehner 2018). Other metals such as silver and iron did exist in a natural state and were subject to oxidation processes, but the collective surface area available for oxidation increased dramatically once people began to smelt ores for metal production.

One of the most important incremental phenomena is vegetation. The human relationship with plants began within a context of thousands of wild species throughout the world, from which humans selected a subset of plants for use. Among that subset of selected plants, humans further invested time and effort into an even smaller subset that they manipulated to the point where those plants became dependent on humans for propagation (those plants—our grain crops—were bred by humans to hold tight to their seeds until threshed, a factor of utility to humans but maladaptive to free-seeding natural plant propagation). The process of agriculture and domestication was an agentive act renewed each season in the face of accumulated knowledge, capacities, and climatic variation, with agricultural fields of purposive species as a monocrop; as an interspersed group of two or three species such as the corn, beans, and squash triad in North America; or as patches of species within a mosaic (such as vegetables and herbs in a kitchen garden). The human and animal relationship with the many wild species that grow adjacent to farmed fields is not necessarily an antagonistic one, however, as untended species can serve as important sources of fuel, raw materials, medicine, and "famine" foods.

Archaeologists have been particularly good at addressing human-vegetation interactions from the perspective of domestication and human volition, with an emphasis on the hardship and energy expenditure of cultivation (e.g., Hayden 2014; Smith 2001). Will Steffen and colleagues (2007: 616) refer to the "biological inefficiencies" of energy capture through the growth of plants and the tending of animals; experimental plantings of early domesticates in the modern day—seeking to replicate ancient conditions—reflect the challenges of actually getting a crop (e.g., Toll et al. 1985). Because the complexities of the vegetative world involve multiple, shifting inputs that vary from year to year (including weather, rainfall, pests, and nutrient load), the process of growing plants involves numerous adjustments even by experienced gardeners growing the same plants on the same plot of land from year to year. In fact, we might analyze human activities of cultivation not under a rubric of performance suggestive of a definitive and planned-for outcome but under a rubric of "practice" (cf. Goffman 1974:64) subjected to constant changes in the natural frames of reference in which the outcome is achieved within a "syncopated rhythm of the river, rain, and seasons" (Erickson and Walker 2009:249).

Unwanted plants, characterized as "weeds," are an integral part of human cultivation systems in which the number of weed species often greatly outnumbers the domesticates (e.g., Kingwell-Banham 2015). Weeds compete with purposive plantings at all scales and grow without any visible human effort, in contrast to the energy expenditure required to grow domesticates. Cultivated grains are disturbed-earth plants, as are many weeds, such that actions undertaken by people including soil clearance, watering, and provision of fertilizers to provide hospitable conditions for wanted plants unwittingly provide environments that are equally preferred by weeds. Our understanding of landscapes as denuded by human actions (as in North America) or by our technologies of lidar downplays the realities of the lived landscape of explosive organic growth. Tall vegetation such as trees impedes sunlight on agricultural clearances and thwarts viewsheds and lines of sight—an especially important point given that many of our understandings of ancient landscape dynamics and intra-community interactions assume visibility across the landscape (e.g., Doyle 2012:366). Particularly in tropical environments, robust year-round vegetation growth would have necessitated continual clearance as a form of architectural and environmental maintenance.

Unwanted vegetation growth also bedevils the built environment of cities. Bettina Stoetzer (2018) has discussed the ways urban centers produce conditions for "ruderal ecologies" in which vegetation grows spontaneously in the forgotten or unplanned interstices of pathways, rubble piles, and garbage heaps. Rooted in place, plants become both a vertical and a horizontal reminder of vegetative agency. Windborne and animal-borne seeds lodge in the crevices of architecture where they readily take root. One might even see cities as an overlap of ecotones, from the wholly human-made conditions of architecture to the channeled and manicured banks of urban waterways to the untamed fringes of forests and abandoned buildings that all serve as hosts to commensal species.

Humans thus live with incremental changes of growth while sometimes initiating sudden and dramatic alterations (such as cutting down a tree, damming a river, or setting fire to a forest). But incremental change is also perceptible at moments of naturally induced failure in which the cumulative effects of incremental processes become visible: the soil creep that leads to a sudden blowout of an agricultural terrace, the metal fatigue that results in the collapse of a bridge, the unnoticed infestation of ants or mildew that spoils a full storage bin of grain. As agents of cumulative incremental change, processes such as oxidation work in concert with the organic materials they attack, resulting in ecosystem changes in which the "tipping point does not have to be large scale" (Wright 2017:2).

Biotic Phenomena

The natural world is replete with living entities that grow, reproduce, and die under conditions broadly defined by the processes of natural selection and "survival of the fittest." Utilizing the definitional rubric of "was it me or was it you," we can evaluate biotic agents at all levels of complexity, from bacteria and fungi to birds and mammals. Today, every biotic agent in the world is implicated in the human realm; in a critique of the concept of the Anthropocene, Piers Locke (2016:3) has noted that "the built environments of human civilizations and the economic activities that support them can no longer be treated in isolation from the ecological processes of a natural world made possible by so many other life forms" (see also Barua 2021). Starting at least 100,000 years ago with the worldwide migration of *Homo sapiens*, humans have created new environmental niches, including agricultural fields, dwellings, storage spaces, and even personal artifacts such as articles of clothing that provide opportunities for some species to expand their range and for new identifiable species to emerge in a process that can actually increase biodiversity (cf. Kittler et al. 2003; Pincetl et al. 2013). Monocropping enabled already extant viruses and bacteria to grow on a scale that would not have been possible without human intervention. Diseases such as cholera, flu, plague, and tuberculosis benefited from the larger and more concentrated pools of biotic vectors present in human settlements.

It is with the interaction with other sentient animals that the complexities of environmental dynamics become particularly subject to the agentive actions of nonhumans. Mammals and birds have complex behavioral characteristics and act with perceptible agency relative to the possibilities available to them through distinct variations of personality such as curiosity, boldness, and timidity that are increasingly recognized by ecologists as factors in individual selective fitness (Biro and Stamps 2008; Locke 2016). Wild animals' interactions with humans depend on individual responses to human enticements of companionship and food, a phenomenon of affect that may have been a contributing factor in the inception of domestication (Reed 1977:563–564). Mutualisms with wild birds involve intensive one-to-one interactions with human caretakers in which individual birds exhibit personalities of compliance and engagement, while humans themselves must also develop skills that are particular to the species and, perhaps most important, to the individual birds with which they interact (e.g., Jepson 2010). Mutualisms also are pronounced in group-to-group behavior, such as the dolphin pods that cooperate with fishermen by driving fish toward boats and giving instructions to humans about the timing of casting and netting (e.g., Daura-Jorge et al. 2012; Smith et al. 2009).

Perhaps the most complex and intense relationship with intelligent, independent-minded creatures is the one humans have with elephants, where interactions are the result of the taming of individuals in which the elephant-human relationship is mediated by the fact that both species typically have long life spans. As with humans, however, elephants' personalities are sometimes superseded by instincts that run deeper than the rationality of the moment or the carefully cultivated mutualisms of physical work (Baker 2016). As extra-large animals in an ongoing competitive dynamic with humans, elephants provide a unique vantage point from which to query the trajectory of human relationships with smaller mammals. Although elephants have been tamed on an individual basis, they have never been fully domesticated—a configuration that can inform us about the way other animals have been incorporated into human lifeways across a gradient of "wild" to "domesticated," with intermediate characteristics exhibited by both individuals and populations until free-ranging populations were either extinct or vastly outnumbered by domesticates. And while our colloquial understanding of a "commensal" animal is something of rodent size, Charles Santiapillai and S. Wijeyamohan (2016:235) have revealed that in the case of elephants in Sri Lanka, the human modification of the landscape to include hundreds of artificial reservoirs starting more than 2,000 years ago constituted a technological change that facilitated the growth of both elephant and human populations.

As Locke (2016:1) has observed for South Asia, humans have regarded elephants through a variety of lenses: prey, cohabitants, companions, weapons of war, emblems of prestige, symbols of divinity, objects of entertainment, commodities, and sources of labor. One could invest many of the large domestic animals of both the Old World and the New World (cattle, sheep, goats, llamas, horses, camels, reindeer) with the same dynamic range of words. Domestic animals ostensibly under the control of *Homo sapiens* act in ways that are sometimes in compliance with and sometimes defiant of human volition, with individual variations of personality that play into the human selective process as well as subsequent long-term relationships that involve close daily proximity and mutual dependence. Intensive relationships with domesticated animals are then projected back onto the wider world of sentient creatures on the continuum from free-ranging "wild" populations to habituated to tame animals, in which the language of animal husbandry applies to many species beyond those that are domesticated (see Jepson 2010:325).

Cultural shifts in human preferences for ornamentation, food, clothing, and architectural elements can lead to localized pressure on or outright extirpation of plant and animal species, a factor evident in extinctions starting as early as 50,000 years ago and continuing to the present (Braje and Erlandson 2013; Houston 2010). Cultural shifts also can result in the differential preservation of species; Stephen Budiansky (1997) suggests that if domestication had not happened, human hunting pressure would have likely rendered horses extinct. Physical interactions with domesticates not only provided new opportunities for food, traction, and symbolic accoutrements but also introduced new vectors for zoonoses as animals were brought into closer quarters with humans. This interaction, in turn, sparked a new dynamism between humans and invisible biotic agents that further stimulated evolutionary responses when "humans that possessed a genetic predisposition to survive zoonoses contributed more offspring to future generations, demonstrating the evolutionary influence of the animal-human relationship" (Olsen 2010:529).

DISCUSSION

As noted in the chapters in this volume, mass-event, incremental, and biotic agents frequently overlap in their environmental effects. Mass events such as volcanic eruptions and meteors can directly or indirectly kill a multitude of organisms, as well as provide new landscape conditions that favor in-migration and colonization by species previously unknown in a region. Analyses of modern and historical large-scale ecosystem events such as storms, earthquakes, and volcanic eruptions enable us to address the challenging complexities of human-environmental interactions when nature is the precipitating agent of change. Further opportunities are provided by humans who make agricultural terraces that provide new verticalities subject to gravity, craft metal objects that provide an increased number of surfaces for oxidation, and engage in foodways that provide new niches for parasites. As the authors in this volume discuss, many other "natural" events set into motion human reactive responses that can, in turn, be generative of new social configurations, including a social milieu in which inventive and creative responses to environmental circumstances enable people to activate new strategies of architecture, agriculture, and resource extraction.

Humans' responses to natural events occur at a timescale that is often inversely proportional to the chronology of natural actions. Rapid-onset events such as earthquakes may last only a few minutes but can trigger human investments in years of planning foresight and reactionary recovery, often resulting in entirely new forms of architecture and anthroposcapes. Fostering plants requires multiple scales of planning and intent, from the collection of seed grains to the preparation of fields to the growth, harvest, and storage of the agricultural resource; each of these stages is subject to the caprices of nature, which require ongoing adjustments to achieve humans' desired outcomes. The capture of a wild animal may take days of planning and mere minutes of direct action but usher in years of painstaking training and taming to make the animal responsive to human commands. Fire, water, air, and earth all provide the opportunity for intense human-nature interactions because of their tripartite capacity: they exist independent of humans, they can overwhelm humans' intentionality, and they can respond to human intervention to create circumstances and conditions that could not have occurred naturally. Fire is controlled by humans to result in high-temperature transformations that produce metal from smelted ores, water is channeled through conduits to places it would not otherwise reach, air is compressed in bellows to speed fire combustion, and earth can be containerized (to promote and deter organic growth) or heated (to produce an artificial stone-like substance in the form of pottery and bricks).

CHAPTERS IN THIS VOLUME

The authors in this volume assess the ways humans respond to natural changes, foregrounding the independence of natural forces at the mass-event, incremental, and biotic scales. Addressing the largest natural phenomena, Matthew C. Peros, Jago Cooper, and Frank Oliva engage with the way hurricanes have impacted ancient human populations and prompted a variety of proactive and reactive responses. They advocate the pursuit of paleotempestology—the study of past hurricanes—not only to understand ancient human activities but also as the only means by which a long record of extreme weather can be generated given the short time span of modern records. Peros and colleagues note that despite the lack of predictable periodicity, storms conditioned ancient peoples' landscape strategies in ways that allowed for resilience and cultural continuity, as they demonstrate through their case studies of medieval Japan, the Terminal Maya collapse, and the archaeology of the Caribbean.

Kanika Kalra's chapter on rainfall addresses the incremental side of the heaven-borne spectrum of water. Through her research on the Indian monsoon, she assesses the environmental impact of regular seasonal rainfall that serves to define entire landscapes and punctuates the annual cycle of human activities. Her chapter contrasts the Bronze Age Indus culture (which was centered on rivers in the western subcontinent) with the Early Historic and medieval cultures of southern India, whose agricultural and political growth took place in a more arid environment in which water capture was essential. Through the comparison of three areas and cultures including Vijayanagara, Tamil Nadu, and the region known as the Raichur Doab, Kalra evaluates the many different individual-, household-, and community-level practices of water management that included wells, reservoirs, cisterns, embankments, and opportunistic catchments woven into the construction of fortifications—all of which served as infrastructure to capture, retain, and divert seasonal rainwater abundance.

The intensity of mass natural events may not be predictable or stoppable, but humans respond to such events in a variety of ways. In his discussion of the effect of earthquakes on ancient Roman cities, Jordan Pickett reconstructs architectural histories to show that our colloquial phrase "don't waste a good crisis" was well understood by ancient civic leaders. In many Roman cities of the eastern Mediterranean, the destruction of buildings by earthquakes provided the opportunity to rebuild to suit new specifications and social movements, most notably the growing influence of Christianity with its new architecture of churches that became the focal point of post-earthquake donations and urban renewal. His treatment of the three case studies of Antioch, Ephesus, and Hierapolis illustrates the ways resilience and sustainability are always couched in social terms.

Fire is a natural phenomenon whose existence on the planet can be documented for the past half-billion years. As Smith examines in her chapter, fire as an interactive system of fuel and combustion has long shaped biotic communities around the world; humans' engagement with fire starting with our earliest ancestors further accelerated the mutual dependence of fire with its surrounding environments. The adoption of fire technologies required a cognitive understanding of unilinear processes, but fire was infinitely scalable and became both a tool and a weapon of mass destruction. In stark contrast to the human relationship to stone as an inert substance, the human engagement with fire was one of constant management and risk: a single spark can result in long-lasting scars to an entire landscape.

Compared to physical events that violently disrupt settlements and their surroundings, diseases are natural phenomena that are invisible but whose effects often are far more insidious, disruptive, and widespread. In their chapter, Sara L. Juengst and colleagues identify all of the types of medical malaise that beset humans from their contacts with each other and with their environments, including viruses, bacteria, parasites, and fungi. These pathogens, widespread but generally dispersed in the natural environment, become pooled and concentrated in human settlements and thrive in the niches created by human habitation, storage, and land-use practices. The authors propose that these human-altered environments, especially after the advent of plant and animal domestication, have become "microbe-scapes" in which human activities actively enhance disease replication and transmission. The bioarchaeological results from their case study of the transition from foraging to farming in Bolivia illustrate that the challenges of zoonotic-origin diseases, as we well know in our own times, also have a long history in the archaeological record.

Incrementalism in natural phenomena presents a subtle but compelling revelation of the way natural processes overwhelm and thwart human intention. In their insightful chapter on vegetation growth, Harper Dine, Traci Ardren, and Chelsea Fisher use the ancient Maya site of Coba to critically address the category of "weeds" in a human landscape of cultivation. They observe that the categories of domesticated plants and weeds emerge simultaneously, with a linguistic gloss on vegetative growth as either wanted or unwanted. While domesticated plants often require conscious tending and a significant amount of work, weeds take advantage of the same conditions of soil tillage and fertility to compete with domesticates. The category of "weeds" is further complicated by the ways both purposefully planted and opportunistic vegetation figures into the human worldview as occasional famine foods, as pharmaceuticals, and as mute evidence of human habitation that can linger long after the abandonment of a settlement.

Human-environmental interactions often are transformed by multiple agents simultaneously. In their chapter, Seth Quintus, Jennifer Huebert, Jillian A. Swift, and Kyungsoo Yoo evaluate the complex relationships among humans, mammals, birds, and plants over the past 1,000 years in Polynesia. Dramatic cycles of change are evident even in the most recently settled islands such as Rapa Nui, the Marquesas Islands, Mangaia (Cook Islands), and Mangareva (Gambier Islands). Configurations of mutual dependence were continually changed at points of inflection that included the introduction of new species and new cultigens, in which humans responded to new patterns of animal and plant activities through actions that, in turn, provided both intentional and unintentional ecological niches.

Katelyn J. Bishop's chapter on birds examines the way birds are able to exploit their capacities of flight to challenge humans' attempts at capture and control. Using a detailed accounting of bird bones from archaeological sites at the ancient site of Chaco Canyon, Bishop creates a rubric for assessing the relative difficulty of engaging with particular birds found in the site's cultural deposits, suggesting that there was a range of human avian use, from routine meals to spiritual investments. Some birds were of value precisely because they were hard to capture; the unexpectedly high rates of recovery of both high-flying raptors and ground-dwelling turkeys illustrate the ways birds' patterns of locomotion and relative ease of capture resulted in differential patterns of appearances in human settlements.

Steven Ammerman's chapter on domesticated animals critically addresses what we mean by the levels of engagement that can be characterized as wild, tamed/habituated, domesticated, and feral animals. Very few species among the world's animal population have been domesticated, and the selectivity for domestication relied at least in part on the extent to which animals of particular species found human settlements tolerable or advantageous. He emphasizes that the domestication process involves the capacity of animals to react to or even initiate their commensal relationship with humans, a factor that illustrates that species—regardless of whether they are domesticated—are not composed of identical individuals but present variance that can aid or hamper the trajectory toward both domestication and subsequent instances of ferality.

In her chapter on reindeer, Silvia Tomášková examines the transactional status of wild and domestic members of this unusual species, given that the two populations live side by side and regularly interact. She details the relative helplessness of human keepers who experience runaway reindeer populations, highlighting that the animals' agency of movement is far greater than that of humans. Using archival historical documents, she critiques the way Siberia has often been made to stand in for prehistory through ethnographic and historical accounts and offers an alternative view of complexity and mutualism as exhibited in the long history of human-animal relations. Through the prism of a harsh environmental zone, she suggests that reindeer in their agentive practices provide an alternative model of domestication compared to the considerably more docile herd animals of the Near East and other temperate global regions.

By way of a concluding chapter, John Robb's thoughts on the future of agency bring the perceptive light of the present day into a reconsideration of the human-environmental dynamic. Using the case of the Black Death in Europe, Robb documents the way scholars have credited a single episode of illness in the fourteenth century with being a critical turning point for political, economic, and social change. Yet as he notes, our current perceptions of the impact of the 1347–1350 CE plague may be greatly overdrawn because those who were in the midst of that pandemic may have perceived it in quite different ways and with far less disruption given the already short life spans of the era, the continuity of religious traditions despite dramatic loss, and the cellular structure of social groups that enabled the rapid regeneration of economic patterns. In sum, crisis and catastrophe are in the eyes of the beholder, and even the most dramatic turns of events are incorporated into prevailing belief systems.

CONCLUSION

Natural phenomena and human cultures interact as systemic interdependencies within complex feedback loops. Humans engage with their environments, both social and physical, within a risk-based rubric of assessment that results in a synthetic physical configuration that can be analyzed as an anthroposcape. Natural forces and human actions occur within physical frames of reference, in which the settlement provides the key archaeologically visible locus of interaction. Many aspects of natural environments (ranging from benign and anticipated conditions of weather and climate to extreme natural events such as earthquakes and storms) are completely beyond human control in initiation, duration, frequency, and magnitude; for all of our sophisticated measuring devices today, we are still unable to predict the weather with complete accuracy, to ascertain the exact forthcoming path of cyclonic storms, or to predict the timing and amplitude of natural events such as earthquakes and volcanic eruptions. The power of nature to shape the environment still overwhelms human capacities and provides the framework within which human responses are proactive or reactive, but never in equal measure.

Acknowledgments. I would like to thank Karl LaFavre and two anonymous reviewers for comments on an earlier version of this chapter. Many thanks go to the participants in the SAA session Things with a Mind of Their Own: Agentive Approaches to Non-Human Agency for their lively interactions and stimulating presentations.

NOTE

1. http://www.ictg.org/blog/learning-phases-of-collective-trauma, August 2017.

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2

Hurricanes as Agents of Cultural Change

Integrating Paleotempestology and the Archaeological Record

Matthew C. Peros, Jago Cooper, and Frank Oliva

ABSTRACT

Hurricanes are major meteorological events with significant impacts in tropical and extra-tropical regions worldwide. Despite this, little research has been undertaken on the effects of hurricanes and other intense storms on pre-industrial societies. New evidence from the field of paleotempestology—the study of past hurricane activity using geological proxy techniques, such as lagoon sediments and speleothems—is shedding light on how hurricanes varied over the Holocene in terms of frequency, geographic distribution, and magnitude. This information, in conjunction with archaeological data from coastal locations, provides a means to better understand human adaptation and resilience in the face of abrupt, high-magnitude climatic events. This chapter highlights three examples where paleotempestology has been (or could be) important at helping us understand past societal responses to hurricane activity: (1) the case of the destruction of the fleets of the Kublai Khan in medieval Japan, (2) the possible effect of hurricanes during the Terminal Maya collapse, and (3) proactive hurricane adaptation strategies at a Taíno site in northern Cuba. These examples show that human responses to hurricane events have varied considerably and highlight ways paleotempestology can be better integrated with archaeological data.

Hurricanes are short-duration, high-magnitude non-biotic agents whose impacts can have devastating consequences for coastal communities and ecosystems. The

https://doi.org/10.5876/9781646423521.c002

2017 hurricane season in the North Atlantic was particularly severe, consisting of seventeen named storms (including Hurricane Irma, which had one of the highest recorded surface wind speeds of any hurricane of all time) that left thousands of people dead and hundreds of billions of dollars in damage (Blake 2018:28). Considerable scientific effort is focused on understanding how hurricane activity will change with global warming, with models generally indicating that the intensity of the strongest storms will increase in the coming decades (Camargo 2013; Knutson et al. 2010). Other recent research has focused on how hurricane activity impacts cultural heritage in coastal regions (Rivera-Collazo 2019). However, there is comparatively little research on how hurricanes impacted pre-industrial societies and how those societies responded or adapted to these events (Cooper 2013:44; Medina-Elizalde et al. 2016). In part, this is due to a lack of reliable data on hurricane activity prior to the instrumental record, but it may also be due to challenges associated with integrating geological and archaeological datasets at different spatial and temporal scales (Stein 1993). Nevertheless, the frequency with which hurricanes occur and the intense rainfall, wind activity, and flooding associated with them (e.g., Murty et al. 1986) means they likely had considerable influence in many coastal regions.

The archaeological literature contains numerous examples of natural phenomena that affected pre-industrial societies, such as volcanic eruptions (e.g., Dull et al. 2001), earthquakes (e.g., Florin and Gerrard 2017), riverine floods (e.g., Muñoz et al. 2015), droughts (e.g., Hodell et al. 1995), and tsunamis (e.g., Bruins et al. 2009; Reinhardt et al. 2006). Hurricanes differ from many of these other phenomena due to their quasi-predictable nature: they virtually always occur in summer and late fall when sea surface temperatures are highest (Emanuel 2003). This is in contrast to earthquakes and tsunamis, for example, whose timing is largely unpredictable due to the apparently random nature of seismic activity. In addition, hurricanes occur with sufficient frequency that individuals living in hurricane-sensitive regions may encounter multiple events during their lifetimes. With the possible exception of floods, this also stands in contrast to many other natural phenomena (e.g., volcanoes), which recur at intervals that can easily exceed several centuries (Deligne et al. 2010). Due to the seasonality and frequency of hurricanes, one specific element of community adaptation that may be important relates to the concepts of anticipation and learning, which can result in policies to reduce risk and increase community resilience (Gunderson 2010). Thus, hurricanes represent a unique opportunity to examine societal responses, adaptation, and resilience in the face of high-magnitude natural stressors (e.g., Holling and Gunderson 2002).

While hurricanes are natural phenomena over which humans have essentially no control, the severity of hurricane impacts is highly influenced by human activity.

Hurricanes become hazards when they encounter and affect human populations, and they can turn into natural disasters if a large number of fatalities or overwhelming damage occurs (Burton et al. 1978). Conversely, human intervention can ensure that the effects of hurricanes are limited and that they do not become disasters (Pielke et al. 2003:101). Impacts can be mitigated through the temporary relocation of people (i.e., evacuation; Huang et al. 2012:285), the construction of household architecture that can withstand severe winds and flooding and can be efficiently rebuilt (Stewart et al. 2003), the construction of settlements in protected areas or the building of flood protection itself (e.g., levees; Cooper and Peros 2010:1229; Merrell et al. 2011), and food procurement strategies that provide a range of resources to buttress against sudden disruptions to the local economy (Cooper 2012:105). Thus, hurricanes as natural disasters are both naturally and socially constructed, especially when social systems fail or are not in place to limit potential damage (Brunsma et al. 2007:34).

The purpose of this chapter is to assess the importance of hurricanes as agents of cultural change in archaeological contexts by reviewing examples in the archaeological and geological literature of past human responses to hurricane activity. To do this, we begin by introducing the field of paleotempestology, a rapidly growing area of research focused on the use of geological proxy data to document prehistoric hurricane activity. We then consider three examples in which paleotempestology has played (or could play) a role in elucidating how hurricanes influenced pre-industrial societies: medieval Japan, the Classic Maya in the Yucatán, and the Taíno in the Caribbean. Hurricanes provide a distinct opportunity to examine unidirectional environmental-human interactions: hurricanes impact humans, and humans—with the possible exception of contemporary global warming (e.g., Knutson et al. 2010)—do not affect hurricanes. However, this does not mean that the only human response to hurricanes is reactive, as there are examples of proactive responses that appear in the archaeological record as well (e.g., Cooper and Peros 2010).

HURRICANES AND PALEOTEMPESTOLOGY

Hurricanes are rotating, organized systems of clouds and thunderstorms that originate over tropical or subtropical waters and which have a closed, low-level circulation with sustained minimum wind speeds of 119 kph or higher (NOAA 2018). At a global scale, these severe weather events are referred to as tropical cyclones, but they are called hurricanes in the North Atlantic and East Pacific Oceans, typhoons in the western North Pacific, and cyclones in the southern West Pacific and Indian Oceans (NOAA 2018). The global distribution of hurricanes (in this chapter, the

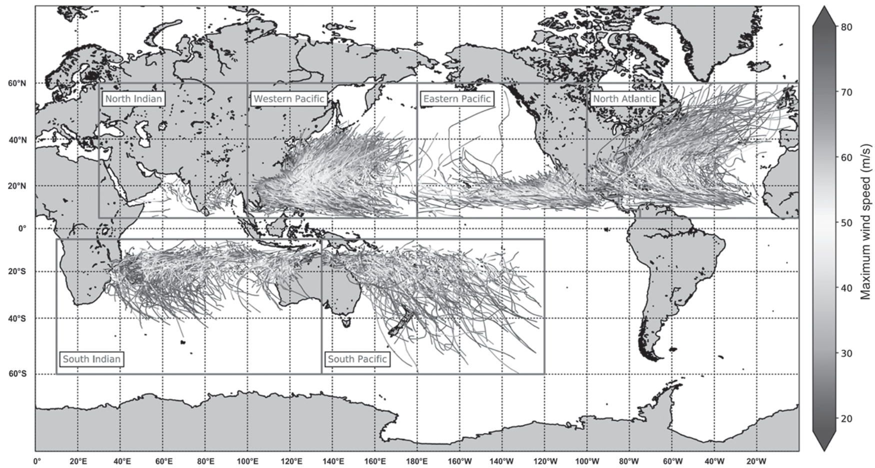

Figure 2.1. Map showing the distribution of global tropical cyclone tracks and intensities for the period 1980–2018 from the IBTrACS (International Best Track Archive for Climate Stewardship) dataset for each tropical cyclone basin (Knapp et al. 2010; Bloemendaal et al. 2020).

term *hurricane* will refer to all tropical cyclones, unless otherwise indicated) shows that they form between 5° and 15° north and south of the Equator and generally track westward before recurving toward the right in the northern hemisphere and left in the southern hemisphere (figure 2.1; Goni et al. 2009). Warm sea surface temperatures (SSTs) and low vertical wind shear (i.e., change in wind direction with altitude) are critical for hurricanes to form and sustain themselves (Corbosiero and Molinari 2002). Because of this, hurricanes are most common and intense in August and September in the northern hemisphere when SSTs are at their maximum (Emanuel 2003:79). Hurricanes continue their tracks until they make landfall or encounter colder water, which diminishes their source of energy (Emanuel 2003:78).

The study of paleotempestology is not just a way to understand human responses to severe weather events; it provides the only way to establish long-term climate records of the kind necessary for understanding the relationship between hurricane activity and Holocene climate change. Reliable and systematic monitoring of hurricane activity only began at the end of World War II, which has hindered the development of reliable, long-term (decadal- to millennial-scale) datasets that record past hurricane tracks, intensities, frequencies, and impacts. Prior to the twentieth century, the documentation of hurricanes was less consistent and many storms were probably never recorded, especially if they did not make landfall (Emanuel 2003:76). In some cases, archival sources have been used to extend the instrumental record and fill data gaps; early Spanish archival documents, for example, have provided evidence for hurricane activity in the Caribbean beginning as early as June 25, 1494, at Isabella, Dominican Republic (García-Herrera et al. 2007:55), and a 1,000-year-long record of hurricane strikes has been developed using local gazettes (i.e., newspapers) in southern China (Liu et al. 2001). While these and other studies highlight the utility of archival sources for reconstructing past hurricane activity, they also indicate that many storms are also likely to have been unreported, especially as one goes back farther in time (Liu et al. 2001:461).

Over the past few decades, the field of paleotempestology—the study of past hurricane activity using geological proxy techniques—has attempted to fill many of the gaps present in the instrumental and historical records and also to extend these datasets back thousands of years (Oliva et al. 2017; Wallace et al. 2014). The most common proxy indicators include sedimentary sources, usually from coastal lakes and lagoons (e.g., Liu and Fearn 2000; Donnelly et al. 2001), along with isotopes of oxygen measured on speleothems (Frappier et al. 2007), corals (Hetzinger et al. 2008), and tree rings (Trouet et al. 2016; Miller et al. 2006). The basic premise behind sedimentary indicators is that hurricane-driven storm surges and wave activity transport coarse-grained sediment eroded from the shoreline into coastal lakes and deposit this sediment as flooding recedes (Donnelly et al. 2004; Liu 2004). These "over-wash" layers are characterized by a sandy texture that differs from the finer-grained sediments that are deposited during normal, low-energy conditions. By taking sediment cores at these sites and dating organic matter present in the sediments, it is possible to use sand layers to identify the presence of past hurricane strikes over hundreds or even thousands of years (Donnelly and Woodruff 2007).

Despite significant progress in the field of paleotempestology, there are still limitations in terms of spatial and temporal coverage as well as with the method itself. A recent meta-analysis of paleotempestological reconstructions for the North Atlantic Basin shows that their spatial distribution is relatively uneven (figure 2.2; Oliva et al. 2017). While there is a high density of data points from sites on the northern coast of the Gulf of Mexico and the East Coast of the United States, there are relatively few records for much of the Caribbean and the East Coast of Central America, even though the latter regions are known for frequent hurricanes. In terms of the length of the records, most reconstructions cover only the last few thousand years, meaning that our understanding of hurricane variability prior to this time is unclear (figure 2.2; Oliva et al. 2017). In addition, paleotempestological reconstructions are generally reliable at recording hurricane frequency (e.g., Donnelly et al. 2015) but are less reliable at documenting hurricane intensity, since it is difficult to determine whether a given over-wash layer was formed by a more intense hurricane that struck farther away from the coring site or a less powerful storm that was a

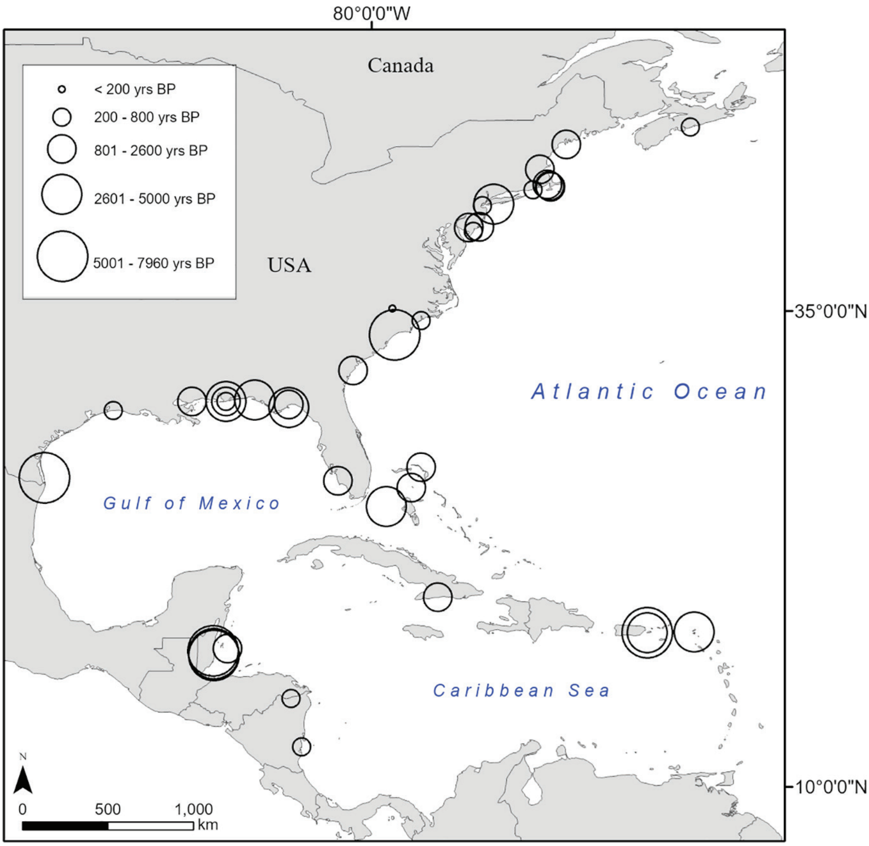

Figure 2.2. Distribution of sediment-core–based paleotempestological sites for the North Atlantic Basin (Oliva et al. 2017). The size of the circle for each site represents the approximate length of time of each record in thousands of years.

direct hit (Woodruff et al. 2008). However, progress is being made in addressing many of these limitations through analyses of different proxy indicators (e.g., speleothems, tree rings, and corals) and the modeling of storm surges and how they affect sediment transport (e.g., Woodruff et al. 2008).

HURRICANE IMPACTS AND THE ARCHAEOLOGICAL RECORD

Hurricanes have the potential to impact human societies and the environment in a variety of ways. During hurricane landfall, damage can result from high winds, hurricane-induced tornadoes, and waves and storm surges that cause marine flooding and excessive rainfall. In the days and weeks that follow the event, additional impacts can include inland flooding (from the rainfall), the salinization of freshwater resources, fires due to the preponderance of natural and anthropogenic flammable debris, and a general disruption of local ecosystem services on which people depend (Sandifer et al. 2017). We now consider three examples of preindustrial human responses to some of these impacts, with "response" in this case broadly defined as how people reacted to the events (Adger et al. 2013:113).

Medieval Japan: Destruction

In a study from the western Pacific, paleotempestological evidence was used to independently verify historical accounts of two "Kamikaze" typhoons that were said to have divinely struck southern Japan in the thirteenth century CE and in so doing destroyed the fleets of the Kublai Khan, whose vast armada had set out to conquer Japan (Woodruff et al. 2014). Legends state that despite being significantly outnumbered, the Japanese defenses were saved by the fortuitous destruction of the Mongol fleets by intense typhoons occurring in November 1274 CE and August 1281 CE, respectively (Sasaki 2008). Noting that some historical accounts can be prone to exaggeration, Jonathan D. Woodruff and colleagues (2014) attempted to assess the presence and possibly the magnitude of these typhoons.

The researchers began by analyzing the most recent sediments in a coastal lake in the region where the ships were supposed to have landed and correlating distinctive sedimentary layers found there against known typhoon strikes that occurred during the last 100 years. These "modern analogues" helped establish a unique sedimentary signature for typhoons in the area. Then, the authors identified two prominent sand layers in cores collected in the lake that dated to the thirteenth century CE (Woodruff et al. 2014). These layers were very similar to the ones left by the twentieth-century typhoons and were also enriched in the element strontium, an indictor of marine sediment over-wash. These data strongly suggested that two major marine flooding events occurred around the time the historical records indicate the fleets were destroyed.

Woodruff and colleagues (2014) argue that it is impossible to unequivocally link the geochemical and sedimentological data to the typhoon events, in part due to the precision of radiocarbon dating, which typically produces ages within a range of a few decades. Still, they argue that the most likely explanation for the sand layers is the Kamikaze typhoons, due to their timing and a lack of evidence for any other natural event that could have produced a similar deposit (such as a tsunami). Their work then places the two typhoon strikes into a broader paleoclimatic context and shows that this period—the thirteenth century—was one in which more typhoons were steered toward southern Japan by changes in El Niño activity in the tropical Pacific Ocean.

The authors thus argue that the typhoons serve as an example of how past events of extreme weather associated with climatic change appear to have had significant geopolitical influence (Woodruff et al. 2014). In this particular case, the impacts were severe, and the response was one of destruction and dispersal of the Mongol fleets—likely due to a combination of high wind, rain, and wave activity. While their study represents an example of the effects of hurricane impacts, it illustrates how geological data can be integrated with the historical record to assess the magnitude of natural events that had significant impacts on humans.

The typhoon strikes in the Japanese historical example also illustrate the concept of vulnerability—the degree to which natural and/or human systems are susceptible to, and unable to cope with, adverse impacts of climate change (IPCC 2014:54). The scale of the destruction indicates that the Kublai Khan's fleets must have been highly vulnerable and leads to questions concerning the quality of the ships and the degree to which disaster preparedness and mitigation was included in the invasion planning. For example, in both cases, the fleets were destroyed in late summer/autumn of 1274 and 1281 CE, respectively, which is the height of typhoon season in the western Pacific. To what extent was seasonality considered when the invasions were planned? Following the destruction of the first armada in 1274 CE, what was done to limit potential typhoon impacts during the second invasion in 1281 CE? Whatever the answers, both events are examples of human systems being overwhelmed by natural phenomena.

The geological evidence itself provides only the starting point for understanding the human response to typhoon activity. The paleotempestological data produced by Woodruff and colleagues (2014) validate and refine the historical accounts of two high-magnitude typhoons occurring around the time of the destructions of the Mongol fleets. But understanding the nature of the impacts themselves requires data from historical and archaeological sources. For example, underwater excavations led by Kenzo Hayashida of the Kyushu Okinawa Society for Underwater Archaeology have produced at least one of the Khan's ships and a range of maritime-related material culture (Delgado 2003). While it is now believed that the size of the Khan's armada was probably exaggerated (Delgado 2010), the archaeological evidence is consistent with historical reports of the incident and geological evidence of the storms themselves.

Finally, the typhoon strikes must qualify as natural disasters, due to infrastructure damage and lives lost (Burton et al. 1978). However, this also is an example of the idea of natural disasters being relative to the actors impacted by the event. From the point of view of the Japanese, the Kamikaze typhoons and their impacts were seen as "divine winds" that essentially saved their civilization, whereas these events could only have been viewed as disasters from the perspective of the Mongols.

While most natural disasters are typically considered to have negative consequences for human systems, it suggests that the concept of natural disaster can be more nuanced and can occasionally produce positive outcomes as well. Examples include the creation of opportunities for upgrading infrastructure and the stimulation of economic growth (e.g., Hallegatte and Dumas 2009), as well as the political and social opportunities for urban renewal (see Pickett, chapter 4, this volume).

The Maya Realm: Destabilizing Force or Unlikely Benefit?

The Caribbean coast of Central America experiences frequent hurricanes, many of which have had devastating consequences for people in both coastal and inland areas. Hurricane Mitch, for example, struck the coast of Honduras in late October 1998 and resulted in more than 11,000 deaths and billions of dollars in damage, much of it due to heavy rainfall that caused severe mudslides in interior mountainous regions (Hellin et al. 1999). In addition, in August 2007, Hurricane Dean struck the Yucátan coast of Mexico as a category 5 storm. Despite causing over $1.6 billion in damage, fatalities from this hurricane were relatively low, with only forty-five deaths recorded in the Caribbean islands and fewer than two dozen in Mexico. This relatively low death toll was attributed in part to reliable forecasts of the hurricane's track and effective warning and evacuation procedures (Franklin 2008).

The frequency of high-intensity hurricanes affecting Central America prompts the obvious question: what impacts did these storms have on pre-industrial people, in particular the ancient Maya, with their sophisticated cities and intricate political alliances? The answer, however, is not entirely clear, in part because of limited paleotempestological research done in the region (although see McCloskey and Keller 2009; Denommee et al. 2014) but also because the effects of hurricanes would have certainly varied given the region's topographic heterogeneity and diverse landscapes and cultures.

Some of the earliest work examining this question argued that hurricanes may have been "trigger mechanisms" for configurations of settlement patterns, subsistence strategies, warfare, trade, and migrations and demographic stability (Konrad 1985). As a result, "The hurricane was an integral feature of the pre-Hispanic Maya cosmology and ecological paradigm" in the first millennium CE (Konrad 1996:99). Herman W. Konrad (116–120) also argued that the presence of hurricanes led to local adaptations, such as household architecture characterized by rounded roofs and walls—features that are common along the Yucátan coast—that would have better withstood the impact of hurricane-force winds (123). More recently, others have argued that hurricanes were a destabilizing force for the ancient Maya and may have precipitated episodes of warfare (Dunning and Houston 2011:64). While some evidence—in the form of epigraphic, iconographic, and geoarchaeological data—exists to support this view (Dunning and Houston 2011), links between hurricane impacts and the ancient Maya are still mostly tentative.

One notable example of the effects of hurricanes on ancient Mayan civilization involves their possible role in the Terminal Maya collapse. This event, which occurred around 900 CE, has been attributed to a number of interrelated factors, including a series of severe droughts (Hodell et al. 1995). Martín Medina-Elizalde and Eelco J. Rohling (2012) analyzed four high-resolution paleoclimatic records (including one stalagmite and three lake sediment records) for the Yucátan Peninsula and concluded that droughts coincident with the Terminal Maya collapse were driven largely by a reduced frequency and intensity of hurricanes (as well as tropical depressions and other storms). Moreover, they argue that the groundwater table in the Yucátan Peninsula is particularly sensitive to tropical storm frequency and that only a modest reduction in these events would be necessary to explain the drought signal present in isotopic records for the region (958).

The hypothesis of hurricane reduction as a trigger for the Terminal Maya collapse has been challenged by Amy B. Frappier and colleagues (2014), who developed a stalagmite-based paleotempestological reconstruction for the northern Yucátan focused on mud layers incorporated into the stalagmite matrix as an indicator of hurricane-induced flood events in a cave. After calibrating recent mud layers to historical hurricanes, it was shown that the Terminal Classic droughts may have coincided with normal or even enhanced hurricane activity and that the severity of the reduction in precipitation during the Maya droughts may have been overestimated (Frappier et al. 2014:5155). Moreover, the study also concludes that hurricane flood events are likely underrepresented in stalagmites at times when droughts do occur, underscoring the complexity of interpreting these records and highlighting the need for more research in this area.

Coupled with the uncertainty concerning the frequency and intensity of hurricanes during the Terminal Maya collapse is the question of what specific effects hurricanes would have had on Maya civilization given the heterogeneous topography of the region. Hurricane activity has been cited as inherently destructive (Dunning and Houston 2011), especially in low-elevation areas such as the Belize coastal plain (Dunning et al. 2012). Medina-Elizalde and colleagues (2016), however, argue that hurricanes could potentially have had "beneficial" attributes, particularly by delivering precipitation to areas that might be drought-sensitive. While hurricane rainfall typically resulted in short, high-intensity bursts that may have damaged field-based agriculture, such storms would have replenished much-needed domestic freshwater supplies that also supported household gardens (see Dine et al., chapter

7, this volume). Moreover, the effects of hurricanes would likely have been different depending on whether settlements were inland or coastal, as sites in the latter locations would be sensitive to the effects of storm surges in addition to rainfall and wind.

The role of hurricanes in ancient Maya civilization requires additional research focused on new paleotempestological data from a range of sources and proxy indicators, including established sedimentological techniques based on the analysis of over-wash layers from coastal lakes and wetlands (Liu and Fearn 2000), geochemical and sedimentological analyses of sediments from cenotes and other karst features that have recently been shown to record past hurricane variability (Brown et al. 2014), speleothem data recording flood events (Frappier et al. 2014) as well as isotopic signals of hurricane rainfall (Medina-Elizalde and Rohling 2012), and tree rings that incorporate isotopically lighter hurricane water into the plant cellulose (Miller et al. 2006). The use of a range of data sources is especially important to document hurricane impacts at non-coastal sites, so that the effects of hurricanes at some of the larger urban centers, located in interior regions, can be better resolved.

The Taíno at Los Buchillones: Proactive Resistance

Ethnohistorical sources reveal that the Taíno, who occupied much of the Greater Antilles at the time of Spanish arrival, had a sophisticated knowledge of hurricanes. Specifically, they sequenced the event into successive stages that included the coming of the winds, the destructive force of the hurricane, and post-hurricane impacts (Cooper 2013:45). Each of these stages was represented by the deities Gatauba, Guabancex, and Coatrisque, respectively (Pané 1990), indicating the extent to which the knowledge and understanding of hurricanes was ingrained in their worldview (Schwartz 2015:8). Indeed, while there is some confusion over the origin of the Spanish word *huracán*—which later became the English word *hurricane* (6)—many sources believe it ultimately derived from "Juracán," the Taíno *zemi* (or deity) for disorder and chaos who also controlled the weather. Given the close cosmological relationship between hurricanes and Taíno society (8), it is not surprising that the Taíno (especially those living in coastal locations) would be well prepared to deal with these events, both physically and psychologically.

The details of Taíno resilience can be evaluated at Los Buchillones, a site occupied between about 1220 and 1640 CE on the north coast of central Cuba (figure 2.3a, b; Calvera Roses et al. 2006; Valcárcel Rojas et al. 2006). The site is presently located under approximately 1 m of water in a lagoon and offshore of a narrow sand barrier. Due to the submerged nature of the site, excavations at Los Buchillones are undertaken by building a sandbag dyke around the area of interest and then

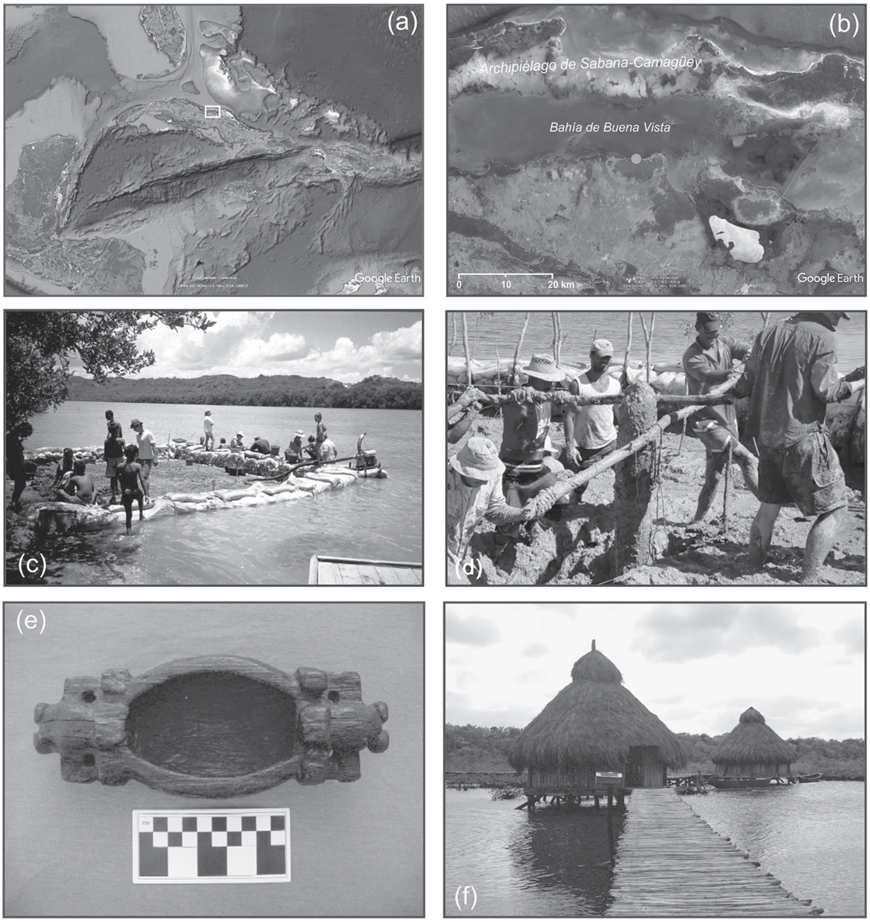

Figure 2.3. (a) Map of the western Caribbean Basin, with the area of the white box corresponding to the frame (b); (b) map of the region around Los Buchillones (indicated by the red circle), showing the offshore reef (Archipiélago de Sabana-Camagüey) and the shallow Bahía de Buena Vista; (c) excavation area at Los Buchillones inside the lagoon, with the pump shown on the right; (d) structural post that would have been at the center of one of the Taíno houses; (e) carved wooden bowl found during the excavations; and (f) modern reconstruction of a Taíno house located at a public park near Los Buchillones.

pumping out the entrapped water (figure 2.3c). Having lowered the water level and removed surficial sediments, archaeologists have recovered a range of archaeological materials—including the remains of approximately forty collapsed Taíno houses, complete with rafters, thatch, and structural posts driven into the earth (figure 2.3d). The excavations also have yielded well-preserved carved wood (figure 2.3e), in addition to chipped stone and groundstone, shell, and ceramics (Calvera Roses et al. 2006), making Los Buchillones one of the largest and best-preserved Precolumbian settlements in the Caribbean.

Geoarchaeological investigations at the site consisted of the collection of a series of sediment cores in a shore-parallel transect through the archaeological remains to determine why the site was submerged (Peros et al. 2006). Based on these investigations, we developed a model for the evolution of the coastline indicating that the village was likely built over water rather than on dry land—a settlement strategy uncommon among Taíno sites (Curet 1992). Worldwide, the reasons for building settlements on pile dwellings vary and can include better access to marine, lagoonal, and terrestrial resources (Peros et al. 2006). However, at Los Buchillones, the nature of the coastal environment and the active hurricane region the site is located in suggest that measures to adapt to this dynamic environment may have played a role in influencing settlement location and domestic architecture at the site.

Los Buchillones is located on the mainland of Cuba, inside a long and wide archipelago of cayes and mangrove islands (figure 2.3b). The tidal range at the site is comparatively small, due to the damping effect of this offshore reef. On a daily basis, the effect of the reef would mitigate tides, but it would also protect against storm surges during a hurricane (Cooper 2013). Indeed, Hurricane Irma struck the area as a category 5 event in September 2017, and anecdotal evidence indicates that most of the destruction from flooding and wind occurred on the outer reef and that the mainland was much less affected. In addition, a network of limestone caves is located approximately 1 km south of Los Buchillones, which would provide hurricane shelters; Precolumbian artifacts found in these caves indicate their use, or at least knowledge of their location, by Precolumbian populations (Cooper 2012). Thus, at the settlement scale, the physical location of Los Buchillones appears to be well suited to mitigate hurricane risk.

The design of the domestic architecture at Los Buchillones may also have been made with hurricanes in mind. The strategy of pile dwellings (figure 2.4f) would have guarded against the effects of flooding, whether from storm surges or excessive rainfall (Cooper and Peros 2010). In addition, the structures include large-diameter wooden posts driven vertically into the ground, upon which lighter structural material (including palm thatch) was placed to complete the walls and roof. While high winds and rain could easily destroy much of the exterior of these structures, those elements could quickly be replaced with locally procured materials following the hurricane event. Indeed, this kind of house architecture contrasts with today's poorly constructed cement and brick buildings in the area, which, when damaged, require considerable effort with non-local materials to repair, making post-hurricane reconstruction time-consuming and costly (Cooper 2012). Thus, Los Buchillones serves as an example of pre-industrial adaptation to high-risk meteorological events—a proactive response–which would have enhanced cultural resilience in the face of extreme storms.

Although there is evidence for strategies consistent with hurricane adaptation at Los Buchillones, no paleotempestological research has been undertaken in this region of Cuba. Such work would strengthen the case for a proactive response to hurricane activity by the Taíno, and the numerous lagoons and mangroves that are common in the area likely preserve evidence of past hurricane events. For example, paleotempestology could provide data to help assess the extent to which the Archipiélago de Sabana-Camagüey protected the site from flooding during the period of Taíno occupation. Paleotempestological data from the lagoons located on the offshore islands (such as Cayo Coco) could be compared to similar data from the mainland—including the lagoon Los Buchillones is located in—to identify differences between hurricane impacts on the exposed, ocean-facing side of the reef compared to the protected mainland. In addition, these studies could help elucidate whether hurricane activity was more active during site occupation (~ 1220–1640 CE), which would provide additional evidence for the need for the adoption of adaptive strategies by the Taíno to reduce hurricane risk.

CONCLUSION

Each year, approximately eighty hurricanes occur across the Atlantic, Pacific, and Indian Oceans—a number that has changed little over the last few decades of hurricane monitoring (NOAA 2018). While not all of these storms make landfall, the widespread and frequent nature of high-magnitude meteorological events means they are a major agent influencing coastal environments and the human populations who reside there. Despite considerable efforts dedicated to hurricane forecasting and emergency preparedness, relatively little is still known about how these events impacted pre-industrial societies. Hurricane impacts are multifaceted and include high winds, rain, and flooding during the event itself, followed by flooding and occasionally fire activity after the storm dissipates or moves on. The review undertaken here highlights a range of past human responses to hurricanes that include near total destruction (the fleets of the Kublai Khan in medieval Japan), possible societal collapse due to a drought-induced reduction in hurricane activity (the ancient Maya), and the mitigation of impact through proactive adaptation measures (the Taíno at Los Buchillones, Cuba). The variability of the human response before, during, and after extreme weather events illustrates the fact that the concept of hurricanes as natural phenomena that overwhelm social and natural systems is simplistic and that their effects are influenced by cultural and historical factors as much as by the hurricane itself.

The growing field of paleotempestology has much to contribute to the question of hurricane impacts on past human societies. However, as this chapter shows, paleotempestological investigations must be conducted in close association with archaeological and/or historical research. For example, in the case of medieval Japan, the paleotempestological investigations were important for providing independent supporting evidence for typhoon strikes around the time of the Mongol invasions, but ultimately it was archaeological and historical evidence—in the form of sunken and destroyed ships, alongside historical records of these events—that helped confirm the human response. In the case of the ancient Maya, ongoing questions concerning the specific way hurricane activity impacted Maya society seem to be due as much to uncertainty in the nature of hurricane activity around the time of the Terminal Maya collapse as to generalizing about what kind of response would be expected from a society as large and complex as the Mayan civilization. While paleotempestological research has yet to be carried out in northern Cuba, it may be that establishing relationships between hurricanes and past societies is most effectively undertaken at the site and landscape level, such as at Los Buchillones, where there is potential to develop reliable and detailed reconstructions of past hurricane activity and where the scale of the human system is relatively small and less complex (compared to a state-level society).

Certainly, the increasing number of paleotempestological proxy records in development will fill geographic and temporal gaps that will help provide contexts for archaeological research. Another promising area of research is the use of large archaeological databases to explore regional-scale demographic shifts in preindustrial populations and site location in response to hurricane activity gleaned from paleotempestological data (Oliva et al. 2017). Moreover, there may be potential for archaeological materials and the sites themselves to be used as indicators of past hurricane activity. For example, could preserved wood from sites such as Los Buchillones contain isotopic evidence of past hurricane strikes, in much the same way speleothems (Frappier et al. 2014) and tree rings (Miller et al. 2006) do? Is it possible for shells from coastal middens to provide very high-resolution isotopic records of past hurricane strikes (Komagoe et al. 2018)? Finally, to what extent can we learn and apply the lessons and examples of past human responses to ongoing and future hurricane mitigation in the face of climate change? This latter question is probably the most important of all, and innovative ways of incorporating traditional knowledge developed from long-term archaeological and geological perspectives should be essential for disaster management in coastal regions and a priority for the future (Cooper 2013).

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3

Navigating the Scarcity and Abundance of Monsoonal Rainfall in South Asia

Kanika Kalra

Abstract

Every June through September, the inhabitants of South Asia welcome and celebrate the southwest monsoons. The monsoons are the lifeline of the region but also are a major threat, inspiring societies to devise mechanisms to both harness their potential and subvert the damage they cause. This chapter analyzes prehistoric and historical responses to the unpredictable aspects of monsoons, with special attention to the societal contexts of rurality and urbanity and how conserving seasonal rainwater is crucial to sustenance but that an excess of that water can cause significant destruction. Poets of the past and the present allude to the vagaries of the monsoons, reflecting a social consciousness of monsoonal deceits. Even today, it is nearly impossible to predict the onset, amplitude, and specific location of monsoon rain, illustrating the agency of these abundant seasonal rains.

Rainfall is fundamental to the circulation and recharging of the freshwater surface reserves that have sustained humans for as long as we have existed, and it is almost magical to watch the rain fall from the skies, moisten the earth, and nourish myriad life forms. Archaeological and historical evidence attests to ancient societies' understanding of annual rainfall patterns and how water flowed across the landscape. This knowledge helped them successfully manage rainwater both for increased agricultural production and for mitigating the effects of flooding on settlements (e.g., Fletcher et al. 2008; Harrower 2016; Marcus and Stanish 2006).

https://doi.org/10.5876/9781646423521.c003

Annual and seasonal variability in rainfall patterns continues to present a challenge to human endeavors for sustainable modern societies (e.g., Cook et al. 2010; Mishra et al. 2012), given that even today, farmers in about half of the world still depend on rains or other forms of precipitation (FAO 2016).

The term *monsoon*, from the Arabic *mausim*, refers to seasonal reversal of wind direction due to differential temperature and pressure that results in significant rainfall in large parts of tropical and subtropical climatic regions of the Earth (Krishnamurti 2019; Roy 2017). Monsoons are usually classified into regional systems such as Asian, African, and American; other regions, such as large parts of Europe and the southeastern United States, also receive pronounced seasonal rainfall that structures the agricultural rhythm of these regions. The South Asian monsoon system is one of the most prominent regional monsoon systems not only because of the duration and intensity of these winds but also because of the sheer percentage of the world population that depends on them. Most parts of India receive 75 to 80 percent of their annual precipitation during the southwest monsoon, which usually hits the western coast of India by the first week of June each year and covers the entire subcontinent with moisture-laden clouds within about a month. Areas in the far south and southeast of India, however, receive most of their share of rainfall during the cooler months, from November to December, through the retreating monsoons.

The monsoon breathes life into the subcontinent—it irrigates the fields, replenishes the aquifers, and feeds the rivers; it also causes seasonal flooding of the kind that is both welcome and worrisome (e.g., Smith and Mohanty 2018). One of the earliest testimonies to rain's centrality to life and society in the Indian subcontinent can be found in the *Rig Veda*, parts of which were composed between 1400 and 1000 BCE (Jamison and Brereton 2014:5). The *Rig Veda* is a compilation of hymns dedicated to animistic deities, including one invoking Parjanya, the thunder god, the rain bearer:

> Address the powerful one with these hymns. Praise Parjanya. With reverence seek to entice him here.
>
> . . .
>
> Like a charioteer lashing out at his horses with a whip, he reveals his rain-bearing messengers.
>
> . . .
>
> (Parjanya,) come nearby with this thundering, pouring down the waters as the lord, our father.
>
> Roar! Thunder! Set an embryo! Fly around with your water-bearing chariot.

> Drag the water-skin unleashed, facing downward. Let uplands and lowlands become alike.
> The great bucket—turn it up, pour it down. Let the brooks, unleashed, flow forward.
> Inundate Heaven and Earth with ghee. Let there be a good watering hole for the prized cows.
> When, o Parjanya, constantly roaring, thundering you smash those who do ill,
> all of this here, whatever is on the earth, rejoices in response.
> You have rained rain: (now) hold it back.
>
> (*Rig Veda* V.83, in Jamison and Brereton 2014:765–766)

The hymn implores the thunder god for rain, which is equated with abundance and richness—"inundate Heaven and Earth with ghee"—especially since a society that thrived on pastoralism also valued lush pasturelands and watering holes. Archaeological evidence attests that agriculture began in different parts of the Indian subcontinent between the seventh and first millennia BCE and also depended on the monsoon (e.g., Fuller et al. 2007; Harvey 2007; Singh 1996; Tewari et al. 2006). By about 3,500 years ago, the Indian subcontinent was dotted with communities with varying degrees of subsistence dependence on agriculture and pastoralism that was, in turn, dependent on seasonal rains. This would explain why rain is celebrated for infusing earth with fertility, not only in this particular hymn but in many others and in association with other Rig Vedic deities such as Indra, the lord of war and storm. Nevertheless, for contemporary societies, the desire for rain paralleled the fear of excess rain. This likely explains why the Parjanya hymn urges the deity to practice restraint after it has rained sufficiently.

Variability in rainfall across both time and space is a key feature of the monsoon. It has always been difficult, if not impossible, to predict how much rain a specific year will bring, how much rain a region in the Indian subcontinent will experience in a year, or whether one year of drought will be followed by another (Webster et al. 1998). Notions of "averages" belie the challenges of amplitude in any particular monsoon season: while the average rainfall in a particular year may fall within the normal range, if all of the rain falls within a short time span, it will likely result in erosion and flooding, which is detrimental to both rural and urban life (Gadgil and Gadgil 2006). The predicament of rainfall has been characterized by Naomi Miller (2011:310) as "predictable unpredictability," but monsoons have a particular cyclical intensity in regions in which there are few alternative sources of surface water such as rivers. Consecutive years of monsoon deficit can lead to loss of life due to lack of potable water, to scarcity of supply or inflation of prices of agricultural produce, and to follow-on effects in which failed crops adversely impact the market for consumer goods.

An appraisal of how ancient societies dealt with the inter-annual variability of the monsoon can serve two purposes: first, to know how societies either succumbed to or built resilience to seasonal rainfall variability, and second, to comprehend the range of human-environment interactions. In addition to the monsoon, people in South Asia also harnessed rivers, aquifers, and springs, especially during dry months or years of drought, in ways that complemented—but never superceded—their dependence on rainfall.

THE NORTHWESTERN SUBCONTINENT IN THE HARAPPAN (INDUS) PERIOD

The oldest urban society in the Indian subcontinent, the Harappan civilization (ca. 3300–1500 BCE), provides a useful case study for understanding the nuances of human-environment interaction in a topographically and climatically diverse region of South Asia. Evidence for the Harappan civilization is found in Afghanistan, Pakistan, and India—primarily in what can be characterized as semiarid regions based on the amount of rainfall received. While Harappan cultural integration is conspicuous in the material culture of these cities—such as brick size ratios, weights, measures, beads, seals and script, ceramics, and settlement layout—certain distinct regional cultural and consumption patterns are also discernible, indicating the diverse nature of the Harappan cultural fabric (Chase 2014a). The Harappans developed complex social and economic systems, with extended trade networks that linked their cities with regions as far away as Mesopotamia and Egypt (Kenoyer et al. 2013; Lahiri 1992; Ratnagar 2004). A high degree of craft specialization and standardization is a hallmark of the Harappan assemblage, which would have been impossible without a reliable subsistence base.

The location and distribution of Harappan settlements suggest that climatic and geographic considerations likely informed the shift of preceding Neolithic settlements eastward to the Indus and the Ghagghar-Hakra. Most pre-Harappan and Early Harappan (ca. 3300–2600 BCE) settlements are located in western Pakistan, where winter precipitation from the Western Disturbances plays just as important a role as the summer monsoons (Spate and Learmonth 2017 [1954]:46–71). The Western Disturbances are extra-tropical storms that are part of the Westerlies rising over the Mediterranean and traveling across West Asia; they bring rainfall to the northwestern parts of South Asia, particularly northern and western Pakistan and northern India, as well as significant snow to the Himalayas (Dimri et al. 2015). The melting ice in spring feeds the rivers and rivulets, which continue to be critical for the sustenance of agrarian and pastoral societies in the region. This region also falls along the edges of the Inter-tropical Convergence Zone (ITCZ), which shifts north from the Equator during summer months, bringing significant monsoonal rainfall to parts of northern Pakistan but only marginal rainfall in south and southwestern Pakistan. The Harappans, therefore, utilized both the summer and the winter rainfall in the semiarid landscapes of the northwestern Indian subcontinent.

Most urban centers of the Mature Harappan era (ca. 2600–1900 BCE) are located along the Indus and Ghagghar-Hakra Rivers. These perennial rivers emerge from Himalaya glaciers and are fed by monsoonal rain, a combination of inputs that resulted in spring-summer flooding that required agriculturalists and urban dwellers alike to construct labor-intensive water management infrastructure. The two archetypal sites of Mohenjo-Daro and Harappa were built in the vicinity of rivers to fulfill people's water needs; however, the seasonal vagaries of these same rivers prompted the Harappans to settle on topographically higher surfaces or on top of platforms constructed to raise their residences above the immediate surroundings. At Mohenjo-Daro, a large number of wells provided urban inhabitants with their daily water needs; most of the wells were lined with bricks to prevent the earth from collapsing and the loss of water from absorption (Jansen 1989). These wells were constructed as part of residential quarters associated with platforms and drains, suggesting their use in what appear to be bathrooms and kitchens. In some of the other large cities of the Mature Harappan era, such as Harappa, Ganweriwala, and Rakhigarhi, remains of wells are not as ubiquitous; it appears that people there harnessed the rivers and seasonal rivulets along which the cities were established for personal and agricultural use.

The Harappans devised multiple ways of managing water in response to the local hydroclimatic conditions of the diverse landscape they inhabited—from constructing earthen bunds to capture floodwaters in the floodplains of perennial and seasonal rivers to digging wells and carving out cisterns or tanks to store surface runoff for long-term use. Shereen Ratnagar (1986) argues that the Harappans instituted labor-intensive means of irrigation to produce agricultural surplus sufficient to support large cities in a high-gradient landscape with large, capricious rivers that were difficult to control. Unfortunately, material evidence of large-scale, labor-intensive irrigation has not been archaeologically recovered; this can be attributed to the changing topography of the Indus floodplain since the time of the Harappans, as well as to the anthropogenic alteration of the landscape for modern construction and agricultural projects.

In the absence of direct archaeological remains of irrigation technologies, archaeobotanical studies help us reconstruct the dietary patterns of the Harappans as well as probable agricultural and irrigation practices. Cultivation of the various subsistence and commercial crops in the vastly different terrains and climatic zones of the Harappan realm necessitated devising adaptive strategies in response to local/regional climate (Petrie and Bates 2017) and socioeconomic needs (Miller 2006). Faunal and palaeobotanical remains from Harappan sites in western India indicate that the inhabitants expanded their subsistence strategies to include winter crops of wheat and barley as well as summer crops of millets and pulses, with a heavy reliance on the latter given that the region receives much less winter precipitation than summer precipitation (Costantini 1990; Fuller and Madella 2001; Kajale 1996; Meadow 1989; Weber et al. 2010, 2011). People also complemented their plant-based diet with a variety of animals, such as cattle, buffalo, goat, and sheep (Chakraborty et al. 2018; Chase 2014b; Goyal 2013; Goyal et al. 2013; Saraswat and Pokharia 2002, 2003).

The Harappans also established a reliable system of exchange across their network of sites spread over the Indus plains and beyond, which may have been used to transport food grains or the knowledge and technology to grow them. Ratnagar (1986:153), however, doubts that large cities were fed primarily through grain imports. Pending further research into palaeobotanical remains from urban as well as rural Harappan sites, it can be asserted that the eastward movement of the Harappans allowed them to connect with agricultural and agro-pastoral communities in northern, western, and central parts of India, which provided access to summer crops such as rice and millets and their incorporation into the Harappan diet. This movement was likely motivated by an increasing demand for agricultural production as well as relatively wet climatic conditions in northwestern India that intensified around 5.0–4.4 kya BP, providing the context for the establishment of major Harappan cities (Dixit et al. 2018).

Among the Harappan sites in India, Dholavira emerged as a truly exceptional locale, with the characteristic features of a Harappan city manifest in its layout and the artifact assemblage (Bisht 2007b). It spans more than fifty hectares, with about 20 percent of the area devoted to conserving and storing water (Bisht 2007a: 9). Dholavira, like other Harappan sites in the Gujarat region, receives most of its rainfall during the summer monsoons, but a heavy reliance on wells was precluded by the high salinity of its subsurface water. The people at Dholavira developed an intricate water management system by building embankments to divert monsoonal streams into a series of interconnected rock-cut cisterns for year-long use (Bisht 2002, 2003, 2004). The primary role of the reservoirs at Dholavira was likely to serve the urban core, although small-scale wet farming may have been practiced within or around the fortified settlement.

The water-aware constructions of the Indus culture allowed for a thriving economy for nearly a millennium, but by ca. 1900 BCE the Indus cities and many smaller sites became depopulated. Interestingly, while the growth and maintenance of Indus cities have not often been linked to environment, with the exception of Gurdip Singh and colleagues (1990), their decline has (Misra 1984; cf. Possehl 1997). Desertion of cities has been attributed to a number of natural factors: flooding of the Indus, as gauged from silt layers found in excavations at Mohenjo-Daro (Raikes and Dales 1977, 1986); changing course of the River Yamuna, causing floods, such as at Kalibangan (Raikes 1968); changing course or drying up of the Ghaggar-Hakra River, which resulted in the desertion of Harappan sites in Cholistan (Mughal 1990); and a change in summer and winter precipitation, causing arid climatic conditions in western and northwestern India (Singh 1971; see also Sarkar et al. 2016; Wright et al. 2008).

Palynological and palaeobotanical studies reconstructing the nuances of human-environment interaction in the context of Holocene rainfall variability and related extreme climatic events are contributing to the discussion of Harappan adaptations to changing environment that may have led to de-urbanization in the Greater Indus region between ca. 2000 and 1500 BCE. At a number of Late Harappan sites in western India, for instance, the Harappans increasingly preferred drought-resistant crops, such as sorghum, and other millets, over staples like wheat (Chanchala 1994; Ghosh and Lal 1963; Reddy 1997; Goyal et al. 2013; Weber 1991). Some argue that these changes are indicative of adaptation in response to a significant drop in monsoonal precipitation (Pokharia et al. 2011; Giosan et al. 2012; Goyal et al. 2013).

Not all Harappan areas experienced the same intensity of arid conditions; in fact, there are places where there was an increase in annual precipitation (Kenoyer 1991; Weber 1992). In fact, Steven A. Weber (1991) established that millets had been part of the Harappan food culture since its earliest days and that they were especially prominent at sites in Haryana, Gujarat, and Baluchistan (see also Pokharia et al. 2014). Rice, which relied heavily on the success of the southwest monsoon, became an important component of the Harappan diet only in the Late Harappan period (Weber 1992; Kenoyer 1998). Plant remains from Harappa and Rojdi, Weber (1999) argues, suggest shifts in cereal use that related to broadening the subsistence base and intensifying agriculture but had little to do with environmental change. At Harappa, barley was the dominant grain in both the early and late levels, while wheat was the preferred grain during the Mature Harappan era. Similarly, at Rojdi, millets continued to be important in both Mature and Late Harappan levels, although among the millets, occurrence of finger millet and little millet plummeted during the late period while foxtail millet emerged as the grain of choice (Weber 1999:822). The environmental and resource needs of the crops that replaced the other grains must have remained unchanged; therefore, it is unlikely that climate change caused the shift visible in the archaeological record. Faunal data from Kanmer reveal a diversified animal-use strategy but a reduced significance of secondary products and greater dependence on stock raising and pastoralism for subsistence in the Late

Harappan period, both of which reflect greater strain on agricultural production, probably due to a drier climate (Goyal 2013; Goyal et al. 2013).

In the last few decades, scholarly interest in monsoonal variability and change in relation to ancient human societies has paralleled the increasing literature on global climate change and human responses to it. Researchers addressing this issue for Harappan societies at both the micro- (site-level and regional) and macro- (inter-regional) scale together have agreed that there seems to have been a gradual change in subsistence strategies involving both plants and animals toward the end of the Mature Harappan era, which continued in the Late Harappan period concomitantly with de-urbanization. Rita P. Wright and her colleagues (2008) point out that around the Middle/Late Holocene, there was a change in the ratio of monsoonal to non-monsoonal rain in the Indus floodplain, which parallels the abandoning of Harappan cities and a shift of settlements in the Late Harappan phase to the eastern, wetter areas of the Upper Ganga-Yamuna River system. This assertion has been challenged, at least in the eastern areas, by other scholars (Madella and Fuller 2006; Petrie et al. 2017), who argue that the Harappans were master adapters and can provide insight into how an ancient civilization coped with climate change. It can even be argued that Harappans gradually shifted to the agricultural practice of cultivating in both the summer and winter seasons, which reduced their vulnerability in case of variable hydroclimatic events, particularly at the sites east and south of the Harappan core (Weber 1999). But a number of other recent studies suggest a strong correlation between extreme monsoonal variability and the end of India's first urbanism, accompanied by higher densities of smaller settlements in the Gangetic plains (Dixit et al. 2018; Green and Petrie 2018; Kathayat et al. 2017).

PENINSULAR INDIA IN THE EARLY HISTORIC PERIOD

In peninsular India, which is devoid of perennial rivers and is characterized by higher temperatures and longer spells of dry months, the short window of receiving most of the annual rainfall creates a special incentive for people living in its arid and semiarid zones to capture and conserve water from the monsoons. The region's rugged and undulating topography has made it possible for people to devise multiple ways of saving surface runoff from the monsoons for use over dry months. In addition, harnessing water from streams and rivers, digging wells, and constructing small farm ponds are common water-procuring strategies across the Indian subcontinent. Scholars have established that the earliest human settlements in peninsular India depended on water collected in natural depressions and rock pools whose capacities they augmented over time (Boivin et al. 2002). In some parts of India, such as eastern India and the middle Ganga plains, monsoon showers tend to create a situation of excess water, resulting in widespread floods in areas that over time have come to be densely populated. The diverse hydroclimatic conditions across India and within a region during any particular year of monsoons prompted people to engineer more than one way of tackling both the excess and the deficit of summer rainfall. With this understanding of the general trends in seasonal and inter-annual climatic variability, people were able to practice extensive and intensive agriculture, which sustained a wave of urbanism in northern and central India in the first millennium BCE.

Inscriptions and the remains of monumental waterworks that survived through the centuries have informed our understanding of how people managed both perennial and seasonal water. We come across rulers repairing canals, cisterns, and embankments or dams after damage from extreme hydroclimatic events, primarily through inscriptions from Bhubaneswar in eastern India (Kharavela's first-century BCE inscription; Sahu 1984) and Junagarh in western India (Rudradaman's second-century CE inscription and Skandagupta's fifth-century CE inscription; Fleet 1888). In fact, the inscriptions at Junagarh include vivid descriptions of the excess rain during the monsoon season ("the season of clouds" [Fleet 1888:63]), which led to the swelling of the river, causing the ancient dam to breach. Some have argued that this dam was not entirely artificial and that parts of it incorporated a natural escarpment (Shaw and Sutcliffe 2003:90). At both instances of dam breach, rulers, local officials, and elites arranged for the dam to be repaired, since the dam and the associated lake (Sudarshana Lake) were crucial to the sustenance and prosperity of the city—not only during the dry months of the year but also during years of drought. These inscriptions, like the many remains of damaged and abandoned embankments, are a testimony to the damage severe monsoonal rains could cause on resource-intensive water infrastructure.

State-sponsored or supported water projects continued from these early to modern times, but we also find instances of individual or collective action to conserve surface runoff, especially in the context of religious institutions. For instance, at the Buddhist monastic establishment at Kanheri in western India (Ray 1994), we find a large number of rock-cut cisterns located outside residential caves. The water for these cisterns was collected through narrow channels dug into the basalt hill surface that carried the surface runoff from more elevated areas to the cisterns (figure 3.1). During the monsoon season, a steady stream flows through the hills with caves on either side. It is likely that the monks and visitors augmented the water supply from the cisterns with the stream during the rainy season but depended largely on the cisterns during the dry months of the year. This system of conserving rainwater provided water for everyday use by the monks residing at the caves in Kanheri and the devotees who visited the site. In fact, a number of these cisterns were donations

Figure 3.1. Example of a water cistern attached to a monastic cave at Kanheri, western India. Water from the surface is directed to the cistern through a channel dug into the rock of the hill (the niche above the cistern is about 1.7 m high). Author photograph.

from lay followers, according to the inscriptions that are usually associated with the cisterns (Gokhale 1991). Similar cisterns also have been found at the Early Historic monastic caves in the vicinity of the ancient dam at Junagarh (Shaw and Sutcliffe 2003:92–95), illustrating a widespread multi-scalar approach to water capture. Buddhist institutions also played an active role in constructing, maintaining, and managing agricultural irrigation works, as seen at the site of Sanchi (third century BCE–twelfth century CE; Shaw and Sutcliffe 2003). The engineering consisted primarily of an earthen embankment constructed across a valley to collect surface runoff from the elevated areas in the valley (catchment area) and to store this water for irrigation purposes during the dry months.

People in Early Historic South Asia addressed rainfall variability not only with irrigation technologies but also through spatial and administrative organization. At the ancient city of Sisupalgarh in the Odisha province of eastern India, for example, people built a city with high ramparts and gates and with monumental architecture starting around the sixth century BCE. Monica L. Smith and Rabindra K. Mohanty (2018) illustrate the subsistence strategies of urban-rural labor and trade involved at every step of agriculture in which monsoons facilitated abundant rice cultivation while also presenting the challenge of "too much" water during seasonal rainfall and cyclonic storms. Since the timing of agricultural tasks such as field preparation, construction of field bunds, transplantation of rice, pest management, weeding, and harvest depended on the intensity, duration, and frequency of rainfall in any given year, it was important that the fields were located within walking distance from the city so that urban labor could easily redirect itself during specific times in the agricultural cycle. Predictable flood events would have easily been managed by this flexibility of labor flow; at times of extreme climatic events, such as cyclones, cities like Sisupalgarh relied on their existing medium- and long-distance trade networks that hitherto circulated non-agricultural goods to provision food for city dwellers from variable landscapes (Smith and Mohanty 2018:1329–1330).

PENINSULAR INDIA IN THE MEDIEVAL PERIOD

By the thirteenth century CE, polities with large territories emerged in the western and southern subcontinent, concomitant with shifts in agricultural practices that had a far-reaching impact on the economy, the polity, and society. Inscriptions indicate a process of agricultural expansion through irrigation technology rather than through intensification proper (cf. Morrison 1994:142) from the sixth to the twelfth centuries CE. In addition to rulers and elites, temples were significant in organizing the creation and distribution of agricultural surplus. More significant than construction perhaps was maintenance of the structures that were already built. Ruling elites, prosperous individuals, and local assemblies all contributed to this task (Mate 1998:35–51). Regional monarchies integrated the countryside into their political and economic networks, sometimes making investments indirectly through local temples, which then undertook the actual construction and management (e.g., Stein 1960).

People's responses to topographic, climatic, soil, and ecological variability across the Indian subcontinent during the medieval period involved increased reliance on iron technology in agriculture, use of manure, and hydraulic infrastructure (Chakravarti 2008) while existing technologies of rainwater management such as embankments, dams, and reservoirs continued in use. Historical and archaeological research shows that the reservoirs of this period were considerably larger than those from earlier times and were a function of expanding and intensifying agriculture and also of the introduction of new cultigens in these areas based on cultural dietary preferences increasingly focused on rice (Bauer and Morrison 2008; Morrison 1995; Smith 2006). A typical rain-fed reservoir in peninsular India in medieval times operated on the same principle as the ones discussed in the context of Sanchi earlier in this chapter. Surface runoff from a catchment area such as a valley was collected behind earthen embankments sometimes dressed with stone.

Some embankments form part of a series of connected reservoirs; the waste weir or spillway of the upstream reservoir allows excess water to flow out and fill the one downstream.

Embankments stored seasonal water and made it accessible for personal consumption, such as for cleaning and washing, while also recharging subsurface water levels and keeping the adjacent soil moist. A reservoir as an embankment with one or more sluice gates and canals, in contrast, was able to make an impact on the wider landscape by transporting water to distant fields compared to more static percolation tanks. These reservoirs represent a more complex social phenomenon because of the need for consensus on issues such as the height of the embankment and the waste weir, the number and placement of sluice gates, the maintenance of the reservoir, and the terms and conditions of water use. The heights of the embankment and the waste weir dictate the capacity of the reservoir; a higher capacity demands that a larger area of arable land behind the embankment be inundated with water for part of a year, putting it out of use for those months. Building reservoirs is a labor-intensive exercise; while there is no direct evidence regarding labor acquisition, conditions, and organization, social scientists suggest that coercive labor may have played a significant role in such construction projects (Shah 2008).

Within peninsular India, three case studies—Tamil Nadu, Vijayanagara, and the Raichur Doab—provide insight into the ways people actively managed monsoonal rains through a proliferation of reservoir construction beginning around the sixth century CE. Inscriptions show that in this period, people intensified agriculture by expanding irrigation to new areas, facilitating and facilitated by the rise of regional polities and cultures (Singh 1994; Talbot 2001; Kapur 2002). Most of these inscriptions, written in Sanskrit, record royal land grants to Brahmanas (the highest social caste and religious functionaries) or non-royal and royal gifts made to different religious establishments.

Tamil Nadu

Tamil Nadu, the southeastern-most state in modern India, is a coastal region with a dry hinterland that receives a significant portion of its annual rainfall from the northeastern monsoons in the months of November and December. Yanni Gunnell and colleagues (2007) studied the response to northeast monsoon rainfall variability in South India over the last 2,000 years, arguing that fluctuations in that monsoon led societies to either scale up or scale down the construction and renovation of reservoirs. For instance, to moderate flash floods and mitigate drought hazards, people constructed large reservoirs that proved highly efficient during such extreme events (Gunnell et al. 2007:210). The Medieval Warm Period (ca. tenth–fourteenth centuries CE) and the Little Ice Age (ca. sixteenth–nineteenth centuries CE) global climatic phenomena further impacted the southwest monsoon by creating wetter and drier summer seasons, respectively, which, in turn, caused corresponding fluctuations in the northeast monsoonal rainfall. Despite these opposite trends in rainfall variability, in both cases researchers found that societies responded in similar ways: by constructing and repairing or renovating reservoirs.

Gunnell and others identify three periods of increased reservoir construction in the region. The first period of increased reservoir construction was during the late Pallava and early Chalukya dynasties (300–900 CE), when the southwest monsoon was weak and there was less cyclonic activity in the Bay of Bengal. This prompted enhanced conservation practices by rulers and state functionaries; for example, the Pallava rulers of South India directly constructed dams and also gave donations of land and money for that same purpose (Mate 1998:42). Mahendravarman I, a seventh-century ruler in Tamil Nadu, constructed a reservoir for public use, but this royal act is matched by examples of private individuals who bought land for the construction of embankments and reservoirs (42). The second construction episode was between the tenth and fourteenth centuries, when there was an influx of socially high-ranking Brahmins from northern India that coincided with the increased precipitation of the Medieval Warm Period and the desire of the stable Chalukya and Hoysala dynasties to develop their states' semiarid interiors. The third episode was at the beginning of the Little Ice Age, when the northeast monsoon weakened; yet people constructed large reservoirs and renovated old ones because of increased stress on available water resources and a deep-seated belief in the advantages of traditional reservoir construction (Gunnell et al. 2007:213). What is significant here is that when confronted with variations in rainfall of either kind, people resorted to labor-intensive solutions through periods of both high and low rainfall.

Vijayanagara

The city of Vijayanagara, capital of the Vijayanagara Empire (fourteenth–seventeenth centuries CE), is situated along the southern banks of the Tungabhadra River in the present-day Indian state of Karnataka. Its urban and agricultural water requirements were met by utilizing the Tungabhadra River and by a dependence on monsoon rainfall. The urban center had a densely populated and constructed core surrounded by agricultural hinterland, where the scale of investment in water infrastructure was both monumental and diverse. A number of anicuts or embankments were built across the Tungabhadra River that helped divert water to adjacent fields through a system of canals and small reservoirs. In addition, aqueducts were built to carry water over large distances across valleys and canals to specific places in the urban core. In the immediate rural hinterland of the city, however, reservoirs dominated the irrigation arrangements to intensify agricultural production.

Kathleen D. Morrison (1995) has traced the process of agricultural intensification in the Vijayanagara Empire using three independent sources: textual material (including inscriptions on boulders, slabs, and copper plates, as well as European travel accounts), archaeological data from surface survey, and pollen analysis. In the Early Vijayanagara period (late fourteenth century), there was a sharp increase in settlement in the core area of the empire, along with an increase in grass pollen and construction of irrigation facilities such as canals, reservoirs, and sluice gates. These trends continued but with reduced monumental construction in the core area during the Middle Vijayanagara period (fifteenth century). Another wave of large-scale investment in irrigation systems and monumental architecture is visible in the Late Vijayanagara period (sixteenth century) when there is a phenomenal increase in grass pollens. Morrison (2009) also notes that some of the reservoirs and related infrastructure constructed by the Vijayanagara rulers in the Vijayanagara metropolitan area fell out of use and maintenance after the dynasty declined in the mid-sixteenth century. The Vijayanagara reservoirs, Morrison (2009) argued, were deemed significant in more ways than one—as monuments, (eternal) oceans, temples, technological devices, and expressions of elite power and influence—and one or more of these meanings outlived the reservoir's use-life. These structures still exist in the landscape and have become incorporated into its modern uses as a form of landesque (or landscape) capital whose physicality provides the starting point for new agricultural regimes (cf. Blaikie and Brookfield 1987; Morrison 2014).

The Raichur Doab

The Raichur Doab is the region located between the Krishna and Tungabhadra Rivers in the northeastern portion of the Indian state of Karnataka, where I conducted fieldwork for the study of medieval water management practices. Both rivers have low water-carrying capacity and flow momentum. Raichur receives about 70–80 percent of its annual precipitation of 600 mm to 715 mm during the southwest monsoons—a span of three months (*Mysore State Gazetteer* 1966:28; *Climatological Atlas of India* 1981). The short rainy season creates a high incentive to conserve surface runoff from the monsoons, but there can be significant differences in water availability from those monsoons on a year-to-year basis. Figure 3.2 demonstrates this variability in surface water as well as vegetation (bright areas) in this region in the years 2001 and 2003. Interestingly, the decreased size of water

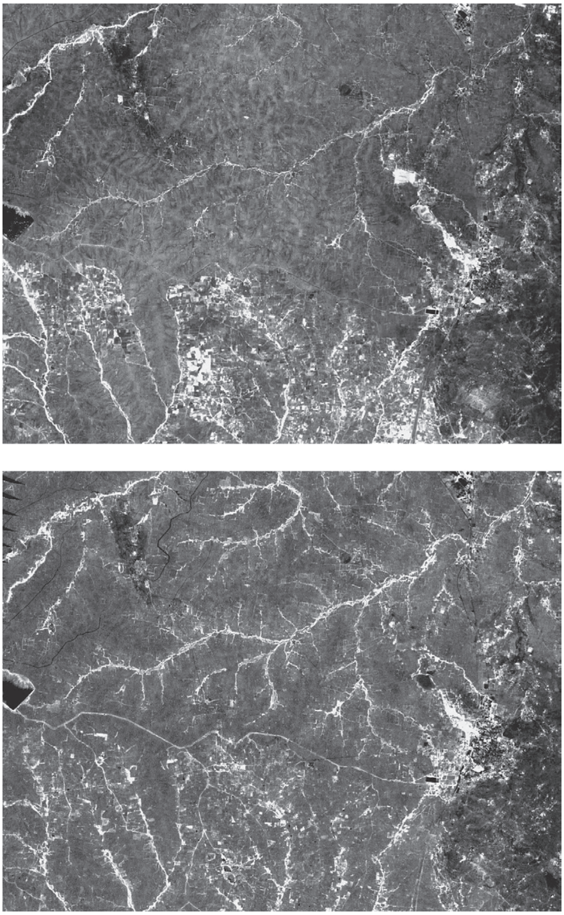

Figure 3.2. Normalized Difference Vegetation Index (NDVI) of Landsat7 image of Raichur taken on May 6, 2001 (top), and May 28, 2003 (bottom), showing differential surface water during the annual dry season in two separate years. Brighter areas on the image indicate vegetal growth. The images cover an area of about 35 × 25 km^2.

reservoirs in 2003 is concomitant with increased vegetal growth in canals and other conduits of water from the reservoirs to the fields downstream, suggesting lower investment in maintenance during years of low rainfall.

I examined two sites in the Raichur Doab—Gabbur and Maliabad—to understand the micro-topographic and localized responses to the abundance of monsoonal rain. Gabbur today appears to be like any other village in the region, but inscriptions from the eleventh century indicate that at that time it was a village donated to religious functionaries, or the Brahmins, and was thus a *brahmadeya* or *agrahara* settlement. Gabbur is replete with temple remains, most of which are located within the village boundary and are constructed along a street that connects the village's largest water body (Elu Bavi) in the south to its northern entrance

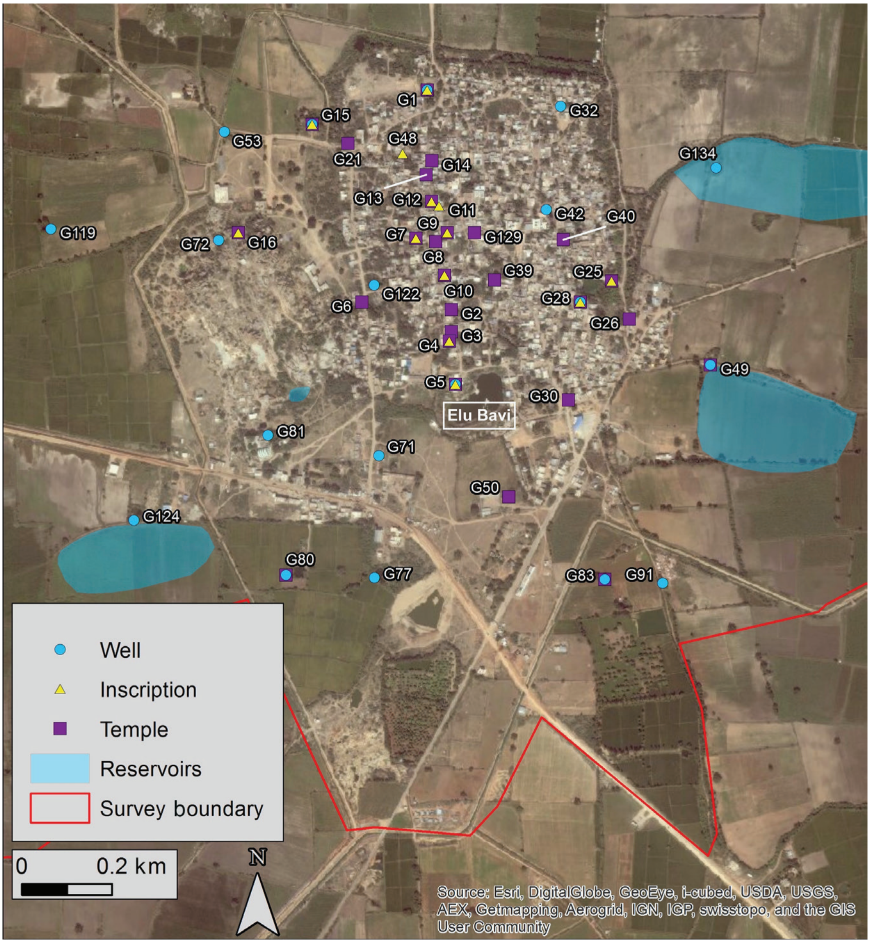

Figure 3.3. Map of temples, inscriptions, wells, and reservoirs in and around Gabbur. The water management feature known as Elu Bavi ("Seven Well") is roughly in the center of the map, within the southern wall of Gabbur village.

(figure 3.3). Elu Bavi ("Seven Well") measures 138 m in length with a maximum width of about 90 m and is located at one of the village's lowest topographic points (figure 3.4). This and other constructed water bodies at Gabbur are almost always found associated with temples and inscriptions from the twelfth century. In addition, water-retention features such as reservoirs and water-diversion features such as embankments were constructed in the surrounding agricultural lands. The wells, reservoirs, and embankments follow not one but a number of different plans, constructed in a variety of sizes using a variety of materials, suggesting a continual

Figure 3.4. Gabbur water management feature known as Elu Bavi ("Seven Well"), west side. Author photograph.

investment that varied according to the residents' perceived needs and construction capacity.

Gabbur's prominence in the sociopolitical landscape was augmented when at some point in its medieval history it acquired a fortification wall around it. This wall, which also enclosed the Elu Bavi, is now damaged at most places, although its rectilinear bastions and gateways are still present. While most of the temples from the survey area were recorded inside the walled area of Gabbur, others were spread out in the agricultural areas outside the village and beyond the walled confines. The human-modified topography of the region includes what appears to be a moat on the exterior of the wall that still collects water during the rainy season; the observation of a purposeful engineering effort to capture water as part of the fortification process is substantiated by a fragmentary inscription from a Gabbur temple complex in the second half of the twelfth century (ca. 1171 CE), which mentions gifts to a certain deity consecrated in the *nirakote* (literally, "water fort") of that locality. The concept of "landesque capital" as a physical modification inherited by subsequent generations is also seen along the western and northwestern edges of Elu Bavi, as if those walls were initially constructed as fortification with bastions but were later incorporated to form the edges of a water body (see figure 3.4).

While the nature of settlement and water resources in Gabbur have changed over the last 800 years, the presence of a number of temples and donative inscriptions

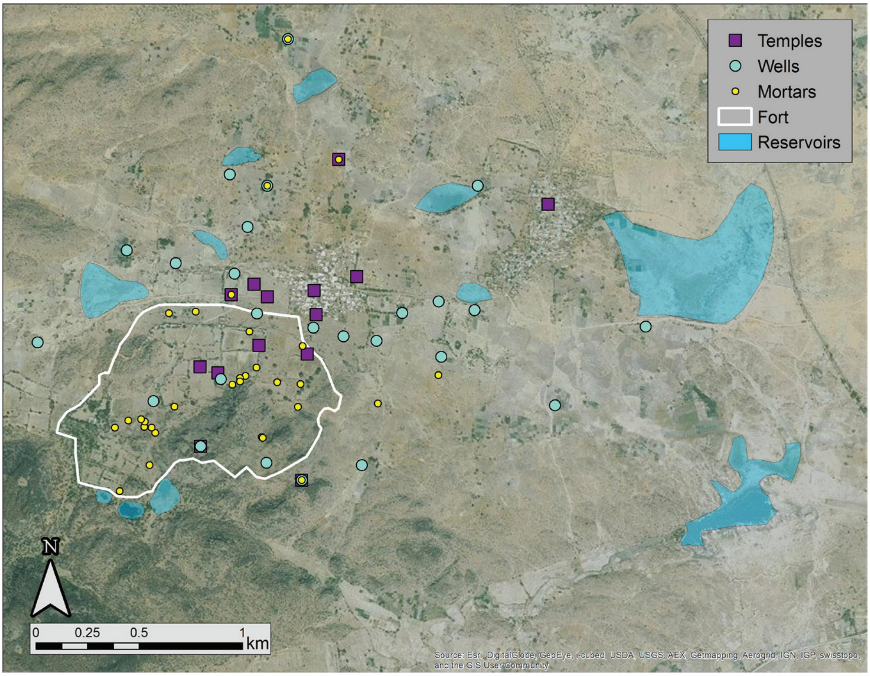

Figure 3.5. Map of temples, wells, and water features in the survey area at Maliabad

in the village provides a material link to its past. The largest reservoir in this area is located about 4 km northwest of Gabbur, with a 1.5 km-long embankment. A reservoir of this size had the potential to irrigate fields throughout the year—even if it was a year of drought—depending on the crop type, crops per year, and area irrigated. At the same time, the diversity of embankments and wells in and around Gabbur asserts the significance of small catchment areas in sustaining Gabbur's settlement and agriculture from an early date of settlement, although ongoing practices have changed water access (for example, our survey revealed that residents had filled in some of the old wells because of the large numbers of snakes present in their vicinity).

The second site of archaeological investigation, Maliabad, is about thirty-five km southwest of Gabbur and can be dated architecturally to around the twelfth century CE, with a fort that was subsequently constructed in the thirteenth and fourteenth centuries. Maliabad is surrounded by hills that constitute naturally occurring catchment areas, and the archaeological evidence from Maliabad reveals the subsequent attempts made by elites, both local and regional, to intensify agricultural production through the construction of wells, cisterns, reservoirs, and embankments along with ancillary water management features such as silt traps and percolation basins.

This practical infrastructure was interwoven, as it was elsewhere in India, with ritual constructions (figure 3.5). Agricultural fields are dotted with temples and dozens of stone memorial markers with the iconography of people (including *sati* stones and hero stones) and the iconography of snakes (so-called *naga* stones that attest to the local preoccupation with snakes). Temple architecture at Maliabad suggests that they were the first constructions in the area along with wells, followed later by the construction of the reservoirs and the fort.

The archaeological survey identified two phases of intensive architectural activity at Maliabad. The first phase lasted from about the eleventh century to the thirteenth century and involved resource-intensive and labor-intensive construction of temples and their associated wells. The second phase, beginning about the fourteenth century and lasting until the sixteenth century, was when the fortification walls of Maliabad were raised. The two largest reservoirs at Maliabad are situated east of the fort and are still in use. They seem to have been constructed after the temples had fallen out of use, and the masonry of one of the embankments displays fragments of temple architecture that were (re)used in its construction. One of the reservoirs has an elaborate stone embankment with distinct quarry marks identical to those found on stones used to build the fort walls. It is likely, therefore, that the reservoirs were constructed at the same time as or after the fortification. These two reservoirs are less than a kilometer apart and seem to have been built to increase the amount of runoff conserved from the wide catchment area. Much like reservoirs elsewhere in the region, the excess water from the reservoir upstream was directed to fill the reservoir downstream.

The only published inscription from Maliabad, a *qaulnama*, dates to the sixteenth century. It lowered the taxes paid by different occupational groups at Maliabad and discouraged excessive exploitation in the form of coercive labor (Kadiri 1964:63–65). This suggests, therefore, that the taxes were hitherto high and unrealistic and that the people of Maliabad were also expected to render services such as forced labor. The stipulated taxes can be used to imagine the complex economic hierarchies at Maliabad and possibly other town-level settlements in the sixteenth-century Raichur Doab. The grocers/sellers and weavers emerge as some of the high taxpayers, much like cultivators who controlled wealth through owning land. The fact that weavers were considered a high-income group might further suggest the growing importance of cotton—a water-intensive crop—in the agricultural sector of Maliabad around the beginning of the sixteenth century. Interregional trade networks were already well-established, experiencing intense activity by this time over both land and ocean. The inscription provides a rare window to observe just how such large-scale processes would have impacted the economy of small towns/villages such as Maliabad, distant from the littoral towns more directly engaged in long-distance trade. Attempts at agricultural intensification in Maliabad, through the construction of the reservoirs, could therefore have been a response to the growing demand for both staple crops such as millets and rice and also cash crops such as cotton for cloth and sesame for oil.

A seventeenth-century inscription from Gabbur, installed on the plinth of a temple, pardons tax on yields from dry fields (Reddy 2003:72–73). The Gabbur inscription only pardons produce from a dry field, which implies two things: that by the seventeenth century Gabbur already had irrigated fields and that irrigation agriculture was expected to give a reasonable yield. Juxtaposing this inscription with the one from Maliabad discussed above, it can be surmised that the inscriptions' tax relief proclamations were made in response to a weakened monsoon consistent with the Little Ice Age, which may have led to lower production per unit area in these frontier regions where widespread irrigation was only possible through small and medium-size reservoirs that depended on an optimum monsoon each year to be operative. In the region's semiarid, undulating landscape, reservoirs have come to play a significant role in the expansion of agriculture, enabling irrigated farming and increasing cropping seasons within a year. Reservoirs were favored over building canals, although canals played a role similar to that of Vijayanagara.

In sum, the three regional examples of Tamil Nadu, Vijayanagara, and the Raichur Doab illustrate that agricultural expansion and intensification in this part of India starting in the medieval period was heavily dependent on artificial irrigation through the construction of either reservoirs or extensive canal systems. The choice of water management infrastructure would have depended on factors such as population, socioeconomic status, and political investment—which, in turn, were partially expressed through the expansion of nearby regional political centers. For example, canals and large reservoirs were an important component of agricultural production in and around Vijayanagara, which was the seat of a far-flung empire. By contrast, smaller reservoirs were favored in the Raichur area, which was a hinterland and a frontier zone for regional polities throughout the medieval period (and to a certain extent into the present, as canals made their appearance only in the twentieth century; see Ahmad 2004 [1915]). Even within a particular region such as the Raichur Doab, there were micro-variations among sites depending on donors' ability to establish their stronghold in the local socioeconomic and political milieu. It was more likely for those with better political networks to sustain themselves through periods of crisis, whether natural or human-induced. Maliabad's temples fell into disuse and the site became depopulated, even though the reservoirs continued in use. Gabbur, in contrast, boasts of a long history of continuous settlement seen both in the continuity of temples and the continued water management strategies of reservoir and well construction over centuries.

CONCLUSION

Although individuals and households can exercise their agency through the capture of rainfall at a local scale, the coordination of efforts through centralized labor investment clearly made a significant difference in the successful long-term sustainability of agriculture and settlement life in the monsoon region of South Asia. Today, despite the technological advancements that permit the construction of massive hydroelectric dams and elaborate water-pumping capacities, the increasing reliance on water from confined aquifers to meet water requirements of commercially and culturally popular crops mean we are gradually limiting our ability to respond to climatic variability, especially in cases of a failed monsoon, given that peninsular rivers and the groundwater table are also largely monsoon fed.

The case studies from South Asia's past demonstrate the various, albeit limited, approaches people adopted when confronted with even slight variations in rainfall patterns. The variables impacting the choice of response include not only the local topography and climate but also the socioeconomic and political milieu of the respective societies. These and other variables continue to determine localized responses to monsoonal variability in South Asia today (e.g., Roxy et al. 2017). For instance, rural and urban societies share the same monsoonal landscape and yet respond differently to monsoonal excess.

The global incidence of floods and droughts seems to have increased dramatically in the last century or so. Scientific studies stand united in their verdict that humans have been the dominant agents of this change by introducing significant anomalies that have modified the temperatures of lands and oceans, with a significant impact on global and regional precipitation systems. Activities that constitute the largest share of carbon emissions include thermal electricity generation, industrial production, transportation, deforestation, cultivation of crops, and rearing livestock—activities that have continued unabated, with progressive intensity, over most of human history. Despite humans being chief actors of this change, it has been extremely challenging for scientists, governments, and people in general to eliminate or even fully mitigate the destruction and damage caused by both routine and extreme rainfall events.

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4

Earthquakes and Agency in the Roman Mediterranean

Resilience and Transformation

JORDAN PICKETT

ABSTRACT

Studies of the sociology of contemporary earthquakes have emphasized the potentialities created by these disasters: earthquake-induced destruction, while traumatic, can also clear the way for large-scale infrastructural and architectural development programs with the potential to reshape aged urban environments and better reflect changing societal values and priorities. This chapter offers a survey of earthquakes as non-human change agents in the Roman and Late Antique Mediterranean, with special focus on the cities of Pompeii, Ephesus, Antioch, and Phrygian Hierapolis. While contemporary Roman sources tend to describe urban rebuilding after earthquakes in a symbolic manner, with a generic picture of cities "rebuilt" or "restored" and state-directed support sent for finance or labor, these literary images rarely correspond with the archaeological evidence for earthquake events in Roman cities, whose records leave little that speaks to the immediate challenges of search and rescue or mortalities but which also provided opportunities for the implementation of altogether new urban schemes.

The geological forces that create earthquakes are so colossal in scale and time that they are nearly incomprehensible from the perspective of our own short human lives. Yet the extraordinary violence of earthquakes transpires in mere seconds, with effects that permanently alter societies and communities. Earthquakes have always been and remain unpredictable, despite pre-modern efforts to understand

https://doi.org/10.5876/9781646423521.c004

their origins. Seneca the Younger's *Natural Questions* (ca. CE 65) offered cautiously that we might "face this disaster bravely [because] it can neither be avoided nor foreseen," before critically considering various hypotheses for the natural causes of earthquakes offered by Greek philosophers in earlier centuries—including the movement of water, fire, earth, and air (Seneca 2010:88). Approximately seventy years later, in Han Dynasty China, Zhang Heng invented a device for detecting and measuring earthquakes that remained in use there for centuries and may have reappeared or been reinvented independently in thirteenth-century Persia (Needham 1959:624–635). In Byzantine Constantinople, Anthemios of Tralles—one of the architects of Justinian's daringly domed Hagia Sophia, completed in 537 CE but which collapsed the first time during an earthquake as soon as 558—is credited with an experiment that produced an artificial earthquake using steam power, a product of ancient interest in earthquakes' destructive potential (Agathias 1975:141).

Earthquakes are endemic to the Mediterranean—whose waters sit astride the conjuncture of Asia, Europe, and Africa—even if the theory of plate tectonics (Mallet 1862; Wegener 1928) that explains them was understood only as recently as the 1960s (Blacket et al. 1965; Le Pichon 1968; Wilson 1963, 1965). The reality that human societies have, perhaps counterintuitively, crowded settlements along continental fault lines may be related to seismicity's less appreciated and more positive consequences: namely, the elevation and depression of landmasses into mountains, islands, and basins that correlate well with biodiversity and the distribution of precious metals and building stone. The resultant hydrology encompasses both the relation of coastal montane uplift with oceanic precipitation patterns and the locations of drainage basins that provide water from rivers and lakes (Broodbank 2013:65–71). These factors together are particularly critical in the Mediterranean, where the tectonic conjunction of three continents has created conditions that both facilitated the development of human society and put it at perennial risk of seismic catastrophe (Herman et al. 2015).

Historical earthquakes can help us understand the agency of the environment in a broader global and historical framework, especially within the operational contexts of resilience and robustness or fragility, adaptation, and sustainability (Walker et al. 2004). While the scaled physical impacts of earthquakes have been quantitatively measured using the Mercalli intensity or Richter magnitude systems ever since those scales were devised in the 1930s, the localized and qualitative effects of a given earthquake depend very much on physical, social, cultural, and historical contingencies. Forms of settlement organization and architectural tradition shape background risk to seismic events. Communal cohesion and organization can affect the scale and efficacy of search and rescue or relief efforts in the immediate aftermath of an earthquake; there are also highly variable capacities of administration

Figure 4.1. The Forum at Pompeii. *Courtesy*, Flickr user labecoaves under Creative Commons license.

and private citizens who can direct funds, materiel, and labor to coordinate reconstruction and mitigation for future events in the longer term (Mordechai and Pickett 2018). Depending on the contours of these factors in any given historical or cultural context, the societal impacts of two geologically similar earthquakes—for instance, at 8.0 magnitude (along the upper range of recorded occurrences)—may vary considerably in different locations and sociocultural milieus (Özerdem and Jacoby 2006).

There are more than 200 documented occurrences of earthquakes in the ancient Roman archaeological and textual record, providing a rich opportunity to address human-nature dynamics in an ancient complex society. A fuller account of seismicity's agency in Roman society—as opposed to notions of the environment as mere passive background, in the typically Braudelian sense (Moore 2003:432)—might begin with discussion of primary sources and archaeological evidence for the infamous earthquake that struck Italy in 62 CE, devastating Naples Bay and, with it, Pompeii and Herculaneum (figure 4.1).

We have two literary accounts of the earthquake that affected the region around Naples Bay and Pompeii in 62 CE, from which Pompeii was still recovering when Vesuvius erupted just a short time later, in 79 CE. Seneca (2010:87) wrote to his friend Lucilius, in a letter later compiled into the *Natural Questions*:

> We have heard, Lucilius, excellent man, that Pompeii, the busy Campanian city, has been ruined by an earthquake, and all the neighboring areas have been badly affected.

> The coasts of Surrentum and Stabiae on the one side, and of Herculaneum on the other, meet at the city, encircling the open sea, which there retreats inland in a charming bay. This event happened during winter too, a period that our ancestors used to promise us was free from such dangers. Campania had always been nervous of this threat but had remained unharmed and had many times got over its fears; but this earthquake, occurring on February 5 [in the consulship of Regulus and Verginius], devastated all of the region and caused great destruction. For part of the town of Herculaneum collapsed too, and even what remains is standing precariously. The colony of Nuceria, though spared catastrophe, is not spared complaints. Naples, too, has lost many private buildings, though no civic ones, being only lightly affected by the vast tragedy. Country houses have collapsed or have often been shaken without damage. In addition to this, a flock of hundreds of sheep was killed, and statues were split apart; afterward some people wandered around in a state of shock and deranged.

Seneca's account of the 62 CE earthquake at Pompeii is the longest on record for this particular earthquake, though it is only the introduction to one book of the *Natural Questions*' much longer and decidedly modern consideration of the geological phenomena of earthquakes. Seneca here acknowledges the frequency of seismic activity around Naples—we know now that Naples stands on a major fault line—and he comments on the highly inconsistent, differential damage of houses ruined when public buildings were left standing. Tacitus (1931–1937:251), our only alternative literary source for this event, reports what happened there with the brevity typical of an annalist: "Pompeii, a famous town in Campania, was seriously damaged in an earthquake." Through the reports of Seneca and Tacitus, we note several salient features of Greek and Latin seismicity, although accounts of Roman earthquakes often lack details of primary seismic effects (Seneca's *Natural Questions* is actually an important exception, with his interest in phenomena such as surface faulting). Among other writers, details of catastrophic damage are sometimes only copied clichés—reports abound of whole cities destroyed or "swallowed up," for instance—yet they are nevertheless adduced by modern catalogers and scientific observers to hypothesize earthquake magnitude or epicenter, often in the absence of corroborating archaeological or scientific evidence (Guidoboni 1994). In the context of Seneca's account, for instance, much ink has been spilled in pursuit of a firm date for the Pompeii earthquake in 62 or 63 CE, though the former is now widely accepted.

Related is the matter of that earthquake's epicenter and its magnitude: Seneca's comparatively detailed account of structural damage following this earthquake, in combination with archaeological evidence (discussed below), have promoted estimates of a 5–6 Richter magnitude, considered a "moderate" seismic event in today's terms. For the simple reason that Seneca's description is quite explicit that Pompeii's buildings suffered more damage than did those at Naples or Nucera, the epicenter is usually placed somewhere in the vicinity of Pompeii near Mount Vesuvius (Cubellis and Marturano 2013; Marturano 2008). Seneca and Tacitus are also (*pace* Agathias 1975:47, 137) little concerned with the secondary and tertiary or knock-on effects of the Pompeii earthquake, such as the organization of search and rescue efforts, or with the conflagrations, epidemics, and social unrest that flared alongside sharp declines in living standards in the immediate aftermath of the disaster.

Such highly literary reports of earthquakes should be understood in the context of Roman interests in environmental phenomena and anomalies, as well as in the frequently encountered suspicion that earthquakes were portents of sociopolitical crisis or manifestations of cosmic drama and divine wrath (Waldherr 2016; Deeg 2016). For example, the *Ab Urbe Condita Libri* (Livy ca. 9 BCE) and the anonymous *Scriptores Historiae Augustae* (ca. CE 350) are replete with this style of earthquake reportage for periods of uncertainty and heightened sensitivity to catastrophe, not least during the troubles of the Roman Republic or the crises of the empire during the third century CE, respectively. During the latter period, the *Scriptores* (1932:27) tell us that "amid so many calamities of war, there was also a terrible earthquake and darkness for many days . . . The disaster was worst in the cities of Asia; but Rome, too, was shaken, and Libya as well. In many places the earth gaped open . . . and many cities were also engulfed by the sea."

The inspecificity of so many Roman earthquake reports, alongside the clichés of longer accounts, has too frequently meant that broader investigations of the social consequences of Mediterranean earthquakes have been neglected. Such factors together are critical for contemporary understandings of the nature of preexisting societal vulnerabilities to earthquakes and the recovery and rebuilding response that followed in ways we might define as *resilient*, *adaptive*, or *transformative*.

Resilience refers to specific ecological and social systems paradigms, which are commonly illustrated with the rolling ball-in-sink diagram (figure 4.2). Resilience here means "the capacity of a system to absorb disturbance and reorganize [or recover] while undergoing change so as to still retain essentially the same function, structure, identity and feedbacks" (Walker et al. 2004:5). Adaptation refers to the capacity of actors to manage resilience, providing a more robust return to the status quo ante but not changing the system itself. In contrast, transformation refers to the generation of an entirely new status quo with different ecological, cultural, or socioeconomic parameters following an event whose magnitude, in combination with existing vulnerabilities, exceeds a society's ability to return to the status quo ante. As noted in the context of earthquakes, these differences are important because earthquakes that are objectively the same on the Richter scale have different

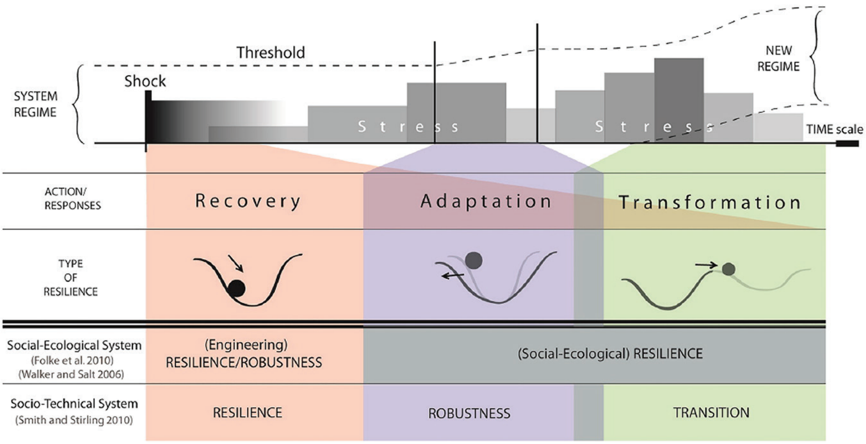


Figure 4.2. The ball-in-sink diagram of resilience. *Courtesy*, Lorenzo Chelleri. See also Chelleri et al. 2015.

effects depending on a society's existing vulnerability or precarity, its preparedness and social cohesion, and its flexibility for either adaptation or transformation: we might compare the similar magnitudes but very different sociocultural effects of modern-era earthquakes in Tokyo and Istanbul to make this point (Özerdem and Jacoby 2006).

At Pompeii, inscriptions point toward the city's *resilience*—the ability of citizenry and the state to organize and restore the city to its status quo ante—following the earthquake of 62 CE. An inscription from the Temple of Isis at Pompeii records its complete rebuilding with the resources of a local freedman: "Numerius Popidius . . . restored this building that collapsed in the earthquake from its foundations" (*Corpus Inscriptionum Latinarum* 1893). Much of the rebuilding work at Pompeii seems to have been organized locally, because decisive imperial or state-level intervention in the aftermath of the 62 CE earthquake at Pompeii is largely lacking in the historical record. There are no indications of immediate action or systemic responses taken here by the Roman emperor Nero, unlike the situation after the Great Fire of Rome in 64 CE when order was imposed on the city's streets, with restrictions on height and requirements for stone rather than timber construction, modifications to water supply for fire protection, and so on (Tacitus 1931–1937 15.43). Imperial interventions at Pompeii after the 62 CE earthquake were limited instead to the single-building restorations attested by inscriptions found at the nearby city of Herculaneum, which date rather later, during the reign of Vespasian (r. 69–79 CE) (*Corpus Inscriptionum Latinarum* 1893; *Année Epigraphique* 1979:170). Not unrelated, a Vespasianic series of boundary-stone inscriptions called *cippi* may also attest to the intervention of imperially directed bureaucrats to confirm the limits of earthquake-damaged properties around the same time (*Corpus Inscriptionum Latinarum* 1893).

Pompeii's archaeology provides an additional accounting of the city's *adaptability*, with evidence for widespread rebuilding in the critical period between 62 CE and the city's final destruction during the volcanic eruption of 79 CE (Adam 1989; Foss and Dobbins 2007). Buildings in Pompeii were to some extent, however incidentally, already built adaptively for earthquakes in symmetrical box-like fashion with limited height. Yet Pompeii also had substantial vulnerabilities. Buildings at Pompeii were typically constructed of very mixed or heterogeneous masonry, with multiple formats and sizes of stone or brick deployed within the walls of the same structure. The resultant variety of materials, each with its own natural frequencies of resonance, compounded risks for collapse during a seismic event (Adam 2005:290–318). Party walls between neighboring buildings were typically unbonded, while tie beams were used to undergird upper-story floors that were not secured across properties. These three common features of local building practice—inconsistent building materials, unbonded party walls, and disconnected tie beams—made Pompeian houses particularly vulnerable to toppling from rocking, horizontal seismic motions (Ruggieri 2017a, 2017b; Ruggieri et al. 2018). This point is acknowledged by the Roman author Seneca (2010:87) when he describes how private housing stock suffered more damage than did public buildings. In this way, local building practice had tremendous repercussions for lower- or middle-income residents living in rented-out rooms on upper floors, which were susceptible to collapse when exterior walls toppled (Scobie 1986; Ruggieri 2017a, 2017b). At the same time, column drums in temples and peristyles were also subject to toppling if they were not firmly fixed to the surface on which they stood. All of these risk factors were compounded by urban density and Pompeii's proximity to the tectonic fault that runs north-south through the Italian peninsula.

Structural repairs and modifications in the years after the 62 CE Pompeii earthquake seem to have addressed some of the city's preexisting vulnerabilities. Widespread cracking and separation in weak walls were repaired by replacement with either similar masonry or new brick-faced concrete called *opus testaceum*, especially in corners and piers. *Opus testaceum* was more resistant to horizontal motions with greater friction than were solid stone ashlars or mixed-format brick-and-stone masonry between courses in addition to being speedier to install thanks to standardized, mass-produced materials (Ruggieri 2017a, 2017b). Column drums across the town were fitted with bronze or lead pins that bonded them to sidewalk surfaces (as at Palestra Grande, Adam 2005:310). And perhaps resulting from a similar criterion—namely, improved resistance to horizontal seismic motions—domestic architecture at Pompeii was also retrofitted with masonry walls installed at around half the height of the columns (as at Villa of the Mysteries) or with buttresses on exterior walls (as at Villa di Diomedi) (Ruggieri 2017a, 2017b).

People at Pompeii were perceptive and innovative in their *adaptations* to the inherent risk presented by settlement in the seismically active areas along the fault that runs the length of the Italian peninsula. Such adaptations are not unique to Pompeii but in fact appear globally—at different times, in different places—as common architectural responses to seismic risk (Ortega et al. 2017). At the same time, we should not overlook the fact that such *adaptations*—which perpetuated human settlement in an endangered place and promoted *resilience* and restoration with clever changes in building practice—were not *transformative* for institutions or ways of living; nor were they ultimately *sustainable* for the city's inhabitants. Pompeii was, of course, buried in ash and lava after the 79 CE earthquake triggered the eruption of Vesuvius and brought the city's existence to an end (Sigurdsson 2007).

Indeed, today's environmental historians, urban planners, and students of historical disasters have emphasized the differences between *adaptation* (incremental innovations that accommodate increased stresses to maintain system functionality) and *transformation* (disruptive innovations implying long-term transitions) to note, for instance, that "the current political arena favors adaptation because it works to maintain the established order and address near-term problems" (Redman 2014:38) while framing neo-liberal urbanism as one "example of how highly . . . unsustainable and inequitable systems can be extremely resilient to change" (Chelleri 2016). Pompeii would never have been sustainable in the long run by virtue of its location—a city built on a fault under an active volcano—but it *was* arguably resilient to 5–6 magnitude earthquakes. On the other hand, Romans had no historical memory of Vesuvius's last eruption 700 years before 79 CE (Sigurdsson 2007:45). Following the latter catastrophe, the city was never rebuilt, even if the region around it flourished in the centuries to come. Indeed, Penelope M. Allison (2002) has argued that the absolute impacts of the loss of Pompeii were surprisingly negligible in terms of the contemporary Roman economy. We might ask, as the Romans may have, too: were the short-term, adaptive gains of rebuilding after the 62 CE earthquake worth the long-term loss following a volcanic eruption? Was Pompeii's response to earthquake typical of other Roman cities faced with seismic threats? Was abandonment the only truly transformative, sustainable approach to settlement in Pompeii? In other Roman cities built alongside a fault but without the threat of an active volcano, how might we recognize resilience, adaptation, or transformation?

Any assessment of the nature of Roman response to earthquakes—whether consistently resilient and adaptive with returns to the status quo ante or indeed

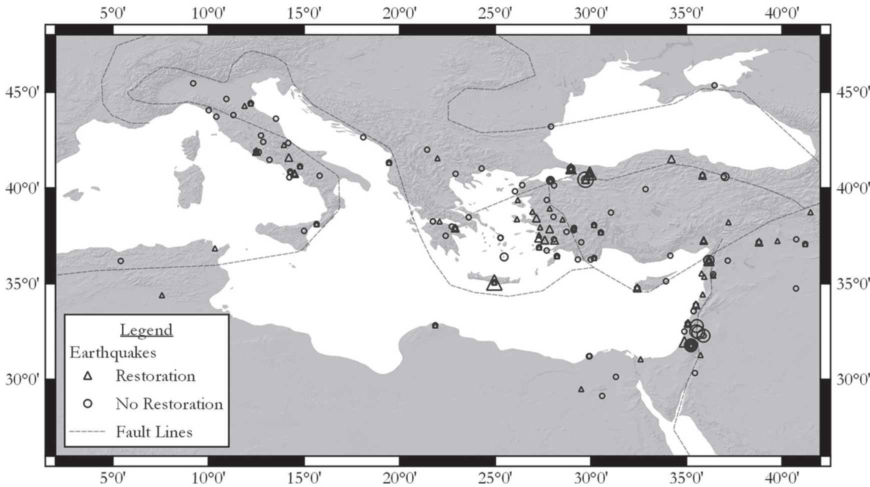


Figure 4.3. Attested Mediterranean earthquakes with or without restorations, between 200 BC and AD 800. Map by Matthew Jacobson, with data compiled by Jordan Pickett from Guidoboni 1994 and Ambraseys 2009.

transformative and perhaps even sustainable—must depend on a larger dataset for seismic events across the Roman Mediterranean, including scientific, archaeological, and textual information. Among these, the corpus of Roman and Late Antique literature and historical attestations of seismic events is still our fundamental and most comprehensive resource. Even in large and long-excavated Roman cities, where earthquakes known from literary sources have long been evoked as agents in narratives of historical change, earthquake damage is only beginning to be recognized and studied scientifically (Rodríguez-Pascua et al. 2011).

A projection of 265 seismic events (figure 4.3) recorded by Roman authors for the years between 200 BCE and 800 CE—compiled from the catalogs produced by Emanuela Guidoboni (1994) and Nicholas Ambraseys (2009)—enables us to visualize several important patterns. It is clear, for instance, that earthquakes reported by ancient literary sources do indeed follow the major Mediterranean fault lines (as indicated in figure 4.3 by solid lines) and that reported earthquakes are clustered in zones of population density. Note, for instance, how earthquakes are densely spread along the Dead Sea transform fault, which connects the Red Sea to the Taurus Mountains, and along the fault as it bends back west through Cyprus—another hotspot—before splitting north along the heavily urbanized and seismically active western Anatolian coast, as well as west toward Crete and Greece and north through Italy into the Alps.

Population size and political importance appear to be the primary factors in the distribution of seismic events attested among Roman primary sources. Provincial cities in the Levant, the coastal Aegean, Crete or Cyprus, and southern Anatolia constituted the primary tax base for the Roman empire, especially between the third and seventh centuries CE. Elsewhere, locales of reported earthquakes reflect the interest of court cultures or particular authors much more than they represent any absolute record of seismic events as they actually occurred, as would be the case for modern instrumental records. For instance, Greece and its environs pick up their seismic signal largely as the product of the second-century CE geographer Strabo, whose attention to anomalies of nature in places of mythological significance was second to none. Later, earthquakes were well reported for the coastal Italian city of Ravenna in the fifth century CE—about which there was no mention before this period—during its brief fluorescence as capital of the Ostrogothic kingdom (and, consequently, the center of activity for royal chroniclers there).

Although accounts of individual Roman earthquakes are markedly uneven, taken altogether, they cohere as a consistent set of Roman expectations and responses congruent with the contours of disaster and disaster response as described by contemporary scholarship: primary environmental and geological effects on the landscape and architecture when a seismic event occurs; secondary-stage social effects immediately thereafter, with search and rescue alongside fire, food shortages, and other dramatic changes in living standards and habits; followed eventually by tertiary rebuilding and reconstruction or mitigation efforts that could, to varying degrees, reshape entire urban landscapes and communities or ways of living.

The immediate responses to earthquakes emanated primarily from local capacities. As a result of slow lines of communication, funds sent by emperors from the capital in the initial aftermath of an earthquake inevitably came too late and could serve only to aid in the recovery of the dead. Witness Anastasius's response to Rhodes in 515: "The merciful emperor sent much gold to those who were found still alive on the island. They started to dig out and extract the bodies of those who had been squashed, as if in a wine-press, by this great cataclysm" (Pseudo-Dionysus 1996:6). Just so, Dio Cassius reports on ill-fated search and rescue efforts made after an earthquake and its aftershocks struck Syrian Antioch in December 115 CE, when the emperor Trajan happened to be passing through the city en route to the Parthian front. Even though Trajan was in a position to immediately bring to bear the resources of the Roman army and state upon the devastated city, these efforts seem to have been unsuccessful:

> Heaven continued the earthquake for several days and nights, the people were in dire straits and helpless, some of them crushed and perishing under the weight of the

> buildings pressing upon them, and others dying of hunger, whenever it so chanced that they were left alive either in a clear space, the timbers being so inclined as to leave such a space, or in a vaulted colonnade. They searched the . . . heaps [of ruined buildings], but were not able to find in them anyone still living save a child sucking at the breast of its mother, who was dead. As they drew forth the corpses they could no longer feel any pleasure even at their own escape. (Dio Cassius 1925:405)

Such accounts constitute the bulk of our information about Roman search and rescue or charitable operations in the aftermath of disasters, which depended entirely on local-level ad hoc arrangements that are often, if only schematically, described by our sources.

To add another unfortunately detailed example, Ammianus Marcellinus (1935–1940:341–345) reports the primary geological and architectural effects of an intense earthquake at Nicomedia in 358 CE, with remarkable (if occasionally clichéd) details, before vividly describing search and rescue efforts—"the highest points [of the city] re-echoed all manner of outcries, of those seeking their wives, their children, and whatever near kinsfolk belonged to them"—that were catastrophically disrupted by a conflagration that burned the beleaguered city's remains. For modern disaster sociologists, community cohesion is key to survival in the hours and days after a seismic event. The vast majority of trapped victims brought out alive from beneath the rubble are rescued in the first twenty-four hours after an event, usually by neighbors and family rather than specialists (Smith 2013:117). Survivors' participation in community-sponsored offerings of thanksgiving, including even the construction of entire temples, may have fostered such community cohesion in future earthquakes: following an earthquake at Antioch in 115 CE, "the surviving Antiochenes who remained then built a temple on which they inscribed 'Those who were saved erected this to Zeus the Savior' " (Malalas 1986:145). Early Christian histories record comparable community events that commemorated earthquakes, incorporated into the annual calendars of the church, which were focused on public liturgies with prayers and processions through frequently afflicted cities like Constantinople—led by authorities that could include the emperor, the patriarch, and his bishops (Croke 1981; see similar activities associated with plague outbreaks discussed in Horden 2008).

Compared to recovery and rescue operations, we are much better informed about the nature of Roman reconstruction activities, at least insofar as such efforts were directed from the capital and recorded by historians. Despite the agency and importance of local communities, rulers who embodied the state or their agents received much of the credit for post-earthquake reconstruction. Textual sources reveal a considerable range of administrative options that evolved to finance reconstruction activities and which testify to the adaptability of the Roman state and its entire bureaucracy under stress. Chief among these options, however, are direct contributions from the state fisc at an emperor's direction or with a senatorial resolution (Dio Cassius 1927:57), as well as imperially financed reconstructions supervised by local officials (e.g., *Année Epigraphique* 1913:227). The provision of construction materials or skilled labor (including engineers and soldiers) was probably of comparable significance with funding for earthquake-damaged communities, if also less easily quantifiable and typically absent or mentioned in passing by Roman sources. Local labor is never mentioned.

Although Roman authors emphasized the importance of direct state contributions for earthquake-damaged cities, imperially allocated funds could be quite limited in comparison with costs for new construction projects during the same period. For instance: among the primary sources describing monetary relief in the sixth century, Malalas (1986:419–422) indicates that 500 pounds of gold were sent to Antioch for reconstruction after the 526 CE earthquake, and 200 pounds of gold were sent to Laodicea after an earthquake in 528 CE (443). Under normal circumstances, such sums were considerable, but they could also be obtained by a single city through its own resources or even by a single individual. During the earlier sixth century, for example, we read that a squadron of merchant ships operated by the church of Alexandria sank in the Adriatic with cargoes worth 3,400 pounds of gold, that the title of Archbishop of Alexandria was purchased for 700 pounds of gold (Monks 1953), and that just one building—the resplendent new Church of San Vitale in Ravenna, famous for its mosaics and sculpture—was paid for by a banker and valued at approximately 400 pounds of gold (Agnellus 2004:59).

Another related option by which the Roman state might finance reconstruction after an earthquake was forgiveness of a city's entire tax bill for a temporary period, often five to ten years. Such tax remittances following earthquakes could be substantial, perhaps more so than direct contributions of coin. For instance, the emperor Tiberius granted that 10 million sesterces were to be wiped clean from the tax bill owed by the city of Sardis in 17 CE (Tacitus 1931–1937:25). In later centuries, after an earthquake at Antioch in 458 CE, we are told that approximately 100,000 pounds of gold were kept from the hands of imperial tax collectors (Evagrius Scholasticus 2000:96). Property owner taxes on individual buildings lost to earthquake damages were also occasionally remitted, or particular forms of tax or service could be suspended for varying lengths of time (e.g., Claudius's suspension of a hearth tax at Antioch, with money redirected to reconstruction of street colonnades and porticoes; Malalas 1986:131). Some communities were also reportedly capable of rebuilding from their own funds, without imperial intervention (Tacitus 1937:151), while others organized donations and incentivized reconstruction of individual structures by local notables (*Corpus Inscriptionum Latinarum* 1893). For example, Opramoas of Rhodiapolis gave huge sums to thirty cities in southern Anatolia after earthquakes there in 141 CE, as recorded by a famous inscription (Petersen and von Luschan 1889:2, 109–115).

Having reviewed some of the finances of Roman reconstruction after earthquakes, we might inquire into the qualitative nature of rebuilding and restoration following seismic events—which, to judge from surviving sources, tended to focus repair efforts on ideologically important buildings such as temples and churches rather than infrastructure or housing (Mordechai and Pickett 2018). Roman sources described post-earthquake urban reconstruction in a decidedly symbolic manner, with a generic picture of entire cities "rebuilt," "reconstructed," or "restored." However, these rhetorical images—wherein cities were recorded as having been returned to their pristine pre-disaster state—rarely correspond to the archaeological evidence.

THREE CASE STUDIES OF POST-EARTHQUAKE RECONSTRUCTION

A comparison of how seismic events reshaped cities and ways of living in three Roman cities—Syrian Antioch, Asian Ephesus, and Phrygian Hierapolis—highlights the intriguing disjunction between "restoration" or resilient returns to the status quo ante that are so prominent in literary sources and the facts of more transformative rebuilding episodes as they are known archaeologically (Mordechai and Pickett 2018:341–343). Post-earthquake reconstruction episodes known from archaeology indicate that whatever the literary sources might tell us, Romans rarely "rebuilt" cities in a literal sense; rather—like Lisbon after the 1755 earthquake (Mullin 1992; Chester 2001; Ribeiro dos Santos 2011)—earthquakes created spaces of institutional and architectural potentiality that were not merely adaptive and resilient but which rose to the level of transformation through a process of provoking or enabling reorganization of institutions and communities from the ruins of cities.

Antioch

The history and archaeology of ancient Antioch (modern Antakya) contain several centuries of transformative changes to urban fabrics that followed closely upon seismic events between the first and sixth centuries. The city had been the capital of the Seleucid dynasty of *diadochoi* that inherited and divided Alexander the Great's empire after 323 BCE, though after 64 BCE it came under the sway of Rome and was, like all Roman cities, successively rebuilt in that city's urban image. Malalas (1986:129) tells us that the earthquake of 37 CE preceded Caligula's construction of Antioch's first bath and an aqueduct; Trajan added a second aqueduct and bath after the earthquake in 115 CE (1986:145). Earthquakes in the region during the 360s may have likewise facilitated additional constructions by Valens that included a forum, basilicas, and vaulting over the River Parmenios for better drainage (338). Earthquakes literally cleared the ground at Antioch for new and significant infrastructure projects that transformed Hellenistic Antioch during the Roman imperial period.

Comparable phenomena can be observed at Antioch in the Late Roman centuries that follow, albeit with more sharply visible differentiation between pre- and post-earthquake urban environments. A series of repeated disasters affected Antioch during the sixth century CE, including earthquakes, fire, plague, and invasion. The relationships among the effects of these disasters are difficult to separate out, both because they came in such rapid succession—leaving damage to structures whose precise etiology and date are unclear—and because the phasing and dating of the early twentieth-century excavations that uncovered so many buildings of Late Roman Antioch have been subject to substantial revisions in recent years (Eger 2013:105–127). Primary sources and archaeology nevertheless suggest that mid- and later sixth-century responses did not literally rebuild the city but instead adaptively restructured it to better correspond to the needs of an evolving society.

The reconstruction of earthquake-damaged churches at Antioch was a priority for local populations and an ideological imperative for elites. Sources indicate that the 526 CE earthquake destroyed the Great Church or Cathedral of Antioch, the Church of the Virgin Mary, and the Church of the Archangel Michael. The former two were rebuilt, not immediately but a few decades later under Justinian, where they survived into the Middle Ages; the latter was abandoned (Mayer and Allen 2012:74–76, 109, 98–99). Antioch's streets, fortifications, and waterworks were maintained and rebuilt during the sixth century, albeit on smaller scales and with modifications (Döring 2012; Procopius 1940:2.10.1–25; Pickett 2017:110–112). In comparison to churches and infrastructure, quintessentially Roman entertainment architecture—including baths, theaters, and hippodromes—was abandoned or repurposed for industry, burials, and agriculture (Eger 2013; Pamir 2014:112, 120). Such changes were hardly isolated to Antioch or indeed to the aftermaths of earthquake events but instead were characteristic of transformations affecting the entire eastern Mediterranean during Late Antiquity. The symptoms of deep structural changes in Roman society typically played out over several centuries, but in some cities as at Hierapolis they appear accelerated or formalized within a few decades after the "clean" slate provided by seismic catastrophe (Saradi 2006; Haldon 2016).

Ephesus

Another case of disaster-accelerated urban renewal can be seen at Ephesus, an important Roman city on the western Aegean coast of Anatolia where excavations directed by the Austrian Institute of Archaeology since 1895 have revealed that earthquakes in the later third and fourth centuries CE were followed by significant transformations of the city's urban fabric after the early fifth century. These interventions "redefined the character of the late antique urban landscape" and reflected broad societal changes that were already transpiring throughout the third and fourth centuries (Ladstätter and Pulz 2007:397–406). Most visibly, the early fifth century witnessed the introduction of church architecture at Ephesus, set into the repaired shells of massive earthquake-damaged pagan temple complexes such as the Temple of Hadrian, whose stoa was incorporated into the new Church of St. Mary (Pickett 2016:306–308). Another ruined temple, originally dedicated to the cult for the emperor Domitian, was converted into a fortified administrative structure. Several of the city's larger bath complexes were abandoned or repurposed around the same time: the East Baths were given over to burials and a small chapel, and the porticos of the Harbor Baths downtown were given over to a combination of middling and elite housing. The Scholastikia Baths on busy Embolos Street were renovated and kept their original function, albeit on a grander plan and under the management of a new patroness.

Industrial watermills also began to appear in prominent public spaces throughout Ephesus during this period, marking a substantial alteration of the city's appearance and function as industrial and utilitarian prerogatives began to replace earlier imperial Roman obsessions with public display (Pickett 2016:299–302). Such changes, finalized in the wake of earthquakes, thus maintained essential infrastructure such as streets and aqueducts but strongly distinguished the Late Roman city both formally and socioeconomically from its earlier Roman predecessor. These urban innovations were maintained until the mid- or late seventh and eighth centuries CE, when the subsequent combination of additional earthquakes, Arab invasions, and long-term political and economic changes prompted the abatement and fragmentation of Ephesus into smaller centers in the surrounding region.

Hierapolis

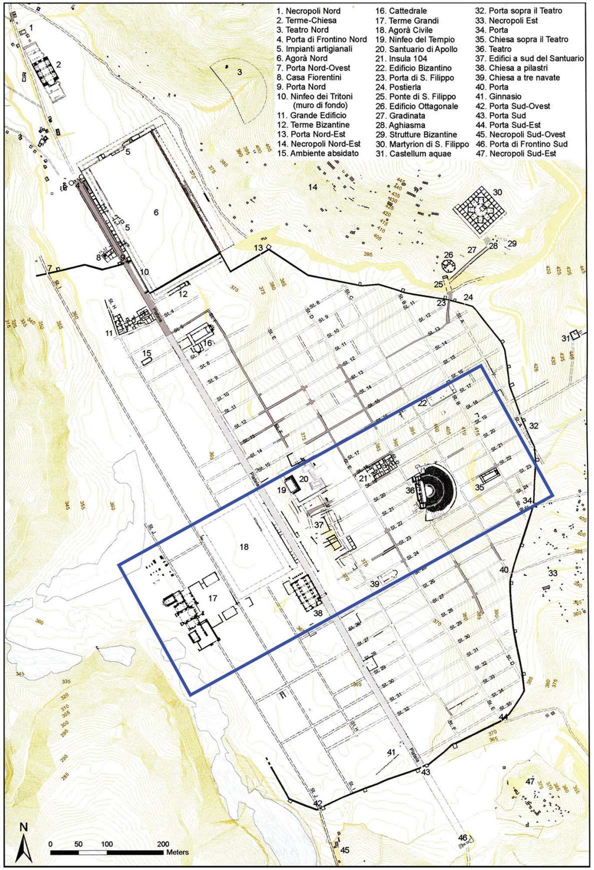
A pattern of seismically driven urban transformation prevails at Phrygian Hierapolis (modern Pamukkale in Turkey), which sits directly on a micro-fault whose surface ruptures are readily visible throughout the site. As at Antioch and

Ephesus, earthquakes in the late fourth century CE gave way to "interventions of restructuring and reconstruction which . . . changed the aspect of the city"—in this case, too, by accelerating the demolition, repurposing, and spoliation of obsolescent public buildings such as temples, whose materials were recycled into new city walls and churches, while the city's infrastructure of aqueducts and streets remained basically unchanged until another earthquake in the seventh century, which precipitated the old urban and Roman core's transition to a village (Arthur 2012:277–279).

DISCUSSION

Despite images of basic infrastructural *resilience* at Hierapolis and Ephesus during the fourth and fifth centuries—accompanied by substantial *transformations* in the cities' fabrics that reflected deep-seated societal evolutions over the previous decades—we are hard-pressed to define these changes as *resilience* or *transformation* unless we also ask, change for whom? Earthquake-induced changes at Hierapolis and Ephesus did not hinder the state-level functionality of either city as a center for tax collection, always the primary desideratum of the state, through regulation of trade or hinterland resources. The frequency and chronology of coin finds in those two cities could suggest a reflorescence of economic activity in the years following earthquakes. But should we view renewed activity as *adaptations*? Earthquakes transformed late Roman cities in ways that may have been unsettling to urban elites, obliterating traditional venues and forms of public display and munificence (e.g., portraits and inscriptions at temples or the theater) or repurposing them to more mundane, if economically satisfying, functions of lower- and middle-class artisanal housing. From these perspectives, earthquake-induced reorganizations of urban form and function might well be labeled as transformative for members of all social strata.

Ambiguities of resilience, adaptation, and transformation resolved with a cluster of devastating earthquakes in the late seventh century that pushed Hierapolis into a different state entirely (figure 4.4). This transformation—which excavators there strongly associated with a seismic event ca. 670 CE that is well evidenced archaeologically but entirely absent among Roman literary sources—included the total abandonment of the city's public architecture, with its water supply systems and rectilinear streets. Low-density residences and industrial installations moved into the shells of collapsed buildings in the area around the city's unrepaired walls, while the St. Philip complex outside the walls was repaired and seemingly continued to function as a necropolis and a focus of regional and supra-regional pilgrimage long after the city's other churches had collapsed. These seismically triggered changes



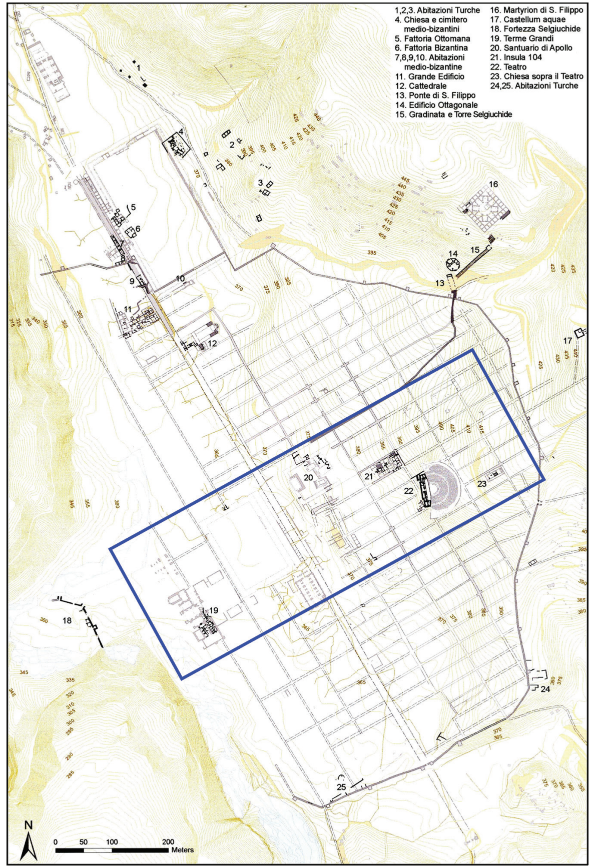


Figure 4.4. Comparison of plans for Phrygian Hierapolis. The city in 400 CE (a) and 700 CE (b). *Courtesy*, Italian Mission to Hierapolis.

constituted a radical, low-cost form of reorganization of settlement patterns and re-focus within the remains of the ruined antique city, which survived in this form for six centuries until the arrival of the Seljuks in the Lycos valley around Hierapolis in the eleventh century CE.

CONCLUSION

Seismically driven changes were endemic to the urban landscapes of the eastern Mediterranean during the Roman and Late Antiquity eras, symptoms of deep structural changes in Roman society made manifest in spaces of potentiality. The role of earthquakes in urban change during this period should be understood as only one pendulous contributing factor, whose magnitude could punctuate or accelerate longer-cycle evolutions and thereby push urban systems, such as Antioch or Ephesus or Hierapolis, into a transformed condition. Seismic events in the Roman world were not merely occasions for rebuilding and resilience, with adaptations that could return urban societies to the status quo ante; earthquakes also provoked, enabled, and formalized longer-term urban and social transformations.

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5

Fire as an Agentive Force, from Forest to Hearth to Forest Again

Monica L. Smith

ABSTRACT

For at least the last half-billion years, fire has had a life of its own as a combustive interaction with fuel, air, and humidity. In its much more recent engagement with humans, fire has become a transformative technology, the control and spread of which are intertwined with human intentionality and innovation. Our earliest human ancestors approached fire deliberately, using it at first to improve comestibles such as meat and tubers and to heat-treat stone for flaking and later mastering the control of fire for pyrotechnical processes of ceramics, glass making, and metallurgy. Humans' interactions with fire paralleled their creation of numerous flammables such as textiles and architecture, resulting in increased niches for the agency of fire through both accidental combustion and the use of incendiary devices in warfare. Although humans' sponsorship of many intentional niches for fire suggests that it is a controllable entity, its inherent capriciousness still makes it a perpetual source of risk.

Fire is a natural phenomenon whose existence long predates the emergence of the human species. Started by processes such as lightning strikes or at the edges of lava flows when molten rock meets flammable organic material, natural fire is propagated only under accommodating conditions. Fire's interplay with constantly shifting elements of fuel, aridity, and wind give it the capacity to change local pockets of land or to engulf entire landscapes, a scalability that is unleashed at every instance of ignition (figure 5.1). In cultural contexts, fire is both a welcome addition to the human

https://doi.org/10.5876/9781646423521.c005

Figure 5.1. Wildfire, Canadian Yukon. Photo by Julie Sprott, Alamy.com image BCJP5C.

technological repertoire and a sobering phenomenon when it escapes uncontrolled, as illustrated by the massive wildfires that are increasingly prevalent today and that result in billions of dollars in damage and the loss of human and animal life.

The natural history of fire indicates that, like earthquakes and hurricanes, it is a phenomenon that has been part of the Earth's system for millions of years. The earliest primitive plants are discerned in the Ordovician period 450 million years ago (Rubenstein and Vajda 2019), constituting the first organic matter whose dried-out mass would have been susceptible to combustion. The advent of the first trees—and the first forests—in the Devonian period starting 393 million years ago represents what William E. Stein and colleagues (2020:1) have called "a turning point in Earth history, marking permanent changes to terrestrial ecology, geochemical cycles, atmospheric CO2 levels, and climate." The close tracking between the availability of vegetation and climate fluctuations culminated in numerous periods of heightened temperature in which there was increased burning of biomass recorded in ice cores, including during the Paleocene-Eocene thermal maximum 55 mya, in which the Arctic terrestrial mean annual temperature was 21°C (Denis et al. 2017).

In the past as in the present, there are multivariate factors that make it difficult to accurately predict the directionality and ferocity of any particular fire or the rapidity of healing any particular burnt landscape. It also is difficult to directly correlate long-term effects because specific episodes of climate change do not always lead to predictable conditions for vegetation: although cycles of warm climate can increase the dryness of some species, rendering them vulnerable, cycles of increased precipitation also can result in more biomass to burn. Different species of plants recover from fires at different rates, which along with factors of moisture and temperature results in differential vegetation renewal after fire events. Vegetation itself responds to cycles of climate on both the short and long term, resulting in shifts in the types of plants and their abundance. The overall conditions that result in vegetation being fire-prone are additionally overlain by atmospheric loads of carbon, in which higher levels of CO2 are correlated with an increase in lightning strikes that cause fires (Denis et al. 2017).

The complex interactions of fuel, climate, wind, vegetation growth, moisture, and species types provided the conditions for fires' dynamic engagements throughout time. These interactions include obligate co-dependencies, such as plants that require fire to propagate or the cyclical opportunities afforded by the clearance of larger plants that allow other forms of vegetation to establish themselves in fire-cleared land, as seen, for example, in the establishment of savanna grasslands in sub-Saharan Africa 5–6 million years ago (Clark and Harris 1985). All of these developments long preceded the first human use of fire starting as early as 1.9 million years ago, which is indirectly suggested by the evidence for our ancestors' occupation of cold climates and for the reduced dentition resulting from the use of intermediate mechanisms of food processing such as cooking (Wrangham 2009; Wrangham et al. 1999:567). The essential function of cooking is further supported by work by Karen Hardy and her colleagues (2015), who propose that the cooking of starches was the only mechanism that could have produced the glucose needed for rapid infant brain development, high-energy hunting, and overall hominid health in a genetic trajectory starting 2 million years ago and accelerating after 800,000 years ago.

At present, the most robust direct evidence for deliberate fire use comes from the site of Gesher Benot Ya'aqov, dated to 790,000 years ago (Alperson-Afil and Goren-Inbar 2010; for discussion of this and other early sites of human fire use, see Roebroeks and Villa 2011; Twomey 2013; Marshall 2020). Fire enabled our ancestors to achieve mastery over other predators, to live in climates colder than the human body will otherwise tolerate, to modify environments at a large scale through the systematic burning of vegetation, to alter the physical qualities of materials such as food and stone, and to enhance a sense of "home" long before the development of permanent architecture (e.g., Hardy et al. 2016). The first fires used by our human ancestors were most likely scavenged from natural fires ignited by lightning or spontaneous combustion and curated as glowing embers that could be magically revived through the skilled addition of fuel. Eventually, people also learned to create fire at will, a process of invention that still did not come with automatic control over the process or prevent the dangerous escape of flames when handled carelessly.

HUMANS APPROACHING FIRE

Contrary to popular thought, humans are not unique in their ability to approach fire without fear. Some years ago, J. D. Clark and J. W. K. Harris (1985:19) made a case for a very long association of hominids with fire by noting that other animals ranging from birds to mammals will gather near smoky fires to dislodge insect pests; this factor, along with the propensity of grasslands to burn periodically, led them to propose that it "would not be unreasonable to assume that early hominids had learned to live with natural brush fires and so were not particularly afraid of them." The subsequent accommodation of humans to fire can be parsed into specific types of actions that reflect increasing deliberation and control:

Habituation → Use → Curation → Manufacture

Following the logic of Clark and Harris, habituation would have enabled early hominids to view fire as a predictable component of the landscape, making fire no different from other resources. Fire might sometimes be a point-specific resource similar to an outcrop of stone suitable for making tools; at other times, fire might be prey-like in its mobility and unpredictability of location. The deliberate use of fire would have been the next stage of human interaction. Because fires occur in nature through lightning strikes and lava flows, it is likely that our hominid ancestors' first encounters with fire would have occurred in the course of scavenging fire from already burning materials available in nature (figure 5.2).

The next step, curation, would have involved significantly more cognitive interaction and capacity for planning, as well as an understanding of the specific physical interactions of fuel, air, and humidity that enable fire to be prolonged (see Twomey 2013). The most comprehensive type of control, encompassing the manufacture of fire, would require the careful manipulation of stones or friction in combination with kindling. Because of the paucity of data, there is a robust argument about the timing in which fire was deliberately manufactured, with some researchers proposing a date of 700,000 years ago, others favoring a date of 300,000–400,000 years ago, and still others advocating a much more recent date of 250,000 years ago (summarized in Shimelmitz et al. 2014).

Throughout the stages of use, curation, and manufacture, fire was implicated in the domestication of human social life long before the development of architecture. As Dragos Gheorghiu (2007:3) has noted, a hearth is a sum of artifacts, operations, and activities (see also Hardy et al. 2016). Engaging with fire requires a working knowledge of the component parts of the process in which compensation might be required for gusts of wind, for the placement of materials to be cooked on a fire without snuffing out the flames, and for the effective management of sub-par sources of fuel such as flammables that were too green or too wet. The multiple and

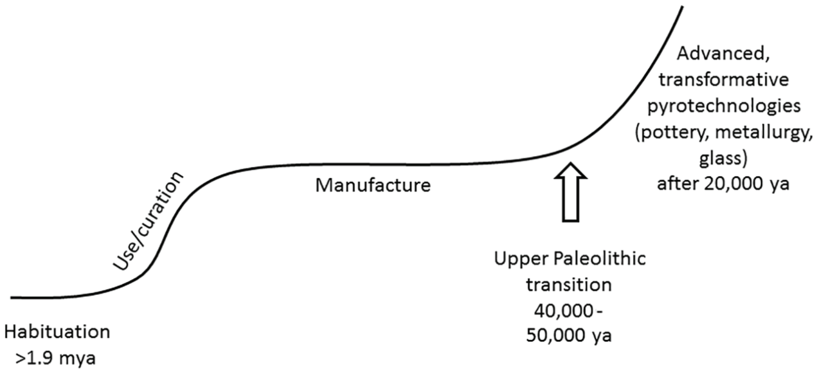

Figure 5.2. Trajectory of human interactions with fire, 1.9 mya to present. Author image.

ongoing calculations of input can be evaluated through an analogy with modern technological processes to understand the importance of recursive human behavioral patterns. Multiple inputs result in a "complex technological system," as characterized by Michael Brian Schiffer (2005a:486), consisting of "a set of interacting artifacts (in which) interactions among these artifacts—and people and sometimes environmental phenomena—enable that system to function."

In Schiffer's view of complex technological systems, two key aspects are encompassed in the development of new technologies. One of these is the concept of the "life history processes" of technology, characterized by "interrelated activities, which in turn incorporate one or more technological objects" (Schiffer 2005a:488). Another is the concept of the "invention cascade," which is defined as the way people address the shortcomings of technological systems through innovation and invention (Schiffer 2005a:486). Both of these concepts can be applied to the human use of fire. Although fire's basic components are exceedingly simple (air, organic material, and a combustion source mingled in an atmosphere of appropriate humidity), each component can be modified by human action and has a potential for unwanted results that must be mitigated. For example, the need to protect people and objects from accidental burning prompts the development of pits, stone banking, and other containment features. The need to avoid (or capture) smoke leads to consideration for the siting of fire within dwelling areas. The curation of fire requires transport devices; the use of fire requires ancillary technology such as tongs, sticks, props, and hearths; and the creation of fire requires the selection of appropriate materials for the generation of sparks or heat accompanied by the effective placement of kindling.

On the environmental level, the use of fire in a landscape was complementary to other human actions. Just as "landscape learning" is implicated in the collection of stone for tool making (see Rockman 2009), knowledge of the landscape was utilized by individuals for the identification of fuel sources, characteristics of the environment (such as seasonality) that affected the utility of fire, and the types of predators and prey that would be affected by humans' fire use. In Australia, "fire-stick farming" by early human populations was a mechanism through which the landscape and humans co-adapted (Bliege Bird et al. 2008; Denham 2008; Jones 1969). Fire ecologists working in California have noted that the environmental record of fires shows a much higher frequency than would have occurred naturally, suggesting that human occupants substantially changed the ecology and environment of the region in the Indigenous era (Keeley 2002; see also Williams 2005). Although the agricultural period is usually associated with the physical clearance of vegetation using metal implements, fire would have been retained as a quick means of clearing brush and stubble (an observation raised long ago by A. Ghosh for India [1973]; see also Possehl [2002:43] for the use of fire as a pre-agricultural adaptation elsewhere in South Asia). Fire remains an essential component of slash-and-burn agriculture, in which successful burns of wild vegetation provide ash and nutrients for the support of cultivated crops (Fuller and Qin 2009:94; Padoch 1985).

The process of human habituation, use, curation, and manufacture of fire also entailed a number of social adjustments at the daily, lived level of human experience (figure 5.3). Indeed, most of the anthropological studies of fire have concentrated on its social components, such as the use of fire for symbolism and in art (e.g., Bentsen 2007; Jones 2007; Ronen 1998) and as an expression of cooperation and group interaction (Twomey 2013; Wrangham 2009). The habituation of our earliest primate relatives to natural fires may have facilitated a relatively rapid transition to use and curation once the mutually reinforcing feedback loops of starch consumption, group cooperation, migration, and cognitive capacity were established (see Hardy et al. 2015; Twomey 2013; Wrangham 2009). The emergence of regular cooking activities at a scale and predictability that would have had a selective genetic effect suggests that fire use became a routine part of human adaptations starting as early as 1.9 million years ago. The idea of a combination of predictable and unpredictable phenomena guided in part by a human hand also may have been the earliest transition to spiritual phenomena as people interacted with the unknowable or unseen to some visible effect. Fire use may have been the first physical manifestation of human agency upon spirit-world interaction, manifested in much later periods through durable evidence such as ornamentation (first appearing only 120,000 years ago) and burials (starting around 50,000 years ago; McBrearty and Brooks 2000).

Figure 5.3. Fire as a component of field management (burning sugarcane stalks, South Africa). Photo by David Buzzard, Alamy.com image BGA181.

FIRE AND LITHICS COMPARED

As C. Karlin and M. Julien (1994) have noted, archaeologists have emphasized lithics as an entrée to early human cognition because the archaeological record preserves evidence of the entire process of manufacture, from core to waste flakes to a final product and subsequent retouching and resharpening. The manufacture of a stone tool requires a number of steps, including the identification and acquisition of suitable raw material, the use of energy in striking a stone to produce a sharp flake, and the use of the resulting tool(s) to cut meat, skin animals, or extract roots. Once struck from the parent rock, a stone flake cannot be reattached or resorbed back into the original mass. The production of lithics is often described through the rubric of the *chaîne opératoire*, in which stages of production can be identified because lithic manufacture is a glyptic process of reduction in which stone flakes are successively removed in the course of manufacture and use (Sellet 1993; see also Andrefsky 2008).

The archaeological record indicates that the blunt-force creation of lithics with a sharp edge went through several stages of development, resulting in increasingly elaborate tools. The current identification of the earliest stone tools at 3.3 million years ago consists of battered cobbles and flake fragments of what is called the Lomekwian tradition (Harmand et al. 2015). The next development consisted of Oldowan tools as early as 2.5 million years ago, which were simple cobbles with a sharp edge struck off as the result of free-hand knapping (Harmand et al. 2015:313–314; see also Karlin and Julien 1994; Toth and Schick 2009). The next substantial development was the Acheulian, a period marked most dramatically by the teardrop-shaped bifacial hand ax that first appears in the archaeological record as early as 1.65 million years ago (reported in Klein 2009:94). Lithics of a smaller size were subsequently developed for incorporation into composite and hafted tools (including projectile points and cutting implements) by 65,000 years ago, signaling the capacity of humans to understand a tool as something with both stable and disposable components (McBrearty and Brooks 2000:500).

However, lithic technology is limited as a proxy measurement of all early technological adoptions. One distinct characteristic of lithic manufacture is that stone is inert and does not behave independently of a human operator. The production of stone tools can only occur through direct and active human involvement when an individual chooses to apply energy to the raw material. This wholly human-initiated *chaîne opératoire* process means that the timing, speed, and amplitude of blows constituted a unidirectional series of activities; although stone has qualities such as hidden flaws that might prevent a desired result, it has no agentive capacity of its own. A slow process of stone tool creation also enabled the pace of learning to be spaced out according to the capacities of the learner, with the potential for the learner to carefully study the inert material between bouts of energy investment. Steps of the learning process appear to have included not only live demonstrations but also the existence of a demonstration toolkit that could be repeatedly viewed and handled by those who were learning the process (e.g., Karlin and Julien 1994:162).

Indirect evidence of fire use, as well as archaeological evidence, places the use and curation of fire within the same time frame as the development of stone tools, providing the opportunity to compare humans' approaches to inert compared to agentive substances. Both stone and fire can be utilized in their scavenged state without further modification, a simple step that nonetheless includes aspects of scheduling and planning: how to carry the raw material, the path to take from raw material source to zone of use, timing the use to optimize the scavenged material, and how to adjust to the cessation of physical qualities such as sharpness (in the case of lithics) or heat (in the case of fire). Both lithics and fire are characterized by an understanding of unilineal cause and effect that is deeply engrained in our mammalian past, experienced in activities such as hunting as well as through irreversible bodily processes such as birth, death, and the daily realities of voiding bodily waste.

The thought processes encompassing the human use of both fire and lithics enable us to analyze the use of fire in the same way lithics have been studied, including the concept of the *chaîne opératoire*, the idea of raw material portability, the use of both basic and advanced techniques of working, the capacity to plan for desired outcomes, and the need to mitigate unpredictable outcomes. The material components of stone tool making and the use of fire would have been perceived as similarly governed by linear and irreversible processes: stone, once flaked, could not be reconstituted into an unbroken entity, and objects that were touched by fire could not be "unburnt" or food "uncooked."

By contrast with the learning process of stone tool making, in which the natural element of stone is inert, the acquisition of knowledge about fire requires memory and predictive capacity because of the agency of the fire itself. Some rapidity of thought and adjustment to prevailing conditions are required on the part of the individual who uses and curates fire, which has behavior independent of human action depending on factors such as moisture and fuel flammability. Fire also interacts with other agentive natural forces, for example, when wind blows a fire out or out of control. Fire and stone tool making present different scales of danger to the operator as well. While a mishap in stone tool making can involve significant injury (for example, if a fragment enters the eye), most often the dangers to the maker are low. A stone tool production sequence that goes out of control usually results in nothing more serious than a cut or bruise to the hand and the waste of a piece of raw material. Even this aspect can be salvaged, with errors in stone tool making recycled into small or expedient tools or used "as is" for cutting and scraping tasks. By contrast, the consequences of fire being out of control are considerably more significant: injury or death of the human handler, burnt and uninhabitable landscapes, and destruction of animal and plant life.

The energy effects of fire can be vastly disproportionate to the energy expenditure of the human agent. Whereas the development of a stone tool is entirely dependent on a person, fire contains an inherent capacity for self-replication. In a controlled context, such as a hearth, some amount of human energy expenditure is required to supply the fire with fuel. However, in the outdoors, the simple application of fire to a suitable patch of vegetation means that all subsequent action is done by the fire itself, which makes fire an extremely efficient expression of human energy expenditure scaled up to the landscape level. Stopping a lithic production sequence is a simple matter of dropping the raw material, but stopping a fire almost always requires more expertise and energy expenditure than starting one.

FIRE AND HUMANS: AN INTERTWINED AGENCY

Fire's agency in natural contexts interdigitates with human agency of use. Compared to stone tool making, which serves as the standard measure of cognitive capacity and material engagement in ancestral time, the use of fire is a relatively easily learned skill. The period of apprenticeship in fire making is relatively short but allows individuals to gain experience and display expertise in commanding a socially useful technology. For most individuals, one or two demonstrations of the making and application of fire might be sufficient, meaning that fire is a technology that is simpler to make and use than even the most basic stone tool. Fire is scalable through the addition of flammable material, constituting a factor of management and control that could be easily grasped by users across the spectrum of age and dis/ability.

The diverse environmental, economic, and social uses of fire show how it was an all-purpose technology that could be controlled and manipulated by individuals of varying ages and levels of skill. As Clive Gamble and Martin Porr (2005) remind us, a focus on the individual in the hominid context constitutes a critical way of evaluating the development of human cultural diversity (see also Smith 2010). While many components of ancient technology are presumed to be the result of adult hands and adult thought processes (Karlin and Julien 1994:162), the utility and mechanics of fire would have been graspable even by young children. An increased interest in evaluating the role of children in the archaeological record (e.g., Baxter 2005; Crown 2007) means that we should anticipate all of the types of economic and social acts undertaken by young individuals in the past as part of their growth and maturity. From a young age, children could be instructed about fuel using the concepts of dead versus live vegetation, similar to the way children would be taught the relative utility and danger of dead versus live animals (cf. Barrett and Behne 2005). Children could be involved in the technology of fire both as fire tenders (responsible for adding fuel at appropriate intervals) and as procurers of fuel from the surrounding landscape.

Other distinct categories of users who may have gained agency and empowerment through the use of fire would include the elderly and the disabled. As Joanna E. P. Appleby (2010) has observed, there has been little explicit engagement with the concept of the elderly in the archaeological record. In part, this is because life expectancy in the premodern period was relatively low, resulting in a small proportion of individuals reaching old age; however, as the literature on "grandmothering" has illustrated, older individuals became increasingly represented in human communities over time and had a distinct sociobiological niche (Caspari and Lee 2004; O'Connell et al. 1999). The study of disability is similarly poised for greater consideration by archaeologists (see, e.g., Sneed 2020; Southwell-Wright 2013; Tilley 2012). The use of fire would have enabled individuals who were afflicted by physical limitations to display virtuosity in meaningful skills; at the same time, mishandling fire in ways that facilitated its escape and destruction of lives and property would have created or reinforced social stigmas against already marginalized members of the community.

Just as it provides equal opportunities for social actions within a group, fire is also a democratic means of destruction. A flame wielded by a child or a physically disabled person is as damaging and unstoppable as a fire propagated by the most able-bodied warrior, and the destructive capacity of fire rendered it an increasingly potent tool of violence over time. For foragers, the specter of a landscape damaged by accidental or badly managed fire was surmountable, as long as individuals escaped the flames alive. By contrast, many of the things in which agriculturalists make social and economic investments are inherently flammable, such as houses, corrals, textiles, baskets, standing crops, and stored food grains. In addition, many meaningful ritual and religious objects are made of perishable material such as wood, all of which can be destroyed in either accidental or purposeful fires. As Ruth E. Tringham (1991) has eloquently shown, the finality achieved by burning provides an irreversible phenomenological moment for actors and spectators.

The use of fire as a destructive mechanism gained momentum after the inception of agriculture (in many parts of the world, at the beginning of the Holocene 10,000–12,000 years ago). The archaeological record illustrates how fire was used in punitive raids and small-scale warfare, for example, in the American Southwest where researchers working at the site of Burnt Corn recovered large quantities of what would have been edible grain, signifying the catastrophic loss of provisions through intentionally set flames (Snead 2015). In additional to punitive effects, destruction through fire could also constitute a form of cleansing or purification on a large scale. In Neolithic Europe, for example, structures appear to have been destroyed by fire prior to being rebuilt (Bradley 2005; Dufraisse 2008). Historical accounts also illustrate large-scale purification through fire at ceremonies such as the "busk" or "New Fire" annual rites (e.g., James 2000; VanDerwarker et al. 2007). Many other forms of ritual purification through fire also existed, from the use of fire to cremate the dead (Kuijt et al. 2014; Oestigaard 2000) to the decommissioning of structures (e.g., Baltus and Wilson 2019; Tringham 1991) to the creation of aromatic smoke as an olfactory perimeter for ritual activities (Kolb and Murakami 1994).

The archaeological record of massive fires in sites associated with complex societies shows the regularity with which fire was utilized as a cheap, effective way of waging war. Purposeful conflagration resulted in thick lenses of ash and charcoal far greater than the occasional out-of-control household fire (what Possehl [2002:49] calls "the unhappy grist of daily life . . . considerably erased by the process of cleaning up the mess and rebuilding"). Throughout the world, major archaeological sites were decommissioned by fire in antiquity: Hazor in Israel (reported in Lev-Tov and McGeough 2007:89), Kerkenes Dağ in Turkey, Pylos in Greece, Ebla in Syria, Fishborne in Britain, Kot Diji in Pakistan (Possehl 2002:49), and Aguateca in Guatemala (Inomata et al. 2001), to name a few. Fire continues to be a destructive force in the present, whether in the form of wartime actions (such as the fire bombing of many cities in World War II) or of anarchic individual expressions of arson.

CONCLUSION

Fire has characteristics that are shared by other contributions to this volume: like monsoon rains and animals, fire is a natural phenomenon that humans can attempt to predict, monitor, and manage for their benefit. Like vegetation and diseases, fire responds to anthropogenic niches as a source of new loci in which it can thrive. Like hurricanes and earthquakes, fire can clear a landscape and enable humans to envision new configurations and new economies. The existence of fire is, however, also intertwined with concepts of risk at every instance of use, from the risk of burns sustained in campfires to the risk of widespread landscape destruction from a single errant spark.

As a combination of both predictable and unpredictable characteristics, one might argue that fire was *the* key transitional technology in the shift from simple, linear activities such as lithic production to all subsequent technological systems. Fire and its management represented both an essential component of cognitive development and the basis for pyrotechnologically informed innovations such as metallurgy, lime slaking, ceramic production, and glass making in the early sedentary period starting 10,000–12,000 years ago (Miller 2007; Roberts and Radivojevič 2015) and the development of electrical devices, internal combustion engines, and steam-powered technologies in the modern era (Schiffer 2005a, 2005b). Indeed, the global effects of fire wielded by human hands and as a result of human land-use changes provide an impact that is so significant that S. J. Pyne (2020:1) has suggested that the entirety of the last 2.5 million years should be termed the "Pyrocene."

In our interdigitated wild and cultivated landscapes, the boundary between "natural" fire and "cultural" fire has become blurred. The complex feedback loop of human and fire interaction is similar to the mutually constituted realms of agency discussed throughout this volume, including the realm of animals (Ammerman; Bishop; Quintus et al.; Tomášková), vegetation (Dine et al.), and diseases (Juengst et al.). While the mechanics of fire have not changed over the past half-billion years (there is still only the basic configuration of a source of ignition applied to fuel), natural and human activities have become accelerated and intertwined. Neither the agency of fire nor the agency of humans has been superceded; rather, each agent has recourse to more opportunities of engagement through recurring episodes that began the moment "a fire-wielding species met a fire-receptive world" (Pyne 2020:1).

Starting with the first experiments with natural fire and continuing into a closer and closer relationship with curated fire and created fire, humans developed increasingly diverse approaches to flammability. Fire also gained increasingly diverse targets because humans created more things to burn, including agricultural fields, organic artifacts, and architectural structures. In more recent times, combustion has gained new opportunities through humans' distillation of hydrocarbons into kerosene, gasoline, and rocket fuel; the creation of more technologies that throw off sparks, such as internal combustion engines and power lines; and the use of chemicals incorporated into buildings and furnishings that serve as unintended accelerants and increase the potency and heat of unintentional fires. Most sobering of all, humans have contributed to global processes of climate change that have resulted in forest fires being increasingly destructive and intense, as seen in the American West, Indonesia, Australia, and increasingly throughout the world.

Acknowledgments. I would like to thank Jed Docherty, Heather M.-L. Miller, Michael Brian Schiffer, and James Snead for much-appreciated comments on an earlier version of this chapter. Thanks also to Dennis Sandgathe for his interest in the topic.

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6

Pathogens with Power

How Diseases Navigate Human Societies

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ABSTRACT

Humans create habitable zones to allow settlement in inhospitable areas, sculpting landscapes to make travel, labor, and agriculture more efficient and harnessing the power and nutrients of plant and animal resources through domestication. However, each of these processes also creates new opportunities for other creatures to affect humans in return. In particular, pathogens have adapted to many various human settlement and subsistence strategies, effectively using anthropogenic systems to their advantage. In this chapter, we investigate how the domestication of animals and increasing sedentism in prehispanic Bolivia promoted circulation of pathogens. Paleopathological lesions and stature estimates from human skeletal remains demonstrate that while nutrition did not decrease with reliance on agricultural products, disease circulation escalated for people living in the Titicaca Basin between 1000 BCE and 400 CE.

Humans are expert habitat modifiers, causing extreme and sometimes calamitous impacts on other biota on local, regional, and global scales. However, as the chapters in this volume emphasize, humans are not immune to influential, external forces, ranging from hurricanes to rats. In this chapter, we focus on how the physical, social, and economic landscapes in which humans live facilitate disease circulation. In effect, human landscapes create and are created by complementary microbe-scapes (Harper and Armelagos 2013), which are dependent on variables of human lifestyle,

https://doi.org/10.5876/9781646423521.c006

relationships with wild and domesticated plants and animals, and local climates. When humans modify their landscapes and relationships to other organisms, they also modify their relationships to microbes, which can have important impacts for humans and microbes alike. In this chapter, we explore how microbe-scapes shift alongside changing human subsistence and settlement patterns.

PATHOGEN-HUMAN RELATIONSHIPS

Like all animals, humans have been hosts to various pathogens, microbes, and parasites throughout our evolutionary history. In fact, the human body averages 10 trillion to 100 trillion microbes, which make their homes on skin and in mouths, guts, navels, vaginas, nostrils, and sinuses (Harper and Armelagos 2013). The majority of these tiny tagalongs have a neutral impact, while many help humans digest food and ward off other invaders, among other commensal tasks. However, some microbes cause harm when humans encounter them for the first time, when they proliferate, or when the host becomes immune-compromised. The most common pathogens humans encounter are various types of viruses, bacteria, parasites, and fungi (Meade and Emch 2010).

For pathogenic microbes to affect humans, several variables must be in place. First, the ecosystems of pathogens, the human host, and any necessary vectors or reservoir hosts must overlap. Many microbes have the potential to make humans ill but never or rarely encounter humans. In addition, there has to be an effective transmission route between human individuals for pathogens to spread to new hosts. This can be achieved in many ways: through a mobile vector (such as *P. falciparum* and other malarial-causing parasites), aerosol airborne transmission (such as various *Coronaviridae* spp. or *Mycobacterium tuberculosis*), water sources and fecal-oral routes (such as *Vibrio cholerae* and *Escherichia coli*), or a combination of the above (Guthman 1995; Meade and Emch 2010; Morawska and Milton 2020; Patz et al. 2004; Roberts and Buikstra 2003; Roberts and Manchester 2007).

Humans have carried some pathogens for a very long time, often referred to as "heirloom" species, such as *Helicopter pylori*, *M. tuberculosis*, and various intestinal parasites (Darling and Donoghue 2014; Larsen 1995, 2018). Many of these pathogens were previously assumed to have been acquired from domesticated animals and are therefore relatively recent additions to the human microbiome. However, new genetic research shows that humans more likely acquired them from wild animals (in particular, felids) long before animal domestication (Araújo et al. 2011; Harper and Armelagos 2013; Pearce-Duvet 2006; Tietze et al. 2019). Zoonotic diseases often transfer to humans after repeated interactions with the animal carriers (Muhlenbein 2016), elevating risk for both foraging groups hunting wild animals and groups with domesticated animals.

However, human relationships with heirloom and more recently acquired pathogens have changed dramatically over time, as human groups moved to new regions, encountered new ecosystems, and—perhaps most significant—modified landscapes and ecosystems to support human settlement and use (Barrett et al. 1998; Cohen and Armelagos 1984; Cohen and Crane-Kramer 2007; Pearce-Duvet 2006; see also Quintus et al., chapter 9, this volume). The transition to agriculture is linked to increases in human population density, close association with domesticated animals, and sedentary settlements (although the mechanism and timing of these developments have varied over time and space). Each of these processes revolutionized the microbe-scape humans lived in, no matter when or where they occurred. By fundamentally changing the overlapping ranges of pathogens, vectors, reservoir hosts, and human hosts, humans living in sedentary and/or agricultural communities altered disease landscapes in irrevocable ways.

Sedentary lifestyles of both foragers and farmers have historically led to increased infectious disease and parasitic loads (Barrett et al. 1998; Cohen and Armelagos 1984; Cohen and Crane-Kramer 2007; Darling and Donoghue 2014; Kent 1986; Larsen 1995, 2018; Larsen et al. 2019; Reinhard et al. 1985; Walker 1986). As a result of living in permanent villages, people confronted with issues of sanitation and increased contact with feces facilitated the transfer of intestinal parasites (Blom et al. 2005; Larsen et al. 2019; Reinhard et al. 1985). While many intestinal parasites were not novel to agricultural or sedentary groups (Araújo et al. 2011; Harper and Armelagos 2013; Pearce-Duvet 2006; Tietze et al. 2019), the frequency of transmission and risk of human exposure generally increased with denser populations and permanent settlements.

Sedentary living also facilitated the emergence and maintenance of new pathogens. Larger and denser sedentary populations could sustain epidemics, and pathogen circulation within dense populations could permit transformation to endemic forms (Armelagos et al. 1991; Larsen 2018; Patz et al. 2004). For example, measles (*Variola* spp.) requires large populations to support spread and circulation. Most closely related to bovine rinderpest and canine distemper, it is likely that the viruses that cause measles emerged from the creation of sedentary settlements and dense populations (McNeill 2010; Pearce-Duvet 2006). More recently, SARS-CoV-2 has been able to circulate globally and to have sustained infection rates, partially because of densely occupied spaces and rapid international travel (Kraemer et al. 2020; Morawska and Milton 2020). Both measles and coronavirus demonstrate how human behaviors and settlements can create and maintain disease spread.

Increased pathogen load and endemic childhood infections decrease bodily resources available for growth and development during childhood as the immune system demands more energy to fight off infection (McDade et al. 2008; Scrimshaw

2003; Scrimshaw et al. 1959). This relationship between nutrition and infection is particularly problematic for agricultural groups, as they are often at higher risk of more catastrophic food shortages. Farmers tend to consume a narrower range of resources than foragers or those using a mixed subsistence strategy, and the risk of crop failures or shortages is more severe. Plants themselves are susceptible to their own pathogens, as the density of agricultural field plants actually elevates the likelihood of experiencing epidemics of plant diseases (Stukenbrock and McDonald 2008). Surplus and grain storage may mitigate short-term food shortages caused by plant disease or other crop failures; however, recurring or long-term shortages can exhaust these supplies, leaving few alternatives. In addition, stored resources attract commensal pests, which may destroy stored human food stocks and are often themselves vectors for diseases (Armelagos et al. 1991).

It is clear that settlement patterns and reliance on agricultural products impact human exposure to pathogens in several ways. Human subsistence strategies and agriculture in particular are major drivers of human pathogen load because they are responsible for "(a) changing the transmission ecology of pre-existing human pathogens; (b) increasing the success of pre-existing pathogen vectors, resulting in novel interactions between humans and wildlife; [and] (c) providing a stable conduit for human infection by wildlife diseases by means of domesticated animals" (Pearce-Duvet 2006:378). However, these patterns are regionally, temporally, and culturally specific; and they depend on what resources humans exploited, the previously existing pathogen load, and other cultural practices that may have amplified or mitigated disease (Pinhasi and Stock 2011). To look at the impact of subsistence and settlement pattern change in situ, we present a case study from the Titicaca Basin of Bolivia and discuss potential microbe-scapes for foraging-herding populations and newly sedentary horticulturalists.

TITICACA BASIN MICROBE-SCAPES

Microbe-scapes in the Titicaca Basin are greatly impacted by the local ecology. Lake Titicaca is at high altitude, approximately 3,810 m above sea level, yet it has a warming effect on the local ecology, raising local temperatures by approximately 8°C (Chávez 2012; Stanish 2003). This makes the lake and surrounding areas hospitable for diverse plant and animal life. The lake itself is home to several indigenous species of catfish and other small fishes, frogs (including the 1 kg Titicaca frog), and many aquatic plants including algae and totora reeds (Erickson 2000; Junk 2007; Miller et al. 2010). The hillsides surrounding the lake reach over 4,200 m above sea level and include patchy grassland used by wild grazers (deer and wild camelids such as vicuña), domesticated camelids (llama and alpaca), and smaller mammalian and reptilian predators and prey (Andean cats, foxes, viscachas, wild and domesticated guinea pigs, and other small rodents and reptiles; Erickson 2000; Hutterer 2001; Moore et al. 1999).

The wild and domesticated animals of the lake basin are certainly not immune to pathogens. Modern catches of indigenous fish show that they carry parasites transferrable to humans; while archaeological studies have not documented these same parasites, paleoparasitology studies from other parts of Latin America have confirmed the presence of various parasitic species linked to fish and mollusk consumption (Araújo et al. 2011; Morrow and Reinhard 2016; Patrucco et al. 1983). In addition, mummified guinea pigs and dogs from prehispanic Peru show that these animals carried fleas that would have been able to spread plague and other flea-borne diseases (Dittmar et al. 2003). Both guinea pigs and camelids carry various intestinal parasites with the potential to spread to humans either through eating infected meat or through contact with animal feces (García J. et al. 2013; Kouam et al. 2015; Saeed et al. 2018). Finally, felid coprolites from Patagonia showed a diversity of parasites, many of which could have been transmitted to humans through close contact or sharing cave dwellings (Tietze et al. 2019).

While not all of these zoonotic pathogens will ultimately cause disease in humans, it is clear that close and repeated human contact with animals elevates risk of pathogen gene swapping and allows microbes to adapt to human physiology (Muehlenbein 2016). In fact, a modern study near Cusco, Peru, shows that children who spend significant time with llama and sheep herds share more similar gut bacteria and viruses with the animals than with non-herders in the region (Rojas et al. 2019). Similarly, peri-urban children in Lima, Peru, share a gut parasite, *Giardia lamblia*, with dogs living in the same area, likely because of infected water sources and close contact between animals and children (Cooper et al. 2010). Thus, we would expect that humans in the Titicaca Basin with exposure to animals would share some of their pathogens.

People have lived in the Titicaca Lake Basin for at least 10,000 years. During the late Preceramic Period (3000–1500 BCE), people relied on foraging wild resources (including hunting wild deer and camelids), fishing and collecting other lake resources such as aquatic plants and frogs, and harvesting wild crops and tubers. Isotopic analyses from late Preceramic peoples indicate a diet high in protein (Juengst et al. 2021), supported by evidence of lithics associated with hunting and faunal remains of wild animals (Craig 2011; Craig et al. 2010; Haas and Viviano Llave 2015; Juengst et al. 2017a). These people likely moved regularly throughout the lake basin and into lower regions (Capriles et al. 2014, 2016; Haas and Viviano Llave 2015). Around 1500 BCE, people in the Titicaca Basin were in the process of domesticating camelids to supplement their otherwise wild diet and to make use of other camelid resources, such as wool and dung (Aldenderfer 1989; Craig et al. 2010; Moore et al. 2007).

In the Early Horizon (EH) (1000 BCE–1 CE), people in the Titicaca Basin began to grow domesticated plants, thus supplementing their foraging, hunting, herding, and fishing activities. Some of the first plant domesticates included quinoa (Bruno and Whitehead 2003) and tubers such as potatoes and oka (Aldenderfer 1989). While these plants quickly became important to the diet, large quantities of fish were also consumed, as evidenced by fish bones and scales present at EH archaeological sites and isotopic signatures consistent with diets high in lake fish (Capriles et al. 2014; Juengst et al. 2021; Miller et al. 2010; Moore et al. 1999).

The household-level cultivation of plants was associated with the establishment of sedentary settlements, terraced field complexes, and civic architecture—all of which became increasingly elaborate during the Early Intermediate Period (EIP) (1–500 CE; Bandy 2004; Bruno and Whitehead 2003; Capriles et al. 2014; Chávez 1988; Chávez 2004; Roddick et al. 2014; Moore 2011; Moore et al. 2007). Quinoa and newly introduced maize became more common throughout the lake basin (Bruno and Whitehead 2003; Chávez and Thompson 2006; Murray 2005; Stanish 2003; Whitehead 1999). This reliance on terrestrial plants complemented a decrease in fish consumption (Capriles et al. 2014; Juengst et al. 2021).

It is clear from the archaeological evidence that diets and subsistence strategies shifted between the Preceramic and the EH/EIP. Alongside these dietary changes, people were modifying the landscape, creating terraces and permanent dwellings. All of these changes would have impacted the microbe-scape as well. Preceramic foragers were likely exposed to various zoonotic pathogens by eating lake fish and other wild animals, and they increased their exposure as they spent more time with camelids. As EH and EIP peoples began to rely on domesticated crops and animals and to permanently live in one place, they escalated their exposure and risk of zoonotic disease.

Skeletons and Disease

Human skeletons preserve records of disease and infection in a few ways. Briefly, long-term bodily stress and presence of infectious pathogens can produce proliferative bony reactions on the surface of long bones (called periosteal reactions) and potentially infiltrate the medullary cavity of long bones (creating a condition called osteomyelitis; Larsen 1997; Ortner 2003). In addition, childhood stress episodes from malnutrition and infection can disrupt the production of dental enamel, creating dental lesions called linear enamel hypoplasia (Armelagos et al. 2009; Boldsen 2007; Larsen et al. 2019; Hillson 1996). Malnutrition and disease experiences

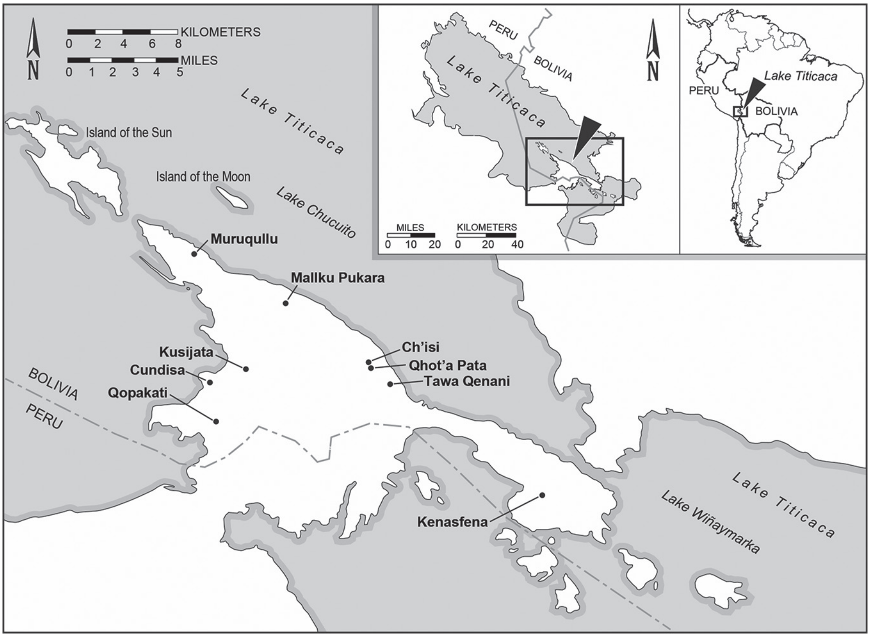

Figure 6.1. Map of the Copacabana Peninsula and relevant archaeological sites. Map drawn by Susan Brannock-Gaul.

during childhood can also prevent individuals from attaining their potential adult height. While adult stature is controlled by a number of factors, including genetics and environment, a comparison of stature between two groups with similar genetic backgrounds and in similar environments may thus reveal differences in these childhood insults (Larsen 1995). Few diseases leave specific fingerprints on skeletal remains; however, we can reconstruct broad patterns of infectious disease using this combination of indictors (Larsen 1997; Ortner 2003).

To investigate pathogen loads in the Titicaca Basin, we analyzed human skeletal remains excavated from seven sites around the Copacabana Peninsula (Chávez 2004, 2008; Chávez and Chávez 1997; figure 6.1). This included 14 individuals associated with foraging, herding, and fishing subsistence strategies during the late Preceramic Period and 129 individuals associated with mixed fishing and agricultural strategies during the EH and the EIP. While the foraging sample size is significantly smaller than the agricultural sample, both samples included male and female adults and juvenile individuals.

We compared the skeletal evidence for infectious disease between these groups based on the presence of periosteal reactions, osteomyelitis, and linear enamel hypoplasia. The presence and appearance of these lesions were recorded through macroscopic observation following bioarchaeological standards (cf. Buikstra and Ubelaker 1994; Ortner 2003). Linear enamel hypoplasia were also documented using a Dino-Lite Pro AM413T Microscope Camera. We also compared average statures for these groups as a proxy for childhood growth and development. To calculate stature, we measured maximal length of intact femora whenever present. When both femora were present for an individual, we measured both bones and averaged the results. Then, we used the formula for Andean groups suggested by Emma Pomeroy and Jay T. Stock (2012) to convert femoral length to approximate adult stature.

Statistical tests were used to compare paleopathological lesion frequency and stature estimates between time periods and within a time period based on sex estimates. We used Pearson's Chi-squared t-tests to compare lesion frequency between groups, where $p \leq 0.05$ is considered a significant correlation between variables. To compare stature, we tested for statistical outliers using Grubb's test for outliers and unpaired t-tests to compare between time periods and between sex estimate categories (Couderc 2007; Xu et al. 2017).

Forager and Farmers: Differentials of Health

Among the Preceramic (PC) group (n = 14) in our sample, there were two individuals with periosteal reactions (14.3%) and no evidence of osteomyelitis or linear enamel hypoplasia (table 6.1, figure 6.2). Average stature was 164.2 cm and ranged from 148.8 cm to 176.2 cm (table 6.1, figure 6.3). Males were generally taller than females, although unpaired t-tests indicate that this correlation is not significant ($p = 0.2669$). One individual was several centimeters shorter than the rest but was not a statistical outlier based on Grubb's test.

Among the subsequent EH and EIP burials (n = 129), there were 49 individuals with periosteal reactions (43.75% of 112 observable individuals), 7 with osteomyelitis (6.25% of 112 observable individuals), and 23 with linear enamel hypoplasia (17.8% of 129 observable individuals; table 6.1, figure 6.2). Average stature was 158.7 cm and ranged from 145.6 cm to 173.2 cm (table 6.1, figure 6.3). Males were significantly taller than females ($p = 0.0009$) based on unpaired t-tests, indicating that sex was significantly linked with stature during this period. No individuals were statistical outliers for height.

There were statistical differences in paleopathology between time periods. Periosteal reactions were significantly more common during the EH and EIP based on Pearson's Chi-square tests ($p = 0.034211$; $p \leq 0.05$ is considered significant). There were numerical differences in osteomyelitis (no cases for the PC sample,

Table 6.1. Frequency and percent of Preceramic and Early Horizon/Early Intermediate Period groups affected by skeletal and dental lesions (LEH = linear enamel hypoplasia), and stature averages and ranges for both groups. Stature calculated based on Pomeroy and Stock 2012 (females: 48.34 + [max fem length × 2.593], males: 44.803 + [max fem length × 2.738]).

Period	*Periosteal Reactions*	*Osteomyelitis*	*LEH*	*Stature Average*	*Stature Range*
PC	2/14 (14.3%)	0/14	0/14	AVG: 164.2 CM MALE: 171.8 CM FEMALE: 156.6 CM	TOTAL: 148.8–176.2 CM MALE: 166.6–176.2 CM FEMALE: 148.8–164.8 CM
EH/EIP	49/112 (43.75%)	7/112 (6.25%)	23/129 (17.8%)	AVG: 158.7 CM MALE: 166.6 CM FEMALE: 151.8 CM INDETERMINATE: 157.9 CM	TOTAL: 145.6–173.2 CM MALE: 158.9–173.2 CM FEMALE: 145.6–157.0 CM INDETERMINATE: 157.9 CM

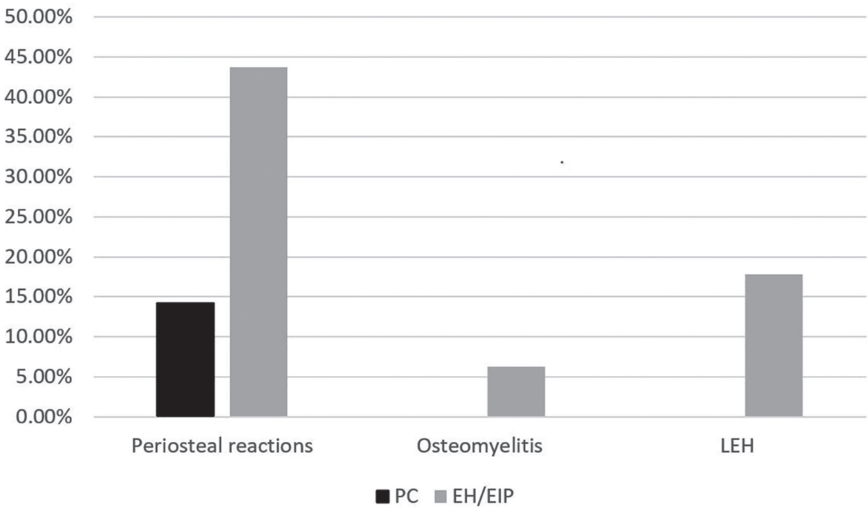

Figure 6.2. Percent of sample affected by pathological lesions for Preceramic (PC) and Early Horizon and Early Intermediate Period (EH/EIP) groups

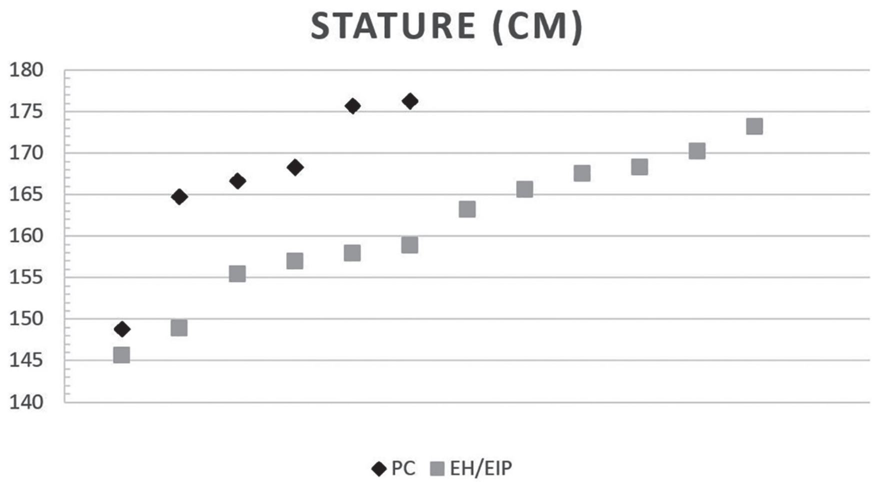

Figure 6.3. Range of heights (cm) plotted for Preceramic (PC) and Early Horizon and Early Intermediate Period (EH/EIP) groups

seven in EH/EIP) and linear enamel hypoplasia (no cases for PC, twenty-three in EH/EIP), although these were not statistically significant. There were no significant differences in lesion frequency between demographic groups during either time period.

Unpaired t-tests for stature indicated a statistical difference in stature ($p = 0.0103$) between periods, with EH and EIP individuals significantly shorter than PC individuals. This difference was not tied to one sex group, that is, there were no statistical differences between Preceramic females and EH/EIP females or between PC males and EH/EIP males. However, EH/EIP females were significantly shorter than EH/EIP males ($p = 0.0009$), based on unpaired t-tests. Stature differences between males and females in the sample overall also approached significance based on unpaired t-tests ($p = 0.0514$). This suggests that some of the stature differences were correlated with sex and time period.

DISCUSSION

Differences in pathological lesions and stature suggest that Titicaca Basin foragers and farmers experienced different microbe-scapes. Preceramic Period individuals were significantly less likely to develop periosteal reactions and more likely to achieve greater adult stature. These patterns of paleopathology and stature suggest that they encountered fewer stress-inducing pathogens, despite their regular interactions with animals. It is possible that a lack of pathology reflects rapid mortality, with these individuals dying from diseases prior to forming lesions (Wood et al. 1992). While we cannot entirely reject this scenario, the overall height and robusticity of the Preceramic individuals suggest that they were overall well-nourished and physically fit and that they should have been able to combat infectious disease. Likely, the lack of pathology among Preceramic foragers related to their residential mobility, which limited parasitic load and re-infection of individuals from others or animals.

Conversely, Early Horizon and Early Intermediate Period peoples lived in permanent villages and increased their contact with domesticated animals, including camelids and guinea pigs. The increase in periosteal reactions and decrease in adult stature suggest that this group was exposed to more pathogens and suffered from infectious disease more regularly. Notably, the rate of periosteal reactions observed for this group (44%) is higher than for many other forager and agricultural Andean groups (Andrushko et al. 2006; Gómez Mejía 2012; Klaus and Tam 2009; Lowman et al. 2019; Suby 2020; Ubelaker and Newson 2002; Williams and Murphy 2013). While rates of osteomyelitis and linear enamel hypoplasia were not statistically more common among EH and EIP burials, it is notable that the Preceramic individuals did not present either of these conditions. This may be a sample size issue, but given the increase in periosteal reactions and decrease in stature, we suggest that these lesions reflect a true difference in experiences with infection and childhood stress.

The new subsistence strategies and settlement patterns of EH and EIP peoples created opportunities for microbe transmission that were enhanced through sedentism. While we cannot determine exactly what microbes were causing disease for this group, we can imagine that changing contact rates with other people and animals and physically changing the landscape created new microbe-scapes unique to this place and time. For instance, direct transmission of pathogens from animal to human or human to human was possible based on new subsistence and settlement patterns. With domesticated guinea pigs and camelids, people spent more time near these animals, providing more opportunities for zoonotic diseases to mutate into human pathogenic forms (Muehlenbein 2016).

In addition, as seen elsewhere, sedentary settlements promoted waste accumulation that people with more mobile lifeways avoided. Additional risks for new EH and EIP farmers may have included the use of waste as fertilizer for newly created agricultural terraces (Chávez 2012) and/or camelid dung as a fuel source (Moore et al. 2007). Since wood is scarce at this altitude, camelid excrement may have been seen as a convenient fuel source and as relatively easy to collect from domesticated herds (Moore et al. 2007). By interacting more closely and regularly with human and animal fecal matter, risk of pathogen exposure and likelihood of transmission were elevated for these farmers.

Decreases in stature associated with agriculture are commonly documented around the world (Cohen and Armelagos 1984; Larsen 1995; Mummert et al. 2011) and in South America as well (Ubelaker and Newson 2002; Verano 1997). Traditionally, these decreases in stature have been broadly linked to the poor nutrition most commonly available from agricultural diets. Recently, Jonathan C. K. Wells and Jay T. Stock (2020) argued that the increased burden of disease associated with sedentary settlements and the change in diet prompted adaptations in life history and growth trajectories, with bodies allocating more energy toward reproduction and immune defense rather than investing in maintenance or growth. This interpretation also accounts for increased periosteal reactions as evidence of stronger immune defenses, as people were able to combat pathogens longer (Wells and Stock 2020). In brief, the increased burden of infectious disease with sedentary settlements prompted a lifelong adaptive change in resource allocation that has global implications.

Across the Andes, while some parasites had great antiquity, the frequency of intestinal parasite infection likely increased with sedentary settlements and agricultural diets (Verano 1997). Interestingly, this has not always coincided with decreases in overall health; there was no documented paleopathological change after the introduction of agriculture and camelid pastoralism in coastal Chile (DiGangi and Gruenthal-Rankin 2019). Continued health in that case was attributed to ongoing use of marine resources, which buffered the stress of agricultural diets. It is also possible that parasitic load was already elevated prior to the introduction of agriculture, based on evidence of fish-borne parasites (Araújo et al. 2011). In the Titicaca Basin, we also do not observe a decrease in nutritional health (Juengst et al. 2017b); however, in this case, it does not seem that adequate diets were able to buffer the other stresses of sedentism.

While stature decreased overall for EH and EIP peoples, females were especially impacted. Interestingly, during the Preceramic, there was no statistical difference in stature between male and female individuals. While humans typically do exhibit some sexual dimorphism in height, patterning of human sexual dimorphism is tied to many variables such as genetics, diet, and climate (Gray and Wolfe 1980; Gustafsson and Lindenfors 2009). Here, a new trend in sexual dimorphism emerged during the EH and EIP, with particularly short females. This could be due to a number of factors. First, EH and EIP females may have been particularly at risk of childhood infections or malnutrition, stunting their stature attainment. However, pathological lesions do not vary significantly between male and female individuals, and previous isotopic studies do not show significantly different diets for males and females during this time (Juengst et al. 2021).

Another possible explanation is the energy toll of menarche and pregnancy. This correlates with Wells and Stock's (2020) life history hypothesis: due to the elevated pathogen load and changed nutritional source, energy was devoted to reproduction over growth. Rather than accelerating growth in stature during adolescence, female bodies may have diverted energy toward supporting reproductive processes and immune defense. Males may not have experienced these pressures as strongly, as their bodily energy investment in reproduction is comparatively less (Ellison 2003). Thus, adult females experienced growth stunting more strongly than males, reflected in the stature differentials presented here.

CONCLUSION

Overall, we can see that Preceramic foragers and EH and EIP agricultural communities navigated different microbe-scapes, which influenced the health and energy allocations of these peoples for both individuals and groups. Preceramic foragers were not immune to pathogens, likely acquiring parasites from wild camelids, cats, and fish through eating contaminated meat and exposure to feces. However, it is clear that the shift toward sedentary settlements and associated increases in contact with other people, domesticated animals, and fecal matter elevated pathogen load for EH and EIP communities. The combination of exposure to zoonoses, waste, and increased circulation of pathogens between sedentary groups likely resulted in elevated pathogen load for EH and EIP peoples, as reflected by the increase in lesions and decrease in height.

Even though most pathogens are not visible to the human eye, they are capable of having dramatic effects on human lives. Human relationships with these tiny organisms correlate with relationships to other natural forces, including animals, plants, and landscapes. These relationships can promote or limit the impact of disease on human groups, depending on how humans structure their economic, political, and social settings. Importantly, rarely do diseases affect groups evenly—some members of society (in this example, females) often feel the weight of pathogenic burdens more heavily. Understanding how human habitats and lifestyle choices alter microbe-scapes is vital because current human groups still struggle to prevent and control disease outbreaks and because these patterns can potentially reveal underlying social inequities in human societies.

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7

Vegetative Agency and Social Memory in Houselots of the Ancient Maya

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ABSTRACT

It is difficult to pin down the definition of a weed; rather, the idea of a weed is constructed through a set of characteristics that are, for the most part, dependent on context and relative interactions. Following existing literature, we describe this dynamic, ongoing construction as a product of the agency of both people and plants. We interpret studies of ancient Maya agricultural techniques through the lens of plant agency and human-plant relations and aim to investigate the placemaking of garden landscapes through an analysis of both helpful and destructive "weed" agencies in traditional planting and weeding practices. Using new LiDAR data from the ancient Maya site of Coba, we examine the spaces in and around houselots, sometimes called "toft zones," to look at time management and placemaking at different temporal scales. The result is a view of how weeds participated in ancient Maya agricultural landscapes, as well as a new appreciation for how certain plants impacted daily time management schemas and contributed to generational social memory.

Vegetation is usually considered to be the epitome of the "natural world." But vegetative landscapes, like other landscapes, are culturally constructed. This becomes most apparent when focusing in on those plants commonly referred to as "weeds." Weeds defy cultivation and maintenance, but they are brought into existence by an imposed cultural interpretation defined by these same processes, resulting in a paradox. As such, it is difficult to pin down the definition of a weed; rather, the idea

https://doi.org/10.5876/9781646423521.c007

of a weed is constructed through a set of characteristics that are, for the most part, dependent on context and relative interactions: place, time, and intention (e.g., Doody et al. 2014; Harlan and de Wet 1965:17, table 1).

Here, we consider the placemaking of agricultural landscapes through an analysis of how "weed" agencies would have contributed to everyday life in the houselots of ancient Coba, a large Classic Maya urban center in Quintana Roo, Mexico. Using new LiDAR data, we analyze two houselots at Coba, as both an experimental test of the technology's utility in visualizing houselot terrain and as part of the larger intention of understanding weed agency as it would have been experienced in the houselot. LiDAR is found to be a useful predictor of exposed bedrock, and combined usage of these data with those collected through visual inspection allows us to assess the tableau of nature within which humans engaged with both purposeful and unplanned vegetation.

WEEDS

Kristen J. Gremillion (1993:506), in a study of *Chenopodium* seed morphology in the Eastern Woodlands, emphasized that the distinction between wild and cultivated seeds is a spectrum involving a "crop/weed complex" in which weeds have actually affected the evolution of the cultivated plants (see also Baker 1974:12–13). This complex problematizes the distinction between uncultivated and cultivated plants, or weeds and crops, which becomes even more intricate when domestication is added to the equation (see also Alcorn 1984:324–327). Similarly, Robert A. Bye Jr. (1981:118) notes that weeds and domesticated plants are *both* "end products of genetic and ecological alterations mediated by human activities" (see also Casas et al. 2007). So, how can one define a "weed?" Although most people would probably agree that they understand the term, definitions of weeds can be extremely varied (see Harlan and de Wet 1965) depending on whether they are contingent upon plant part morphology (e.g., Gremillion 1993), plant behavior and/or characteristics (e.g., Baker 1974; Doody et al. 2014:126, table 1; Harlan and de Wet 1965; Radosevich and Holt 1984), or the continuously navigated interactions between people and plants that in themselves construct the plant's identity as a weed (e.g., Doody et al. 2014; Radosevich and Holt 1984:1–2).

Botanist Herbert G. Baker (1974:1) wrote that "definitions of a weed are almost as numerous as the authors of papers dealing with them." He employed his previously published definition, which outlined a weed as the following: "In any specified geographical area, its populations grow entirely or predominantly in situations markedly disturbed by man (without, of course, being deliberately cultivated plants)" (1). This biological definition is striking in that it logically lists contextual (and social) variables needed to define a weed: space, disturbance (e.g., building, clearing, or agriculture), and intention. Furthermore, because weeds enjoy disturbed environments, people (perhaps despite their strongest wishes) are constantly creating weeds' ideal habitat (Harlan and de Wet 1965)—necessitating follow-up practices of "weeding" as a process of removal. Finally, the definition of a weed is especially difficult to standardize when we consider that weeds are also often useful plants (Bye 1981; Kawa 2016; Stepp 2004). Because of these factors, the term *weed* itself, as a supposedly standardized classification of plants, may be misleading. We use the term *weeds* here to refer to "volunteer" plants—thus not excluding those plants that are then used by people (e.g., Dine et al. 2019).

Within biological literature, weeds have been discussed in terms of their relationships with humans (Harlan and de Wet 1965; Radosevich and Holt 1984:v, 1–2). Since people use weeds for medicinal and other purposes (Kawa 2016; Stepp 2004), both parties benefit from the relationship, though in different ways. Through use of the descriptors "obligatory" versus "facultative," Jack R. Harlan and J. M. J. de Wet (1965:20) outline a spectrum of how closely tied different plants might be to human-made spaces and places. It is useful here to consider commensal organisms, which Elizabeth Matisoo-Smith (2009:152) defines as "animals living in close association to humans," providing as examples species such as pigs and rats. Commensal animals are often used to track human migration or the movement of domesticated species (e.g., Fuller and Boivin 2009; Matisoo-Smith 2009; Storey et al. 2013; see also Ammerman, chapter 10; Quintus et al., chapter 9; and Tomášková, chapter 11; all this volume). Dorian Q. Fuller and Nicole Boivin (2009:10) in particular look at weeds as an analogous way to investigate agricultural plant species.

A closer look at the weed/non-weed relationship demonstrates that it is less straightforward than it might immediately seem, especially with respect to the attribution of agency to one party or the other. A commensal organism is not necessarily in a commensal symbiotic relationship, which is defined as a relationship that benefits one party and does not affect the other (Radosevich and Holt 1984:126). Commensal organisms most certainly benefit from spaces they share with humans, but they also actively influence the very nature of that relationship in ways both positive and negative—for example, rats carry diseases that can be dangerous to humans. There is no way to neatly categorize or quantify this entanglement. Similarly, assuming that weeds are the only party affected by their relationship with humans may be denying them their agency or at least the effects they have on the lives of people. These plants are an important resource and serve as or for food, medicine, animal forage, soil nutrient deposition, and erosion prevention (e.g., Alcorn 1984:327–336; Bye 1981; Casas et al. 1996; Fujisaka et al. 2000; Kawa 2016; Vieyra-Odilon and Vibrans 2001). In fact, edible or useful weeds are a category of plants referred to as quelites, originating from the Nahuatl word *quilitl* (Bye 1981; Casas et al. 1996; Vieyra-Odilon and Vibrans 2001).

The study of ancient weeds proceeds according to the same methodological protocols as the study of ancient domesticated plants, as part of the range of plant remains recovered from excavations (Fuller and Boivin 2009; see also Slotten 2015:127). Paleoethnobotanists—archaeologists who study plant remains—examine seeds, charcoal, plant parts, starch grains, phytoliths, and pollen as categories of macro-botanical and micro-botanical evidence for various types of ancient plant use (e.g., Dussol et al. 2017; Marston et al. 2014; Pearsall 2015; Piperno 2006). Christopher T. Morehart and Shanti Morell-Hart (2015) have called for a more social approach where plants can be interpreted in a light similar to a potsherd or an obsidian flake, in which relative perceptions of utility or value are context-dependent.

VEGETATIVE AGENCY

One of the most common areas in which discussions of vegetative agency come into play in archaeology is within studies of domestication. Melinda A. Zeder (2012:162) has reviewed some of these approaches, noting that "the primary difference between different definitions of domestication lies in the degree of emphasis placed on either the human or the plant/animal side of the equation." BrieAnna S. Langlie and colleagues (2014) provide a useful review of some of the ways archaeologists can access questions of plant domestication, including assessments of morphological evolution in plant parts, documentation of micro-botanical plant remains, and considerations of taphonomic processes (see also Smith 2001). They note that domestication is often conceptualized as "coevolution," but their discussions of agency revolve around humans (Langlie et al. 2014:1611–1612). Marijke van der Veen (2014:801) challenges such approaches to domestication, asserting that "while the process of domestication has often been regarded as a process brought about by people, we might equally consider it something that plants and animals have done to us."

Contemporary studies of weeds and weeding provide insights into the ways people engage with intentional and unintentional plants. Working in Christchurch, New Zealand, Brendan J. Doody and colleagues (2014:125, original emphasis) use Judith Butler's work on performativity to consider how "rather than having a prefigured meaning, weeds are *performed* together by people and plants." The implication of considering a category of plants in this manner is that their meanings at any given moment are heavily based on context. However, people in Christchurch do not simply decide which plants will become "weeds" but instead react to qualities of the plants themselves in association with other spatial factors (Doody et al. 2014). Doody and colleagues' conceptualization of people-plant interactions reflects a give and take that defines the identity of weeds. Somewhat differently, Guntra A. Aistara (2013) found that a socially (and institutionally) ingrained definition of weeds caused Latvian farmers to be wary of permaculture strategies, which embrace those plants as part of the landscape.

Alternatively, Nicholas C. Kawa (2016:89–91), working in rural Brazil, has observed the "weedy" characteristics of many medicinal plants in people's house gardens. Interestingly, these weeds are caught up in cultural and religious practices in the area—an important example of how being forced to react to the materiality of a plant is in some ways a manifestation of its agency (Kawa 2016; see also Jones and Cloke 2008). In another example, ethnobotanical research with the Teenek of northern Mexico led Janis B. Alcorn (1984:324–327) to reject classification by imposed terms such as "domesticated" or "cultivated" and to question spatial designations that leave no room for the fluidity and messiness of everyday life among plants. The category of "spontaneous vegetation" is used rather than the word *weeds* (327–328). Finally, as demonstrated in John Charles Ryan's (2012:113–115) case study of the West Australian Christmas Tree, a "human-plant studies" approach draws on a variety of scholarship, including Western science as well as Indigenous knowledge and practices, to conceptualize a network of interaction with plants as agentive beings. What these examples emphasize are the effects of (1) materiality and (2) social context on local interpretations of weeds.

Thinking about weeds raises the question of what it means for a plant to belong—or not belong—in a certain place and the spatial and environmental politics implicated in attempting to answer this question (Besky and Padwe 2016; Head et al. 2014). In considering Tim Ingold's (1997:250) approach to the theorized dichotomy between what is "natural" and what is "social," human agency is not eliminated; we instead embrace a foundational premise that the way we experience "nature" is also social. Ingold's evaluation of the problem provides necessary nuance as he writes that "one cannot get rid of a troublesome dichotomy, such as that between nature and society, simply by collapsing one side into the other" (250). Following Ingold, we evade the dangers involved in approaches such as actor network theory, which Robert W. Preucel (2012:17) has warned involve a move away from "the social." Furthermore, regardless of whether we conceptualize nature socially, the materiality of natural processes is real (Jones and Cloke 2008:94). When agentive decisions made by humans are in reaction to environmental phenomena, those phenomena must be considered important forces (see Smith, chapter 1, this volume). This is not to deny the profound effects of human agency; rather, it is to place human agency in context and acknowledge real influences on our decision-making processes (Ingold 1997; Jones and Cloke 2008).

Furthermore, Clark L. Erickson (2010 [2008]) has emphasized that landscapes seen as "natural" have long been managed by people; the idea of wilderness as separate from and opposed to human activity can even hinder conservation efforts (Ardren et al. 2015; Gómez-Pompa and Kaus 1992). Humans and crops similarly exist in the same environment as weeds (see also Ingold 1997:244). There is also a philosophical-botanical avenue of approaching the agency of plants from plants' points of view, encompassed in theoretical notions of consciousness as well as quantitative assessments of communication (Calvo 2017; Gagliano 2013; Marder 2012). We find this particular realm of engagement with plant agency useful to think with, but we turn to more context-specific understandings of plants to conceptualize how people might have engaged, at a macroscopic level, with weeds at ancient Coba. As Stephen Houston (2014:78) notes, Classic Maya understandings of animacy operate within a contextualized worldview or cosmology given that "Maya evidence . . . pushes and concentrates energy in all manner of ways."

PLANTS AND PEOPLE IN THE MAYA WORLD

Paleoethnobotanical studies of ancient Maya agriculture and plant foods have yielded information about the use of a wide variety of species, including the staples of maize, beans, and squash, as well as garden plants like chile and bush spinach and tree crops such as mamey, avocado, and nance (Lentz 1999; Ross-Ibarra and Molina-Cruz 2002). In addition to house gardens and orchards or areas designated for plant cultivation, the Maya would have maintained what Arturo Gómez-Pompa (1987:6, table 1) calls " 'Natural' forest ecosystems," again highlighting the fluidity between the "natural" landscape and the constructed one. Such engagement with and embeddedness in the surrounding natural world (or socially constituted nature) would have given the ancient residents of Coba direct and extended experience with the relentless, creeping growth of plants (e.g., Besky and Padwe 2016:21) as well as garden constituents that required both care and caution (Ardren and Miller 2020). In fact, imagery from elite Maya ceramics highlights the active role of many culturally important plants by depicting them in a "personified" manner (Houston and Scherer 2020).

Archaeological data from the site of Joya de Cerén, destroyed and preserved by a volcanic eruption, show that the ancient population grew a wealth of plant resources in their house gardens and, significantly, heavily relied on plants commonly described as so-called alternative resources (Lentz and Ramírez-Sosa 2002; Sheets et al. 2011; see also Slotten 2015). This perspective is bolstered by the work of Venicia M. Slotten (2015:116–121), who found significant amounts of weed seeds in paleoethnobotanical samples from agricultural contexts at Cerén and suggested that these plants may have been useful to residents. Were these plants simply left to grow, or were they carefully managed as part of the houselot landscape (Slotten, Lentz, and Sheets 2020)?

For the Classic Maya, spirit and personhood could be situated in various materials, objects, or entities (Harrison-Buck 2020; Houston 2014; Jackson 2019). Stone, as monumental fragmentation of the earth itself, was animate, a quality that could be more explicitly revealed by careful carving (Stuart 2010). Plants were sometimes portrayed as the living embodiment of past souls (Houston 2014:13). Materials imbued with life force were, "in their working . . . magical and revelatory, releasing by human craft the potentials promised by myth" (Houston 2014:98). Perhaps cultivation and farming over generations produced similar results in agentive plants. Today, some individuals among the Tzotzil Maya–speaking people of Chiapas define weeds by the fact that they "do not have good souls" (Laughlin 1993:105). The agentive properties of these plants are evident in the anger they feel upon being removed and the jealousy they feel toward those plants that were spared (106). In fact, an ethnobotanical work by Dennis E. Breedlove and Robert M. Laughlin (1993:463) has a section dedicated to "Plant Emotions." Karl Taube (2003:469) has cited some of these negative conceptions of weeds as supporting evidence for a notion among the Maya of an untamed and dangerous forest as distinct from civilization, where the "constant encroachment of weeds" is an ever-present reminder of what lies outside. However, it is not only "weeds" that show agency (Laughlin 1993:106); and Taube (2003:465, 485-486), too, recognizes the ambiguities that arise from attempts to apply a rigid separation of nature and culture to Maya conceptualizations of the environment, including the important role the "forest" played in daily life for the ancient Maya. Here, we consider previously published mapping data on houselots and analyze how LiDAR data may provide new insight into how certain plants—those classified as "weeds"—would have factored into daily life and time management in the northern Yucatán.

COBA

Coba is a Classic Maya site in the northern lowlands (Folan et al. 1983), located in the modern-day municipality of Tulum, Quintana Roo, Mexico (figure 7.1). The site played an important role in the Classic period (300–900 CE) as a royal dynastic polity that may have engulfed surrounding cities such as Yaxuna (e.g., Loya González and Stanton 2013), but it was also occupied in the Postclassic (1100–1500 CE) when many building additions were constructed (Andrews 1981:7–8). As an urban center, it contained centralized elite households and spaces that intersected with a radiating pattern of raised causeways (Folan et al. 2009; see also Andrews 1981:5). Plant resources were unevenly distributed within the city (Folan et al. 1979). William J. Folan and colleagues (2009:65) have suggested that Coba may have been a "garden city," citing the importance of "in-between" areas amid structures. An important resource at the site was *sascab*, or powdered limestone, extracted from *sascaberas*, which may have eventually become spaces used as gardens (Folan 1978; see also Folan 1983:24–25).

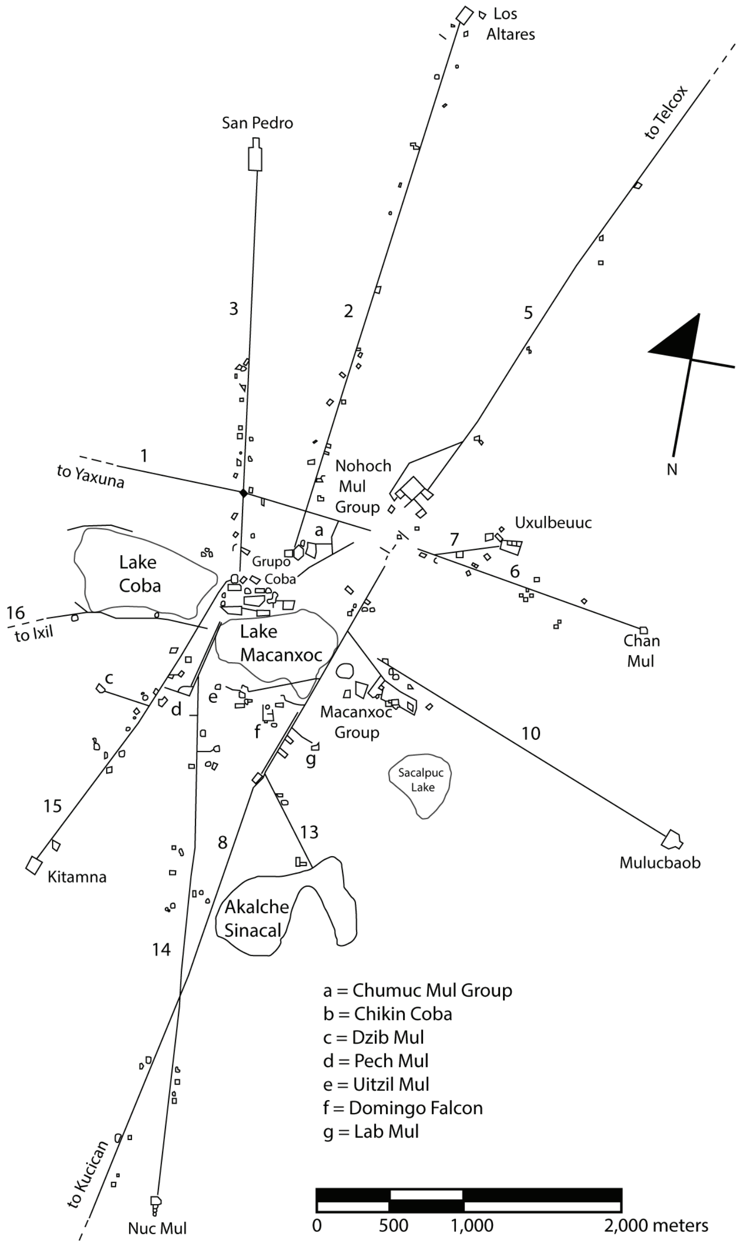

Figure 7.1. Map of the ancient Maya archaeological site of Coba, Mexico. Map redrawn from Loya González (2008:4), figure 3, after Benavides Castillo (1987:24), map 2.

Houselots, Social Memory, and Space

Much of Coba's settlement is partitioned into houselots, which were open areas attached to or surrounding residential structures enclosed by low stone perimeter walls (Fletcher 1983). Gardens, orchards, and infields were typically situated in houselots at Coba (Folan et al. 1983; Manzanilla and Barba 1990). Keeping these landholdings close to the house not only provided protection and sent a message of household ownership but also made it more convenient to keep up with the regular labor inputs of horticulture and intensive agriculture (Smith 2014:362; see also Nations and Nigh 1980).

Working at Chunchucmil, Yucatán, Scott R. Hutson and colleagues (2007) have described the importance of conducting analysis in "non-architectural space," emphasizing that these locations can provide valuable information about past ways of life. This conclusion was facilitated by Chunchucmil's visible houselot boundaries (Hutson et al. 2007; Magnoni et al. 2012), which are also an advantage in the study of Coba. In addition, Aline Magnoni and colleagues (2012) have described how the organization of houselots at Chunchucmil reflected simultaneous processes of both individuation and cohesion, as well as social memory. Similarly, in a study of houselots at three Maya sites in the northern lowlands, including Coba, Chelsea Fisher (2014:202) used calculations of non-architectural houselot area and number of houselot structures to assess the importance of "multigenerational houselot-based subsistence." As an indication of social memory at work, Fisher (208) emphasizes that it is important to view the houselot as a result of generations of decision-making processes about agriculture. One of the decisions and continual labor inputs related to houselot maintenance would have been the removal of weeds.

Weeding and the other tasks of the houselot garden were and remain a foundational part of a household's daily and seasonal labor. Ethnographic data from contemporary Maya houselot gardens provide clues for thinking about how people interacted with these spaces and about the plants that resided there—desired or otherwise—in the past. Scott L. Fedick and colleagues (2008) have described the practice of using depressions in bedrock for "container gardening" among modern Yucatec Maya–speaking people in the village of Naranjal. Furthermore, Lourdes Flores-Delgadillo and colleagues (2011) used the concept of "Maya precision agriculture" to describe the way people adopt farming practices that are specific to the landscape. These types of relational practices, likely also conducted in the past, reflect processes of dwelling (Ingold 2010 [1993]) and placemaking (Cloke and Jones 2001; Pierce et al. 2011; Rubertone 2008) that would have contributed to the construction of human-plant relationships and thus weeding practices, which, in turn, would have had a profound effect on the physical shaping of the landscape.

Victor M. Toledo and colleagues (2008) calculated that a typical modern Maya household invests almost 100 person-days of labor in gardening every year, which accounts for almost 20 percent of all annual household labor. In the wet months, weeding is viewed as the most important practice in the houselot garden (Benjamin 2000:75), another facet of the ways natural processes influence patterns of labor (see van der Veen 2014). By monitoring the effects of various garden management strategies, Tamara Jo Benjamin (2000) found that weeding can help desired plants improve rates of photosynthesis and sap flow as well as increase leaf nitrogen in some species. Weeding is an important part of Boserup's "intensive bush fallow" cultivation model, but significantly, the removed weeds themselves become an important part of the puzzle (Johnston 2003). Converted into mulch, they release nutrients into the soil that would otherwise be unavailable to cultivars, if not passed through their weedy metabolisms (146). Thus, though weeds must be actively removed from the milpa (a general term for non-mechanized subsistence farming, usually of maize), in this model they are also an indispensable part of the process. One must negotiate with their needs and capacities.

In an ethnographic study in highland Guatemala, Eric Keys (1999) noted that weeding was learned at a young age and that women often performed this task while multitasking with other household activities. Weeding was also practiced at different intensities depending on the crop (Keys 1999), highlighting the fact that weeding is not practiced indiscriminately. James D. Nations and Ronald B. Nigh (1980), in their work with Lacandon Maya in Chiapas, stressed the intensiveness of weeding as a practice, as well as the fact that the workload is significantly different depending on whether milpas were established in primary or secondary forest. They also note that as larger communities cause people to live farther away from their milpas, they weed less often, which actually limits the number of years they use that particular plot (14). This means that weeding directly facilitates the fact that the houselot or milpa becomes a place of inheritance and generational memory in more ways than one.

In the Valley of Toluca in central Mexico, weeding is practiced for about a month after planting, and then volunteer plants are left alone as at that point they do not disturb the maize growth (Vieyra-Odilon and Vibrans 2001:431)—a practice similarly documented in the Petén, Guatemala (Schwartz and Corzo M. 2015:75). Significantly, volunteer plants are an important part of the harvest (Vieyra-Odilon and Vibrans 2001). In a somewhat different manner, in a study of cultivation practices in central Mexico, Alejandro Casas and colleagues (2007:1102) found that "let standing" was an important strategy utilized "to maintain within human-made environments useful plants that occurred in those areas before the environments were transformed by humans." Management strategies contribute to evolutionary changes in plants (Casas et al. 2007), meaning that these practices unite humans and plants in a mutually influential relationship. Farther away, S. Fujisaka and colleagues (2000:176) noted that in the Peruvian Amazon, farmers modify their swidden methods to specifically manipulate weedy plant communities.

The spatial placement of gardens and orchards near the house allows weeding, as an agricultural strategy, to occur more frequently (Fisher 2014:199). The areas beyond this more intimate space of the houselot likely received less attention and thus would have accordingly been weeded less frequently. Scholars have used the phrase *toft area* or *toft zone* to describe the liminal area around the houselot, often designated for refuse or storage (e.g., Hayden and Cannon 1983; Hutson et al. 2007:443). Philip J. Arnold III (1990:918) relates the toft zones around households in Veracruz to the buildup of refuse as a result of sweeping (see also Smyth 1990:58). This explanation indicates that the toft zone and its associated debris cannot be conceptualized simply as the "unmaintained norm," or what happens when waste management practices are not applied. Rather, the toft zone is created *by* waste management practices. Even within the immediate houselot space, different areas require differential labor devotion to weeding (Alvarez-Buylla Roces et al. 1989:141), potentially creating overlapping and intersecting conceptualizations of weeds. Finally, the larger garden space is often located beyond the toft zone (Killion 1990:202, figure 6). Thus, in addition to the notion of weeding practices tapering off with distance from the residential structure, there may also be a band of less intensely weeded space between the patio and the garden area, which accommodated weeds used for medicinal properties. An application of the houselot model (e.g., Hayden and Cannon 1983; Smyth 1990) can be used to emphasize a gradual, spatial continuum in how land, and thus weeds, are defined.

LiDAR and Houselots at Coba

The study of ancient houselots at Coba suggests that gardens and infields were integral components of these walled spaces. Earlier mapping efforts at Coba contributed significantly to our understanding of Classic Maya settlement patterns: by calculating the area of 144 walled houselots at the site, Folan and colleagues (1983) demonstrated that there is a remarkable amount of spatial variability across houselots and that these size differences do not necessarily correlate with known status markers. However, measurements of area alone cannot capture the variability of terrain and ecological features *within* houselots—what we might call the "houselot landscape." Areal measurements also do little to help us reconstruct Maya notions of how plants and humans should share household space.

LiDAR, or light detection and ranging, has yielded new insights into settlement studies because it penetrates forest cover to produce detailed 3D-like images of topography, alerting archaeologists to the presence of previously unrecorded landscape features (e.g., Chase et al. 2012; Stanton et al. 2020). Recent collection of airborne LiDAR data at Coba by the Proyecto Sacbe Yaxuna-Coba has helped enrich our understanding of Maya houselots and the human-plant interactions that took place there. LiDAR mapping for Coba was conducted during April and May 2017 as part of a broader LiDAR mapping project that included other areas of Quintana Roo and Yucatán. The National Center for Airborne Laser Mapping at the University of Houston collected the LiDAR data using an Optech Titan MW at 15 points per square m. Roughly 100 square km of data were collected as part of a block around Coba itself.

For Coba, LiDAR data not only help us confirm (and potentially revise) the areal calculations made by the 1980s conventional mapping project undertaken at the site (Folan et al. 1983), but they also offer the opportunity to ground-truth differences in terrain within particular houselots so we can refine the way the LiDAR data are interpreted (cf. Brewer et al. 2017). Through LiDAR, we can infer the terrain of Coba houselots at a much greater scale without having to clear as much tropical vegetation (see Reese-Taylor et al. 2016). With a better understanding of terrain and its variability, we can avoid monolithic notions of domestic space and begin to approach an understanding of how Classic Maya people embraced the natural resources available in domestic areas. Plants such as weeds were only one of the resources that acted upon human activities on a daily basis.

Focusing on two houselots at Coba, we calculated the ratio of soil to exposed bedrock. This ratio is critical; the raw measurements of houselot area mean very little to our reconstructions of past land-use practices without this more nuanced view of terrain. Contrary to what might be expected, localized bedrock formations may actually be *more* desirable for intensive cultivation in houselots. This can be surprising, as it was to the Colonial Spaniards and continues to confound those who would mechanize agriculture in parts of the Yucatán Peninsula (e.g., Restall et al. in press; Faust 2001), but it is a practice with a deep and ongoing history in the region. Given the container gardening strategies noted by Fedick and colleagues (2008), where gardeners actively seek out these pitted areas because they accumulate soil and maintain moisture levels, as well as Benjamin's (2000) observations of Maya houselot gardens, it is apparent that natural bedrock containers in which trees and other perennials might be planted are precisely the areas where weeding would be focused in the rainy season. Ground-truthing of LiDAR for visual differences between bedrock and soil in select houselots may allow for the projection of those patterns across the LiDAR data and generate a detailed picture of the terrain of a much larger sample of houselots. As a measure of potential for agricultural intensification and thus for the intensity with which strategies such as weeding may

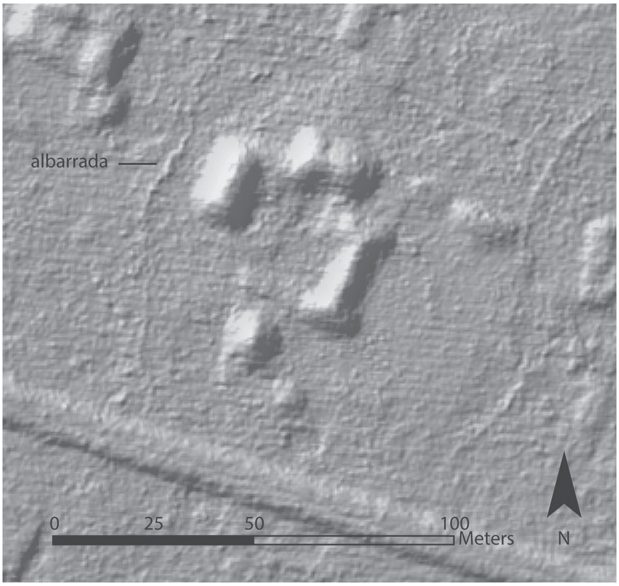

Figure 7.2. LiDAR image of Coba Group 1

have been practiced, we will then be able to compare this to other houselot metrics that act as proxies for ancient household labor, such as the number of structures, distance to the site center, and proximity to water and other natural features.

CASE STUDY: COBA GROUP 1

Group 1 at Coba is a cluster of nine small to medium-size structures surrounded by a stone boundary wall. It is located 890 m north of the center of urban Coba, as designated by the tallest pyramid (known by its Maya name, Nohoch Mul), but within the broader urban core and adjacent to the longest ancient Maya road, which runs for 100 km from the center of Coba west to the smaller urban center of Yaxuna. Group 1 has a primary cluster of four larger structures arranged around a central interior plaza, with five smaller domestic structures and adjacent open areas to the east. Sacbe 1, the ancient road, forms the boundary of this group to the south, while the dry stone wall (*albarrada*) encircles the other three sides, for a total enclosed area of 8,372 m^2 (figure 7.2). The group is located in a part of the site that incorporates mid-level residential structures with administrative and ritual architectural features. Some of the structures within the main cluster of buildings are over 4 m tall and exhibit elements that suggest they are funerary or ritual monuments.

Ground verification of LiDAR data covering Group 1 was performed during the 2018 field season. The area in which Group 1 is located is currently covered by secondary forest growth. According to local officials, in the early 1980s this area was under cultivation, as milpa and cattle were allowed to graze there; since then, it has seen only periodic visitation by local residents to collect firewood or other forest products on a very small scale. Group 1 was intensively excavated during the 2018 field season, which necessitated clearing much of the underbrush—revealing additional structures not visible in the LiDAR, specifically the low domestic structures in the eastern part of the walled group (see also Hutson et al. 2016). A small rectangular depression visible in LiDAR was determined to have been a stone quarry, and bedrock was visible in approximately 15 percent of the ground surface in Group 1. There were no cavities visible in the bedrock within Group 1.

Given the relatively small presence of bedrock on the ground surface of Group 1, as well as the lack of solution holes or other depressions in the bedrock, intensive weeding would likely have been directed toward the entire houselot rather than concentrated in one space. It is also likely that weeds' agency went less contested on the open, eastern side, as the performative delineation between the houselot and surrounding areas was farther away from the structures themselves. The stone quarry may have provided an advantageous location for tree crops or other plants that needed both deeper and wetter soils (see Folan 1978). Given the large amount of open area adjacent to the structures of Group 1 and within the boundary wall, weeding could have consumed a significant amount of time regardless of whether this space was used for cultivation or kept clear for household activities. The location of Group 1, along one of the most important ancient roads emanating from the city center, also suggests that humans may have spent significant time addressing the agency of plants that sought to enter the road, activity areas adjacent to the road, or ritual structures visible from the road. It is also possible that daily traffic on the road had the effect of inhibiting weed growth, in which case the definition of such plants would need to be reconsidered, as people may not have been interacting with them intentionally at all.

CASE STUDY: COBA GROUP 28

Group 28 at Coba is a cluster of five small structures around a central patio area surrounded by a rectilinear dry stone boundary wall, located 3.2 km south of Nohoch Mul in an area of dense residential settlement (figure 7.3). The five small structures are distributed in a single cluster of domestic platforms on three sides of a central patio in addition to sixteen ancillary structures within or adjacent to the walled group. Between the dry rubble wall surrounding the domestic structures and a quadrangular grid system of larger and more substantial masonry walls that define this "neighborhood," or region of the city, is an extensive open area that would have provided garden and activity space for the group's inhabitants. The quadrangular design of

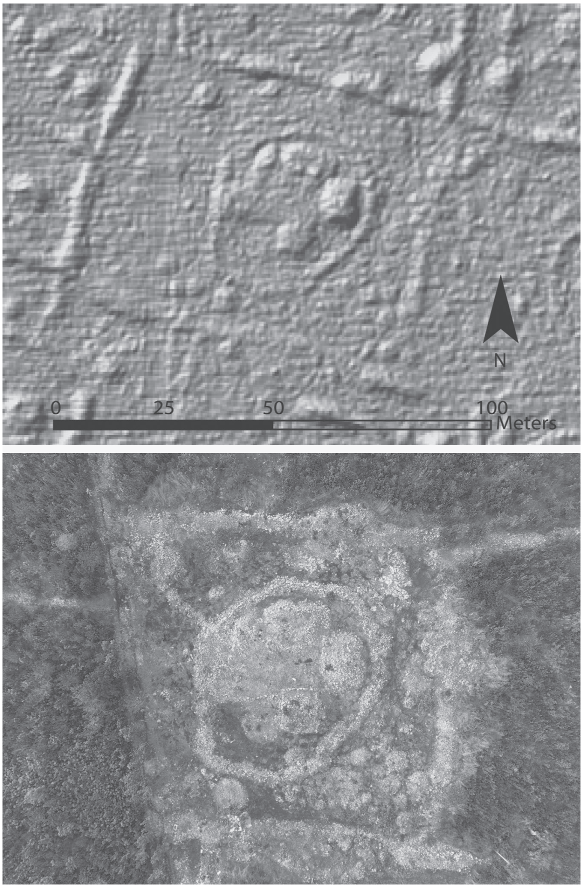

Figure 7.3. LiDAR image of Group 28 (*top*); drone image of Group 28 before excavation (*bottom*). Drone image by Ashuni Romero.

the broader neighborhood of modest residential settlement that contains Group 28 is distinctive from other residential zones, even some that are adjacent to the north and east. Starting in the mid- to late 2000s, the area in which Group 28 is located has been under periodic milpa cultivation and is also used as cattle pasture. It was last cleared for planting in 2017, so there is minimal tree growth or other large vegetation, but the area nonetheless was covered with bushy undergrowth that was removed in 2018 to allow for horizontal excavation of living and activity areas. Local Maya residents saw the bushy undergrowth as economically useful cattle fodder, while our archaeological team viewed the same plants as weedy impediments to research.

The LiDAR survey was performed in 2017, with ground verification in 2018 that involved clearing vegetation—an activity that revealed details of the very small ancillary structures and a previously undetected stone walkway that connects a circular structure in the northwestern part of the group. However, for the most part, groundtruthing did not reveal new structures, and it was demonstrated that the LiDAR data were extremely accurate for this group. Bedrock was present at ground surface in only one very small area of the group, along the northern boundary wall; and the vast majority of the open areas was covered in soil. This small patch of bedrock likely comprised only approximately 1–2 percent of the walled area. Open areas with soil cover comprised the majority of Group 28 and would have provided ample space for gardening and its attendant responsibilities of weeding, without apparent specific focus in any one space. The presence of two wall features, the circular one around core residential structures and the more substantial rectilinear one outside the houselot area, suggests that a greater effort was made to prevent plants from entering the domestic compound. The human occupants of Group 28 spent significant time and resources to secure their living space—not from the forest, as this group is located in an area of dense settlement, but perhaps from the smaller weedy intrusions that might have impeded full (human) use of the landscape. It is also useful to consider how the rectilinear boundary wall would have made a sharp delineation of labor investment compared to the usual development of a toft zone resulting from a gradual tapering application of labor as one moved farther away from buildings.

Visual examination of the cleared ground surface at Groups 1 and 28 of Coba allowed us to return to the LiDAR imagery and refine our processing in order to attempt to correlate bedrock visible from the ground surface with LiDAR visual data. With minimal modification of the digital elevation model files to enhance color we noticed open areas of bedrock were visible in LiDAR data as areas of smooth, texture-less background. This pattern held true for both residential groups, one of which was much more heavily forested than the other. Thus both case studies suggest that LiDAR data provide useful information about the houselot landscape and thus time spent in negotiation with weeds.

CONCLUSION

Although the phenomenon of weeds is found globally, the interaction between weeds and cultigens has a distinct mutualism in Mesoamerica. As biologists have found for weed growth in milpas, weed biomass increases every year a plot is cultivated until, by the third year, weed growth significantly decreases agricultural yields by out-competing maize plants for critical resources (Lambert and Arnason 1980, 1986). Soil quality does not decline; in fact, weeds lock soil nutrients into place by preventing leaching. The subsequent stages of vegetative regeneration in an abandoned milpa or any land that has been managed for cultivation involve predictable sequences of secondary growth (e.g., Ford and Nigh 2015; Ford et al.

2012). For example, the length of fallow time can eventually affect fallow plant communities within a milpa plot (Johnston 2003). Local knowledge of these secondary vegetation patterns could therefore be used to infer past land-use patterns in a particular place.

There is an under-considered nuance to human-weed interactions: in cases of long-term habitational changes, weeds act as conveyors of localized ecological knowledge of a particular place. In cases where households continuously occupy a landholding over generations, older household members act as the repositories of this ecological knowledge (Netting 1993); but when breaks occur in the history of a houselot's occupation, new occupants have to learn the localized landscape without the benefit of the accumulated wisdom of previous generations. Perhaps the existence of weed communities was able to communicate a story of past land-use practice and agricultural strategies to the newcomers in a particular houselot landscape, taking over the role of repository of localized ecological knowledge in the houselot and instructing inhabitants on localized ecological potential: how long had it been since people last occupied this space? Which parts of the houselot had been used for cultivation, and where did the greatest amount of water accumulate? Had certain species been allowed to proliferate where others were not, indicating their utility? Weed communities contained the answers to these questions.

Weeds would also have contributed to social memory. Rosemary Joyce (2003:112) has described the role of movement around a city, including within houselots, as part of the memory-making process (see also Magnoni et al. 2012). Patterns of movement produced by realization of daily chores in the houselot would have relationally altered the landscape, connecting it and those within it to a multitude of meanings and memories (e.g., Ingold 2010 [1993]). One can imagine that weeding would have been an activity that allowed ancient residents of Coba to shape the landscape, but at the same time, through habitual motion, it left its own mark on their bodies (e.g., Bourdieu 1990). In studies of ancient identities, the domestic world has been identified as a primary arena where culture is reproduced. Due to the importance of household gardens in the subsistence success of ancient families, tending plants in the household compound of ancient Maya centers was a highly charged repetitive activity that helped convey cultural values and solidify the social imaginary while providing nutritional content.

Coba has already played a groundbreaking role in our understanding of the highly localized interactions between Maya people and plant communities over generations in houselots. As demonstrated here, LiDAR data were useful and reliable predictors of both domestic architecture and natural features such as bedrock at ground surface, a significant factor in calculating work hours for estimations of weeding, gardening, and other household tasks. Archaeological fieldwork has allowed us to evaluate LiDAR's potential to predict terrain differences that can inform our understanding of how weeds and plant communities more generally were part of the lived experience at Coba on a daily, seasonal, generational, and centennial scale. By calculating the ratios of bedrock to soil cover and observing the nuances and idiosyncrasies of the bedrock itself, we can better understand how people would have engaged with the landscape and contended with vegetation at the level of the houselot. LiDAR becomes a way not to reconstruct architecture but to reconstruct human-plant relations, understanding where, spatially, people would have spent most of their time and in what ways their interactions would have co-constructed the category of weeds.

We have discussed and applied this under-utilized approach to LiDAR technology by considering its productivity in predicting bedrock-to-soil ratios and thus factoring into interpretations of human-plant relationships. By considering these results through the lens of vegetative agency, we have presented an archaeological approach to the study of weeds as a relational category that is an essential and inescapable counterpart to domesticated plants. For the ancient inhabitants of Coba, weeds would have been a set of agentive beings that both contributed to the construction of and were defined by spatial boundaries. As pests, medicines, and archives of knowledge, depending on the context, weeds would have affirmed their own agency in the creation and maintenance of social memory in ancient Maya houselots.

Acknowledgments. We wish to thank Monica Smith for the invitation to participate in this exciting volume as well as for her productive comments on earlier drafts, as well as the two anonymous reviewers whose comments improved this chapter. We thank the Consejo de Arqueología, Instituto Nacional de Antropología e Historia, for permission to conduct research at Coba as part of the Proyecto Sacbe Yaxuna-Coba. We thank all the PSYC project members but especially Travis Stanton, Stephanie Miller, Ashuni Romero Butrón, and Patrick Rohrer for their generous assistance with the 2018 excavation data, and we thank Stephen Houston and Robert Preucel for helpful comments on earlier versions of this chapter. Dine would also like to thank John (Mac) Marston, whose classes at Boston University provided space to think about vegetative agency. This research was generously supported by the National Science Foundation (award #1623603).

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8

Bird Behavior and Biology

The Agentive Role of Birds in Chaco Canyon, New Mexico

Katelyn J. Bishop

Abstract

As one of the only classes in the animal kingdom capable of flight, birds are privy to a realm of movement that humans can only partially control. Birds possess specific traits and engage in a variety of behaviors that directly affect the mechanics of capture and use, such as gregariousness and flock size, preferences in nesting and feeding locations, wing strength and readiness to flush, and aggressiveness and territoriality. Human-bird relationships also move beyond the semantics of capture to cases in which birds are kept in captivity as sources of feathers and/or awaiting sacrifice, as pets, and as domestic birds. This chapter makes use of data from Chaco Canyon, New Mexico, which was the center of a large regional system in the Pueblo II period (850–1150 CE). This chapter considers the qualities and behaviors of avifaunal taxa that would have influenced human-bird interactions and discusses the implications of these behaviors and the unique ways birds may have exerted agentive force and control over the experiences of capture, captivity, management, and use.

The majority of research on ancient human-animal interaction positions humans as subjects and animals as objects, a dichotomy in which animals are a raw material to be exploited by human actors (Hill 2013:118). But many characteristics of wild animals are capable of "overwhelming human capacities" (Smith, chapter 1, this volume) in a moment of attempted capture, such as the swiftness of a deer, the power of a mountain lion, or the speed of a jackrabbit. Birds, as one of the only vertebrate

https://doi.org/10.5876/9781646423521.c008

animals capable of flight, are privy to a realm of movement that humans can only partially control. Birds also possess many other biological and behavioral traits that can affect the outcome of human-bird interactions. This chapter demonstrates the analytical value of considering birds as agents in their interactions with humans and how these characteristics affected past human-bird relationships, using an archaeological example from the prehispanic American Southwest.

Chaco Canyon, located in northwestern New Mexico, was the center of a large regional system during the Pueblo II period from 850 to 1150 CE. Birds have figured prominently in Pueblo life throughout the Southwest during this and other periods (e.g., Fewkes 1900; Gnabasik 1981; Hill 2000; Tyler 1979), and excavations in Chaco Canyon have produced sizable and rich avifaunal collections. This chapter utilizes the avifaunal collections from three Chaco sites—Pueblo Bonito, Bc 57, and Bc 58—to consider the intricate dynamics of the human-bird relationship. A quantitative model is developed to deal with the species-level biological and behavioral traits of those birds that would have affected interaction between prehispanic peoples and the avifaunal landscape around them. By shifting birds from the position of object to that of subject, we can acknowledge the "mutually generative relationships" (Smith, chapter 1, this volume) between humans and animals, in which the actions of the animal affect the actions of the human and vice versa (see also Ammerman, chapter 10, and Tomášková, chapter 11, both this volume).

ANIMAL AND AVIAN AGENCY

Zooarchaeological research has moved well beyond considering only the utilitarian role of animals in the past, to include the social, symbolic, and emotional roles they have played in human societies (e.g., Morphy 1989; Russell 2012; Ryan and Crabtree 1995; Shipman 2010). Indeed, animals appear to have been an integral part of the human story even at deep evolutionary time depths, when reciprocal interactions became an important part of the human (and the animal) experience (Shipman 2010). Despite the recognition of the intimate connection between humans and animals and of the broad range of roles animals have played beyond serving as a source of human nutrition, much zooarchaeological research continues to position animals as objects acted upon by humans who *use* them as food, raw materials, symbols, sacrifices, or pets (Hill 2013:117; Overton and Hamilakis 2013:114). This orientation in thinking posits a one-way relationship where the animal is a passive resource to be consumed (either literally or figuratively) by the human.

As Erica Hill (2013:118) has observed, the "human-subject/animal-object dichotomy" leaves little space for the consideration of animal agency. Grounded in the Western ontological nature-culture divide, the anthropocentricity of approaches to human-animal relationships of the past largely assume "passivity on the part of non-human animals" (Overton and Hamilakis 2013:114) even where they are accorded special, highly symbolic roles in ritual and ideology. Following Nick J. Overton and Yannis Hamilakis (2013:114), the perspective employed in this chapter accepts that both human and non-human animals were responsible for "co-shaping" their interactions with one another (see also Quintus et al., chapter 9, this volume). By acknowledging that human-animal relationships are deeply mutually influential and multidirectional rather than unidirectional, the intricacies of every human-animal interaction—whether in procurement, management, companionship, use, death, or otherwise—can be better understood. From this perspective, it is easy to afford animals an equal chance at participation in human-animal interactions and, especially in the case of wild animals, a chance at determining the outcome of each interaction. This "co-shaping" of human-animal engagement is the backbone of a more realistic, non-anthropocentric zoontology (Overton and Hamilakis 2013).

Humans interact physically with wild animals in a variety of ways, including (but not limited to) capture and subsequent consumption or retention in captivity. Studies of the procurement of wild animals that focus on the semantics of capture usually focus on the human half of this experience, for instance, on the methods of procurement employed. But the live animal is an "autonomous being" (Overton and Hamilakis 2013:116) whose existence and behavior are not a priori defined by human presence or decision. So how, in any specific attempt to capture a wild animal, did the nature of that animal (both as a specific species and as a sentient individual) affect that interaction? Humans of the past repeatedly interfaced with this independently constituted agency in intimate moments of interaction that did not always result in simple domination. Individual birds in the natural world unarguably possess agency and decision-making abilities that vary at many levels, including at the level of the taxonomic group (species or subspecies); the level of the population; the level of the nest, feeding, or roosting group; and the level of the individual (specific personalities). This agency would have affected human-bird interactions both in terms of finding desired wild birds on the landscape and in terms of the physical experience of capturing or killing a bird.

The biological and behavioral characteristics of birds should be considered in any study of the premodern "use" of birds, since these details would have played an integral and sometimes deterministic role in each individual interaction in the relationship between humans and birds and in societal perception of birds. Surely, the specific characteristics of different types of birds were noted, understood, and considered by people of the past. The endeavor to consider avian agency in the past leads to a better understanding not only of the entangled nature of human-bird engagements but of the great lengths to which many human societies were willing to go to acquire birds of value.

BIRDS IN THE PUEBLO WORLD

Ethnographic research over the last century and a half has documented the importance of birds in the Pueblo world. Today and historically, birds serve as symbols, characters in narratives, participants in ritual, and sources of feathers and sometimes food (Fewkes 1900; Gnabasik 1981; Hill 2000; Tyler 1979; Voth 1912). Birds of prey, waterbirds, parrots, and colorful passerine birds maintain particular symbolic significance (Tyler 1979).

Compared to other regions, the US Southwest benefits from a robust history of avifaunal research, with scholarly interest in the ancient use of birds since at least the 1920s. Archaeologists working in the Pueblo region have largely equated bird use with ritual based on ethnographic parallels, though some birds were and still are eaten. Scholars have used avifaunal remains to address broad anthropological questions concerning topics such as animal domestication, long-distance trade, ritual and religion, social organization, and the relationship between agricultural intensification and birds (e.g., Bishop 2019; Bishop and Fladd 2018; Creel and McKusick 1994; Durand 2003; Eckert and Clark 2009; Emslie 1981; Grimstead et al. 2014; Hargrave 1970; Lipe et al. 2016; Newbold et al. 2012; Roler 1999; Speller et al. 2010; Watson et al. 2015).

Given the robusticity and ever-increasing popularity of avifaunal studies in the US Southwest and elsewhere, (zoo)archaeological research can greatly benefit from consideration of the agentive behaviors and characteristics of animals that constricted, enabled, or otherwise affected human behavior in the past. The model presented here provides one example of how *qualitative* information about species-level characteristics can be factored into more traditionally *quantitative* zooarchaeological analyses, creating a more robust understanding of human-animal interaction. The consideration of animal behavior should always be, and often is, a component of zooarchaeological research, and the model below is one example of how this might be achieved in a data-driven way.

THREE CHACOAN SITES OF INVESTIGATION

The central stretch of Chaco Canyon and its surrounding mesas (figure 8.1) contains at least twelve monumental, often multi-story pueblo structures known as "great houses," which likely served as community centers, residences, and places of pilgrimage. These great houses are surrounded by a number of smaller, usually single-story

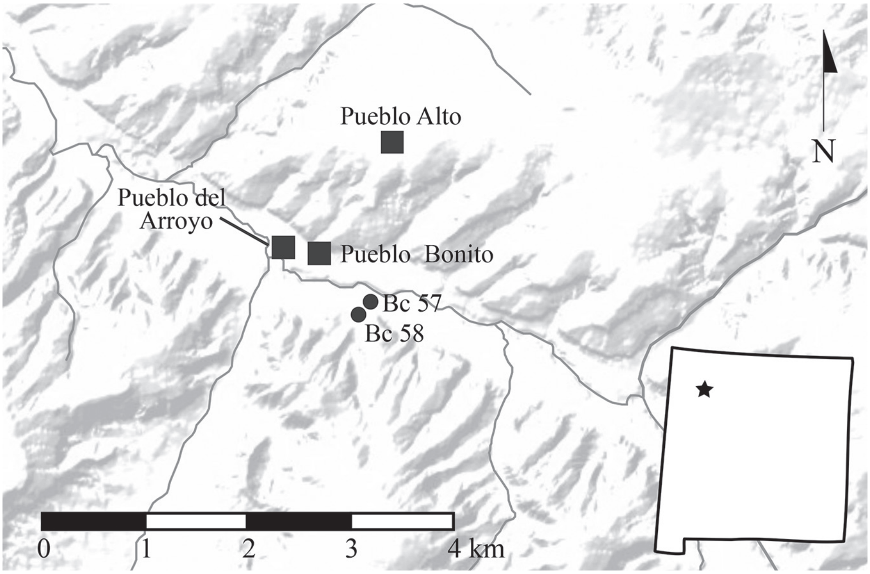

Figure 8.1. Map of Chaco Canyon, New Mexico, showing sites mentioned in the text

pueblos called "small sites" or "small houses." The influence of Chaco Canyon on the surrounding landscape was greatest in the eleventh century CE, when construction of Chaco-style great houses outside of and distant from the canyon was at its height. Characteristics of the "Chaco phenomenon" (Irwin-Williams 1972)—or the characteristics of Chacoan society evident within the canyon as well as Chaco's influence on the surrounding region during the Pueblo II period—include this vast system of outlier communities, an extensive road network, and the importation of many valued goods from other parts of the Southwest, California, and Mexico, including parrots, cacao, marine shell, copper bells, turquoise, timber, pottery, and agricultural products (e.g., Crown and Hurst 2009; Crown and Wills 2003; Heitman and Plog 2015; Lekson 2006; Mathien 2001; Nelson 2006; Toll 2006; Watson et al. 2015). Much debate remains about the social configurations of the Chaco phenomenon, including the degree and basis of inequality, Chaco Canyon's primary function within its regional system, and the nature of social organization in the canyon (Kantner and Kintigh 2006; Mills 2002; Schachner 2015:57).

The largest and most extensively studied great house in Chaco Canyon is Pueblo Bonito, located on the north side of the canyon. Its ground floor alone consisted of over 350 rooms, and parts of the original pueblo stood four stories tall. Initial construction began in the mid-ninth century CE, with expansion of the pueblo continuing into the twelfth century (Judd 1964; Lekson 1984). The acceptance of the presence of some level of inequality in Chaco Canyon is predominantly based on research at Pueblo Bonito, where large quantities of goods imported from other areas were found and two elaborate, rich burial suites were discovered (Plog and Heitman 2010; Lekson 2006; Nelson 2006; Toll 2006). The pueblo was primarily excavated in the 1890s and 1920s by the American Museum of Natural History and the National Geographic Society, with more recent work conducted by archaeologists from the University of New Mexico (e.g., Crown 2016b).

The sites known as Bc 57 and Bc 58 are two adjacent small house sites located across the canyon from Pueblo Bonito. Adam S. Watson (2012) has argued that feasting events at these sites may have been associated with ceremonies taking place at nearby Casa Rinconada, an isolated (standalone) great kiva that likely served as a central location for ritual activity. Bc 57 and Bc 58 were excavated by the University of New Mexico–School of American Research field school in the 1940s (81). The single-story Bc 57 has nine rooms and four kivas (84). Bc 57 was probably constructed in a single episode, with one additional room added later in time. Bc 58, also a single-story small house, consists of fourteen rooms and two kivas. But unlike Bc 57, it may have been constructed and remodeled in stages over time (85). Radiocarbon dating of animal bone from both Bc 57 and Bc 58 suggests that the former was occupied during parts of the tenth, eleventh, and twelfth centuries CE, while the latter was occupied in the tenth and eleventh centuries (109–110). Thus, occupation at both small houses overlapped with occupation at Pueblo Bonito.

Pueblo Bonito, Bc 57, and Bc 58 were chosen for comparison for several reasons. First, Bonito is the most thoroughly excavated of the intra-canyon great houses, and Bc 57 and Bc 58 were completely or nearly completely excavated. Second, Bc 57 and Bc 58 have the largest avifaunal assemblages of all Bc (small house) sites. Lastly, this combination of sites enables the comparison of great houses to small houses and small houses to each other.

HUMAN-BIRD ENGAGEMENT: A MODEL

Birds possess specific biological and physiological traits and engage in a variety of behaviors that directly affect the mechanics of interactions between them and humans. The most obvious variable affecting human-bird interaction is their ability to fly, which makes them unique compared to almost all other vertebrate animals. While almost all birds fly, different species are physically distinct from one another in appearance and have different behavioral traits and tendencies. These species-specific characteristics, classified in ornithology as a part of the "life history" of a species, include, for example, habitat preference, nesting location, food source, and various components of behavior.

The model presented in this chapter relies on eleven aspects—or variables—of bird life history, including physiological, biological, and behavioral traits.

Five physiological/biological aspects and six behavioral characteristics were isolated as particularly relevant for influencing the interaction between humans and birds in the prehispanic past. Physiological/biological traits include (1) the morphology of the foot, which is related to a bird's ability to grasp, pierce, and hurt aggressors and prey; (2) the size and morphology of the beak, or a bird's ability to injure an aggressor with its beak; (3) body size, which can affect a bird's ability to struggle against capture in the case of very large birds but can also affect the visibility of the bird; (4) feather color, which affects visibility to humans; and (5) strength of flight, which affects the bird's ability to evade capture. Behavioral characteristics that affect the engagement between birds and humans include (1) aggressiveness/territoriality of the bird, or the readiness of a bird to defend itself against other birds, which, in turn, is related to home range size and population density; (2) gregariousness/sociability of the bird, assessed through the size of the groups in which a species spends most of its time nesting, feeding/foraging, or roosting; (3) feeding/foraging location, specifying whether a species forages or hunts from the air or on the ground; (4) nesting location, as easy or challenging places for humans to access; (5) migration behavior, which affects the proportion of the year that a species will spend in a certain area; and (6) whether a species is diurnal or nocturnal, which again affects visibility to humans. These variables can be quantified in a model that allows us to compare among different species the relative likelihood of humans finding a bird and the difficulty of capture, as well as different avifaunal assemblages or samples thereof.

To construct an analytical model, the variables listed here were rearranged into two new categories that speak more directly to human-bird interaction (table 8.1). The first, hereafter called *Visibility Factors*, affect the likelihood of happening upon, finding, or otherwise coming into contact with a bird of a given taxon. The second, *Interaction Factors*, affect the actual in-the-moment physical interaction between humans and birds. While Visibility Factors *indirectly* affect human-bird interactions, Interaction Factors *directly* affect those interactions. Where a specific species may have been required and sought after for a particular reason, Visibility Factors would affect the ability of someone to actually find a bird of that species while searching for it. Even when a bird may be taken opportunistically in the pursuit of some other resource (e.g., construction timber; e.g., English et al. 2001) or the performance of some other task (e.g., ridding agricultural fields of pests), Interaction Factors will still directly affect the encounter.

The eleven variables identified above were recorded for each species present in the avifaunal assemblages from Pueblo Bonito, Bc 57, and Bc 58. Species-level

Table 8.1. Visibility and Interaction Factors in birds

Visibility Factors	*Interaction Factors*
Size	Size
Feather color	Foot/talon morphology
Gregariousness	Beak size/morphology
Feeding/foraging location	Aggressiveness/territoriality
Nesting location	Gregariousness
Diurnal/nocturnal	Strength of flight
Migration behavior	

information was gathered from multiple ornithological sources and birding guides (Cartron 2010; Elphick 2016; Sibley 2001, 2014; Cornell Lab of Ornithology [https://www.allaboutbirds.org/]), which, of course, present the characteristics and ranges of these species based on the observance of *modern* birds. While most biological features and many behaviors are unlikely to have changed too drastically in the last 1,000 years, there is the possibility that certain things, such as range distributions and even nesting behavior, may have shifted slightly. Here, I assume that the modern characteristics of these species can stand in for their counterparts of the ninth–twelfth centuries.

For each variable (e.g., nesting location) in table 8.1, the qualitative values (e.g., ground, tree, cliff) recorded from ornithological sources were arranged on a spectrum (figure 8.2). For Visibility Factors, the spectrum runs from “more visible/more likely to be encountered” to “less visible/less likely to be encountered.” For example, options for migration behavior include year-round residents, species that only spend one season (breeding or non-breeding) in the area, and those that only pass through on their migratory routes. Each of these aspects correlates with successively less time in the area over the course of the year.

Interaction Factors were arranged from “easier to capture” to “harder to capture.” The variable referred to as gregariousness, for instance, describes the tendency of the bird to spend time in groups of its conspecifics. Very social birds forage, roost, nest, or otherwise spend most of their time congregating in large groups; somewhat social birds spend some of their time in groups but also perform some activities alone; highly solitary birds spend no time in large groups. This variable also qualifies as both a Visibility Factor and an Interaction Factor. The more birds that are present in a group at the same time, the more visible they will be (Visibility Factor) and the more likely an attempt to capture one will be successful simply because there are more birds present (Interaction Factor).

Visibility Factors	more visible ←		→ less visible
Size	large	mid-size	small
Feather Color	stands out		blends in
Gregariousness	very social	somewhat social	highly solitary
Feeding/Foraging Location	on ground	from perch	on the wing
Nesting Location	ground nest	trees of all heights	cliff
Diurnal/Nocturnal	diurnal		nocturnal
Migration Behavior	year-round resident	seasonal	migratory only
Interaction Factors	easier to capture ←		→ harder to capture
Size	small	mid-size	large
Foot/Talon Morphology	webbed, weak, dull, or small		sharp, hooked talons
Beak Size/Morphology	small, less powerful		designed for tearing meat
Aggressiveness/Territoriality	not aggressive		aggressive
Gregariousness	very social	somewhat social	highly solitary
Strength of Flight	weak flyer	adequate flyer	strong flyer

Figure 8.2. Visibility and Interaction Factors considered, showing variable options for each factor

After this information was gathered for each species in the three assemblages, the options were converted to numbers arranged on a scale, for example, from 1 to 3. Following figure 8.2, values were assigned (starting with "1") from the left side of the scale, increasing moving right. For each species, the values for all Visibility Factors were summed together to give each species a *Visibility Score*, and the same was done for the Interaction Factors, to produce an *Interaction Score*. The higher the Visibility Score, the less likely one might be to spot, encounter, or come across a given species. The higher the Interaction Score, the more difficult a bird of a given species is to physically capture. When the total Visibility Score and Interaction Score are added together for each species, we are left with a total value, the *Total Procurement Score*, ranging from species that are more visible and easier to capture to those that are less visible and more challenging to capture. For example, of the species examined here, the one with the lowest Total Procurement Score is the scaled quail. The scaled quail is a highly social, ground-nesting, ground-foraging, diurnal, year-round resident of New Mexico—all factors that make it more visible. It has a small body size, a small beak, and small, non-threatening talons; is not aggressive; and spends much of its time in large groups—all factors that make it easier to capture. On the other end of the spectrum, the species with the highest Total Procurement Score is the bald eagle, a highly solitary bird that nests in tall trees, hunts from the air, and only winters in New Mexico. In interactions with humans, it is a large-bodied, strong flyer, with sharp talons and beak, that is territorial/aggressive and highly solitary—all factors that render this bird harder to capture. An example of a bird with a median Total Procurement Score is the common raven, which is moderately gregarious and forages on the ground but nests in trees.

The Total Procurement Score is therefore reflective of all of the interaction and visibility variables and thus the biological and behavioral characteristics of each species that are relevant when considering the interaction between humans and birds. In this sense, the Total Procurement Score also reflects the total investment put into acquiring a given species. The systematic recording and quantification of these characteristics of bird biology and behavior allow us to explore patterns within and between avifaunal assemblages and to assess the intensity of interest in different species on the part of past peoples.

PATTERNS OF BIRD-HUMAN INTERACTIONS AT CHACO

Multiple compelling patterns emerge from the avifaunal collections from Pueblo Bonito, Bc 57, and Bc 58. Data were collected from multiple sources; the majority of the avifaunal assemblage from intramural Pueblo Bonito has been analyzed by the author. These data are supplemented by information from two additional sources: first, the report of faunal remains from excavations in the two mounds on the south side of Pueblo Bonito, excavated in the early 2000s by W. H. Wills and Patricia L. Crown of the University of New Mexico (Crown 2016b) and published by Shaw Badenhorst and colleagues (2016). Second, data from Crown's NEH-funded excavations and analyses of Room 28 were provided by Caitlin S. Ainsworth, Patricia L. Crown, Emily Lena Jones, and Stephanie E. Franklin of the University of New Mexico (Ainsworth et al. 2018, 2020). Vertebrate fauna, including avifaunal remains, from Bc 57 and Bc 58 were first analyzed and reported by Adam Watson (2012) and subsequently reanalyzed by the author. A total of twenty-eight species have been identified from Pueblo Bonito, Bc 57, and Bc 58. Rather than focusing on a range of traditional zooarchaeological variables, the present analysis focuses only on the species[1] present in an assemblage and on the NISP (Number of Identified Specimens) of each species. Thus, the numbers presented here do not reflect the entire avifaunal

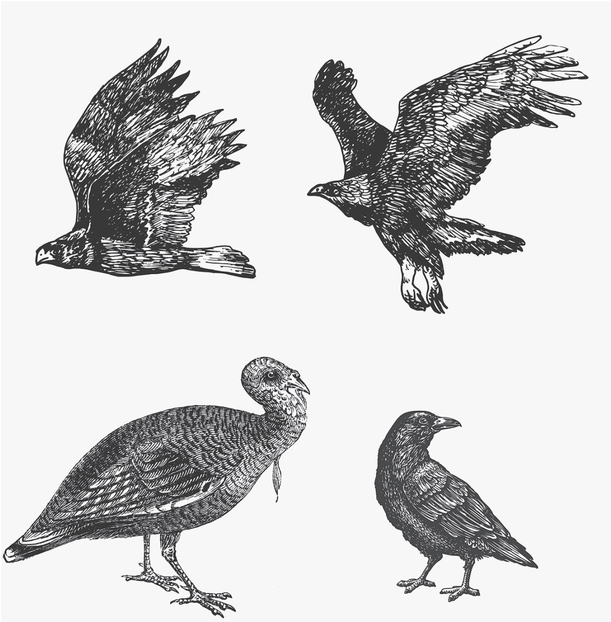

Figure 8.3. Examples of birds from the Chaco Canyon avifaunal assemblage: golden eagle, turkey (*bottom left*), common raven (*bottom right*). Images alamy.com.

assemblage for each site, only those remains identified to species (see Bishop 2019 for analyses of entire avifaunal assemblages).

A range of birds that are local and non-local to the San Juan Basin are present in the assemblages of Pueblo Bonito, Bc 57, and Bc 58 considered here (figure 8.3). Table 8.2 presents each species with its Total Procurement Score (Visibility + Interaction Scores) and NISP by site. Total Procurement Scores range from 30 (bald eagle) to 16 (scaled quail). Galliforms, heavy-bodied birds that feed on the ground (e.g., turkey, quail), score the lowest, followed by a variety of small corvids (e.g., black-billed magpie and different jays). Birds of the orders Strigiformes (owls) and Accipitriformes (which includes hawks, falcons, eagles, and vultures) tend to score high, with Total Procurement Scores ranging from 25 to 30. Eagles (golden and bald) score the highest of all species identified in the three Chaco assemblages, followed by owls (great horned and western screech), while the hawks and falcons score between 27 and 29.5. A variety of passerine birds and others are interspersed with median scores.

Pueblo Bonito

Pueblo Bonito has the largest assemblage of those considered here, with at least 1,016 NISP identified to species (see table 8.2). At least 23 species are represented,

Table 8.2. Total Procurement Score and NISP by site of each species identified in three sites at Chaco Canyon, New Mexico

Species	*Total Procurement Score*	*NISP* Pueblo Bonito	Bc 57	Bc 58
Bald eagle	30	9	–	–
Golden eagle	29.5	331	9	1
Great horned owl	29.5	5	1	–
Western screech owl	29.5	1	1	–
Prairie falcon	29.5	24	1	–
Rough-legged hawk	29	2	1	–
Ferruginous hawk	28.5	43	3	–
Red-tailed hawk	28.5	135	5	2
Cooper's hawk	28	–	1	–
Swainson's hawk	27	72	–	–
American kestrel	27	3	–	–
Turkey vulture	25	1	–	–
Common poorwill	24	1	–	–
Common raven	21.5	29	70	–
Bullock's oriole	21	1	–	–
Black-headed grosbeak	19	1	–	–
Clark's nutcracker	19	2	–	–
Northern flicker	18.5	4	–	–
Sandhill crane	18.5	19	–	–
Great-tailed grackle	18	1	–	–
Mourning dove	17	4	–	–
Black-billed magpie	16.5	33	–	–
Pinyon jay	16.5		–	1
Steller's jay	16.5	2	–	–
Turkey	16.5	293	486	19
Scaled quail	16		2	–
Total NISP identified to species		1,016	580	23

including 11 raptorial species, a variety of corvids, multiple passerine species, large water birds, and others. The Pueblo Bonito avifaunal assemblage also contains the remains of scarlet macaw and thick-billed parrot, which are non-local to the area and excluded from the following analysis for reasons discussed below.[2]

When considering the Total Procurement Score for each species in the Bonito assemblage, a range of difficulty and investment in bird procurement is evident. The lowest scoring species include turkey and scaled quail, while the highest scoring are bald and golden eagle, followed by multiple types of hawks, falcons, and owls. These latter species would have been particularly difficult not only to find or encounter but also to physically capture. Investment in the procurement of these birds demonstrates their importance to the inhabitants of Pueblo Bonito. This is additionally supported by the quantities of their skeletal remains in the Bonito avifaunal assemblage. Despite the fact that golden eagles have one of the highest Total Procurement Scores and are therefore one of the most difficult to procure, they are the most abundantly represented species in the Bonito assemblage, their remains recovered from room fill, floor contexts, and midden deposits. A total of 331 NISP of golden eagle have been identified, a value that exceeds the contribution of turkey (table 8.2). When MNI (Minimum Number of Individuals) is calculated, *at least* 33 individuals are represented. Total Procurement Scores were calculated with fully fledged, independent birds in mind—that is, non-nestlings. If eagles, for example, were taken as nestlings, factors in their procurement would have been different than those considered here. However, no immature eagle remains have yet been reported from Pueblo Bonito, Bc 57, or Bc 58; and no analysis has yet been done to determine if eagles were taken as nestlings and raised in captivity. Regardless of the age at which they were taken, the observed qualities of adult eagles would have contributed to the perception of their value, and the caretakers of birds raised in captivity would still have been confronted with certain biological and behavioral factors, such as size, talon morphology, and aggressiveness.

Similarly, non-eagle raptors are well represented in the Bonito assemblage. Multiple species of hawk contribute between 2 and 135 NISP and reconstruct to multiple individuals. Red-tailed hawk is the third most abundant (NISP) species in the Bonito assemblage, with at least 13 individuals (MNI) present. Similarly, at least 14 Swainson's hawk individuals and 7 ferruginous hawk individuals are present.

These data collectively suggest that people at Bonito pursued a large number of a range of taxa that would have proven difficult to acquire in terms of both visibility and physical interaction between human and bird. In both ethnographic and archaeological cases in the Pueblo Southwest, these high-value birds, especially raptors, are not dietary contributions but important participants in ritual practice or providers of feathers for the manufacture of ceremonial paraphernalia (e.g., Hill 2000; Ladd 1963:88–89; Tyler 1979).

Bc 57

Despite its small footprint and minimal number of rooms, Bc 57 has a sizable avifaunal assemblage, with 580 NISP identified to species, from 11 species (see table 8.2). The majority of these (486 NISP) are turkey, a quantity greater even than at Pueblo Bonito. Quail, raven, and a variety of raptorial species have also been identified. The species with the highest Total Procurement Score at Bc 57 is the golden eagle, while that with the lowest is the scaled quail. Seventy NISP from at least three ravens were identified, one of which appears to have been skinned for its feathers and another that had a healed fracture, evidence that the bird was kept in captivity for some time (Watson 2012:138–139). In addition, the abundance of turkey remains, the presence of skeletal pathologies, the identification of eggshell, and the representation of juvenile individuals support the conclusion that turkeys were raised at or near Bc 57 (146).

A portion of the assemblage, despite being composed of only 22 NISP, is distributed among eight different raptor species, including golden eagle, two owl species, four types of hawk, and one falcon. The proportion of the number of raptor species at Bc 57 (73% of all species) exceeds that at Bonito (48%). The inhabitants of Bc 57 were engaged in the procurement of a diverse range of hard to procure birds, may have kept some wild birds in captivity, and likely raised turkey nearby.

Bc 58

The assemblage from Bc 58 is much smaller than that from Bc 57 or Bonito, with only 23 NISP from four species (see table 8.2); the majority of remains are turkey. The remainder of the assemblage is composed of golden eagle, red-tailed hawk, and pinyon jay. Despite the small size of the assemblage, half of the taxa represented at Bc 58 are raptorial. It is clear, however, that compared to Bc 57 or Bonito, at Bc 58 the use of birds that resulted in the deposition of their remains was comparatively minimal.

Inter-site Comparisons

It seems abundantly clear that raptors were valued at all three sites examined here, despite how difficult they are to find and capture relative to other birds. Raptors are well represented at all three sites despite being some of the least abundant birds on the landscape due to their solitary nature combined with the large size of the territorial home ranges of individuals or breeding pairs (which in the case of golden eagles can range from 20 km^2 to 200 km^2 or even larger; Cartron 2010:374–375). Remains of eagles are abundant in the Bonito assemblage, even greater in quantity than turkey, which is otherwise the most abundant at many other sites in Chaco Canyon—including Pueblo del Arroyo, Bc 57, and Bc 58 (Bishop 2019) and Pueblo Alto (Akins 1985, 1987; Bishop 2019). While all of the raptor species at Bc 58 were also identified at Bc 57, at least one species (Cooper's hawk) was identified at Bc 57 that was absent in the Bonito collections.

While Pueblo Bonito has the highest NISP and greatest taxonomic richness, it also has the largest assemblage and is the largest site. When we compare the density of raptors at each site by standardizing raptor NISP by number of ground-floor rectangular rooms, Bc 57 instead has the highest density of raptor remains, with 2.4 NISP per room (22 NISP/9 rooms), compared to 1.8 at Bonito (626 NISP/350 rooms) and only 0.2 at Bc 58 (3 NISP/14 rooms). Regardless of the method used to judge their importance, it is clear that birds of prey, including hawks, eagles, falcons, and owls, featured prominently in activities resulting in deposition that took place at Bonito and Bc 57 but not at Bc 58.

The presence of two species of parrot at Pueblo Bonito also reflects a high level of investment in the procurement of birds that had great symbolic and ritual value. Remains from at least thirty-seven (MNI) parrots have been recovered from Bonito, representing two thick-billed parrots and thirty-five macaws (Bishop 2019). Twelve of these were intentionally deposited in burials or floor-level deposits (Bishop and Fladd 2018), while the remainder were recovered as partially articulated individuals or disarticulated remains that may or may not have been formally deposited. In this analysis, biological and behavioral variables were not recorded for parrots, and they were excluded from the quantitative analysis. Because both species were non-local to northwestern New Mexico and only distantly available, the biological and behavioral characteristics that are relevant in the direct procurement of local species by hand become irrelevant in the case of parrots. Recent research has confirmed that macaws were traded into the canyon over a span of nearly 300 years (Watson et al. 2015) and that they arrived from a breeding center in the Southwest that has not yet been discovered (George et al. 2018). Therefore, the inhabitants of Chaco did not procure these birds directly from the wild but instead through an intermediate party.

The exclusion of parrots from this analysis, however, should not discourage an appreciation of the difficulty involved in acquiring these birds. First, these parrots were only distantly available and had to be obtained through established social connections. In addition, parrots are notoriously difficult to care for. While other species may have been kept in captivity at times, parrots were routinely kept alive in pueblo rooms that served as cages (Judd 1954:264; Pepper 1920:195). Macaws are known for their strong personalities, developing attachment to a single caretaker while being aggressive toward others. In addition, they require extensive care when young (Crown 2016a:333). The acts of acquiring and caring for live macaws would have presented unique challenges. While they are present at Bonito, no parrots were recovered from Bc 57 or Bc 58.

The absence of parrots but the abundance of raptors at small sites, compared to the presence of both at Bonito, indicates differences in the nature or scale of ritual or other activities conducted at each of these pueblos. The proximity of Bc 57 and 58 to Casa Rinconada suggests that residents of these sites may have been responsible for the procurement of raptors for activities that were conducted in the great kiva.

The Role of NISP

While the comparison of different species and their Total Procurement Scores allows us to consider the importance of different birds at different sites, we can also take into consideration the relative quantities of each species procured. For instance, though golden eagle is present at all three sites, its remains make up different proportions of each assemblage. At Bonito, golden eagle remains comprise 33 percent of all avifaunal remains identified to species, while at Bc 57 they comprise only 2 percent and at Bc 58, 4 percent. The presence of at least thirty-three (MNI) golden eagles at Bonito clearly represents a greater level of investment in procurement than at Bc 57 or Bc 58. When NISP is taken into consideration, we can compare overall investment in the procurement of birds between these sites.

In examining a single species at a single site, the Total Procurement Score of that species can be multiplied by its NISP to produce a value that represents all of the remains from that species. For example, golden eagle has a Total Procurement Score of 29.5, and at Bc 57 there are 9 NISP, resulting in a value of 265.5. This calculation can be made for each species in an assemblage, producing the *Acquisition Value*, which theoretically is a reflection of all the "effort" expended in the procurement of all the birds of a given species whose remains are present in an assemblage. Next, the Acquisition Values for all species at a site can be summed together, producing a number that theoretically reflects the total amount of investment put into the entire assemblage of a single site. Of course, the Summed Acquisition Values for each site are driven by sample size. We can control for this by dividing the Summed Acquisition Value for each site by the total NISP for each site to obtain values standardized by assemblage size that can be compared among sites. In so doing, we can see that the highest value by far (24.4) is at Bonito (table 8.3), driven in part by the large quantity of golden eagle remains. Bc 58 has the second largest Standardized Summed Acquisition Value (18.1), followed by Bc 57 (17.6).

The importance of golden eagle to the inhabitants of Chaco Canyon, reflected in their NISP, Total Procurement Scores, and summed and standardized Acquisition

TABLE 8.3. Calculated Summed Acquisition Values in three sites at Chaco Canyon, New Mexico

	Pueblo Bonito	*Bc 57*	*Bc 58*
NISP	1,016	580	23
Summed Acquisition Values	24,749.5	10,195	416.5
Summed Acquisition Values standardized by NISP	24.4	17.6	18.1
Without turkeys	27.5	23.1	25.8

Values, is rivaled only by the contribution of turkey—a very different type of bird—to the assemblages analyzed here. The domestication history of turkeys in the New World is especially complicated. While DNA and other evidence indicates that domesticated turkeys may have been present in the Southwest as early as 200 CE, people also likely continued to exploit local wild turkey (*M. gallopavo merriami*) at the same time they were raising domestic stock (Grimstead et al. 2014; Speller et al. 2010). Population-level patterns in the isotopic analysis of strontium ($^{87}Sr/^{86}Sr$) have suggested that turkeys in Chaco Canyon may have been kept or raised in pueblo rooms or potentially tethered (Grimstead et al. 2014:141). Contrary to many other birds, turkeys appear to have often been a source of food as well as feathers in the ancestral Pueblo world, although their primary role likely changed over time (see Beacham and Durand 2007; Breitburg 1988; McKusick 1986; Windes 1987).

Because much debate still surrounds turkey procurement and domestication, they must be reconsidered here. Wild turkey already has a low Total Procurement Score (table 8.2) and would be relatively less difficult to capture in the wild than other species. Maintaining populations of turkeys at or near habitation sites would make their procurement even simpler. The factors that are important in the procurement of wild turkeys become irrelevant where domesticated turkeys are concerned, since variables such as feeding/foraging and nesting locations are controlled by humans. Treating all turkey remains in the assemblages analyzed here as either wild or domestic, when in reality both may have been present simultaneously, has the potential to obfuscate other patterns by inflating or deflating summed and standardized Acquisition Values. Turkeys were therefore experimentally removed from the calculations of Summed Acquisition Values just discussed (table 8.3). Even so, the same patterns already observed are maintained; Pueblo Bonito still has the highest Standardized Summed Acquisition Value, followed by Bc 58, then Bc 57.

Importantly, MNI would be an equally acceptable and an even more logical value to use in calculating Acquisition Values. Using NISP in the analysis presented here allowed for the unification of multiple datasets from different sources, produced by different analysts and of varying degrees of detail, where MNI was not always available or reconstructable. Using MNI would be appropriate because the measure approximates the minimum number of birds (as individuals) present in an assemblage rather than the number of bone specimens of a given species. However, preliminary analysis of the effects of using MNI versus NISP in this analysis has revealed little difference in results. In future and similar analyses, MNI can simply be used in place of NISP in the model and calculations presented here.

The Standardized Summed Acquisition Values, calculated with or without turkeys, indicate that residents of Bonito expended greater effort in capturing wild birds likely of ritual and symbolic importance than did residents of Bc 57 or Bc 58. While Bc 58 has a higher value than Bc 57, the much larger avifaunal assemblage and high number of raptor species at Bc 57 indicate that residents of Bc 57 were still more involved in the procurement of birds likely for ritual purposes.

CONCLUSION

During the occupation of Chaco Canyon, high-value birds, particularly raptors, were of great importance as evidenced by the frequencies with which their remains occur and the proportion of assemblages their remains comprise. The significance of these types of birds has been demonstrated ethnographically. The disproportionate contribution to these assemblages of species with the highest Total Procurement Scores stands in opposition to the expectations of a more diet-oriented use of birds. Many species that are gregarious, ground-dwelling, and medium- to large-bodied and that would have provided good additional sources of food are common in northwestern New Mexico. The low proportion of these birds, with low Total Procurement Scores, suggests that wild birds—besides turkey—were likely not sought out for food. Quite the opposite pattern is obvious; the inhabitants of Chaco Canyon routinely desired and acquired types of birds that, relative to other species, would have been challenging to procure. This fact underlines their evident significance to people of the past, with the implication that these birds likely figured prominently in ritual practices.

Differences in the scale of bird procurement and the proportions of high-value birds at each site may indicate differences in the nature or scale of the types of ritual that took place at each of these pueblos. While inhabitants of Pueblo Bonito imported high-investment parrots in addition to acquiring birds of prey, people at the small sites across the canyon focused on local but still hard to capture birds, with this endeavor greater at Bc 57 than at Bc 58. Procuring particularly significant types of birds may have been a specialized task undertaken by only certain individuals or social groups, a pattern that has been noted ethnographically in the case of raptors at Hopi (Fewkes 1900; Voth 1912).

The model presented here provides a way to incorporate the agency of wild animals into our understanding of human-animal interactions in the past. It considers eleven aspects of bird biology and behavior and provides a way to include them in zooarchaeological analyses. Calculating Total Procurement Scores allows the comparison of different species relative to one another and affords an understanding of investment in bird procurement at a single site. Incorporating NISP allows comparisons between sites and would be equally applicable to differentiating between different areas of a single site and different types of contexts and to examining change over time. This model is easily adaptable to avifaunal assemblages around the world.

When considering human interactions with birds and other wild animals, detailed consideration must be given to the characteristics of particular species. Birds are uniquely capable of flight, but, like other animals, they have other characteristics that constrain or otherwise determine the outcome of a single interaction between them and humans. By considering agentive actions on both sides of the human-animal relationship, we can acknowledge the role birds played in these interactions, in which they were not merely passive objects to be consumed and controlled by active human subjects. From this perspective, human "use" of birds becomes human *engagement* with birds and acknowledges that both parties co-shaped their relationship with one another. Presumably, it is this agency endowed by behavioral and biological characteristics, especially concerning flight, that has given birds such symbolic importance throughout time and throughout the world.

Acknowledgments. I am grateful to Monica Smith for organizing the conference session in which an initial version of this chapter was presented and for providing feedback. I am also grateful to Patricia Crown, Emily Lena Jones, Caitlin Ainsworth, and Stephanie Franklin for graciously sharing avifaunal data from Pueblo Bonito Room 28. Adam Watson, Greg Schachner, Tom Wake, Samantha Fladd, and Reuven Sinensky were all helpful sounding boards during the planning of this chapter. Funding for portions of the research presented in this chapter was provided by the National Science Foundation (Doctoral Dissertation Research Improvement Award 1817552), the Fred Plog Memorial Fellowship, the PaleoWest Foundation, and the UCLA Cotsen Institute of Archaeology.

NOTES

1. The model presented here can, by necessity, only use species-level data. Where remains are identified to only genus or family, for example, too much variability in biology and behavior exists at these taxonomic levels to be able to assign accurate values for each Visibility and Interaction Factor.

2. *Ara macao* (scarlet macaw) is a non-local species whose native range appears to have never extended into the Southwest. In historical times, *Rhynchopsitta pachyrhyncha* (thick-billed parrot) was an occasional visitor and probably a resident breeder in southeastern Arizona and southwestern New Mexico (Phillips et al. 1964; Wetmore 1935; Cornell Lab of Ornithology [https://birdsna.org/Species-Account/bna/species/thbpar/distribution]).

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9

Rats, Bats, and Birds

The Role of Non-Human Ecosystem Engineers in Pre-European Polynesian Agriculture

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ABSTRACT

Agricultural practices modify the environment, and that modified environment is, in turn, inherited by subsequent generations. Humans are not the only animals that transform the environment, however, and humans often use ecosystems that depend on the engineering and services of other animals for maintained functionality. In this way, non-human animals also influence trajectories of agricultural change, as we demonstrate empirically using case studies from East Polynesia focused on Rapa Nui, the Marquesas, the Cook Islands, and the Gambier Islands. Through the discussion of ecosystem engineering and ecological inheritance, we show how non-human animals bring about incremental changes to the environment, which are then inherited by human populations and come to affect the ways food production and other cultural practices intersect and cascade through time.

Historically random processes can produce novel opportunities and constraints for cultural practices (Bintliff 1999). For instance, the cumulative outcomes of land use can carry significant and sometimes unintended ramifications for the behaviors of successive generations (van der Leeuw 2013). Such impacts are especially apparent in sequences of agricultural change when people create the environmental conditions and social context of food production through long-term activity of agricultural infrastructure, anthropogenic soils, and land tenure (Morrison 2006). All practices of cultivation modify the environment, even in subtle ways, and that

https://doi.org/10.5876/9781646423521.c009

modified environment is transmitted to future generations in that location. As the modification and inheritance of the environment create a different context for cultivation, they often lead to changes in the way production is practiced.

Understanding the scope of human modifications to the environment and their recursive influence on human societies has profoundly influenced discussions of human agency in landscape evolution (e.g., Balée 2006; Balée and Erickson 2006). However, humans are not the only animals that modify their environments, and these other animals live alongside and become entangled with humans, as noted also by Ammerman (chapter 10), Bishop (chapter 8), and Tomášková (chapter 11, all this volume). Such multi-agent landscape modification is accentuated when humans and other organisms migrate or are introduced to new regions. These impacts are especially apparent in the relatively small, isolated islands of Oceania, where human voyagers brought animals intentionally (e.g., pigs, dogs, chickens) and unintentionally (e.g., rats, land snails, earthworms) to islands already inhabited by birds, bats, lizards, and other organisms. Habitation in new environments by migrating or introduced organisms created a catalyst for changes and disruptions to organisms long in place.

We structure our discussion of non-human agency around the concepts of niche construction and ecosystem engineering. These concepts highlight the capacity of non-human animals to reshape environments in ways that impact material and energy flows (Jones et al. 1994), as well as the evolution of other species (Odling-Smee et al. 2003). Ecosystem engineers often play disproportionately larger roles than other organisms within social-ecological systems, given their involvement across a wide range of services including provisioning services (e.g., food), regulating services (e.g., decomposing wastes and maintaining water quality), cultural services (e.g., recreational and spiritual benefits), and supporting services (e.g., soil formation, photosynthesis, and nutrient cycling; MEA 2005). In this way, the activities of non-human animals can influence human agricultural development by contributing to the socio-ecological context of production each generation encounters. To empirically investigate the contributions of non-human actors in sequences of agricultural development, in particular those that are non-domesticated, we use four archaeological case studies from Polynesia (Rapa Nui, the Marquesas, Mangareva, and Mangaia) that illustrate ecosystem services or engineering activities provided by several key fauna: native birds and bats and the human-introduced Polynesian rat (*Rattus exulans*).

NICHE CONSTRUCTION, ECOSYSTEM ENGINEERING, AND ECOLOGICAL INHERITANCE

Humans and other organisms impact the evolution of themselves and other species through the modification of their environment and the transmission of that modified environment, a process now referred to as niche construction (Odling-Smee 2003). This process can be described by two separate mechanisms: ecosystem engineering and ecological inheritance. Ecosystem engineering describes the actions of organisms to modify their environments in such a way that it changes the availability and distribution of resources for themselves and others. In turn, changes to resource availability and distributions alter or create new habitats and transform nutrient and energy flows, thereby altering the selective pressures within a particular ecosystem (Jones et al. 1994, 1997). The modified ecosystems and novel selective pressures are transmitted to subsequent generations in that same location, a process referred to as ecological inheritance. Within a niche construction framework, this inheritance serves as the crucial link between the engineering behavior of past organisms and the viability and development of future organisms in the same location.

Humans are thought of colloquially as the ultimate ecosystem engineers, and humans have certainly had substantial impacts on their environments (ArchaeoGlobe 2019; Boivin et al. 2016; Ellis 2015). Significant ecosystem engineering effects are also made by non-human and non-domesticated animals. This can be most easily appreciated for large animals such as African elephants and other megafauna that transport large amounts of sediment and nutrients from one location to another (Doughty et al. 2013; Haynes 2012). Yet animals do not have to be large in stature or body mass to make significant alterations to their surrounding ecosystems (Wilby 2002). Earthworms, ants, termites, and gophers all modify landscapes through the movement of soil (Lavelle et al. 2006; Johnson et al. 2005; Yoo et al. 2005), constructing landscape features such as mounds that are evident within landscapes of human activity (McKey et al. 2010; Zangerlé et al. 2016). Burrowing animals also substantially affect water and sediment fluxes, not only vertically within soil profiles (Capowiez et al. 2014) but also laterally at landscape scales (Wackett et al. 2018). These behaviors extend outside of terrestrial environments as well. Beavers are the best-documented example, as their construction activity contributes to the modification of stream stability, channel width, and the texture of stream bank sediments (Polivi and Sarneel 2018). Modification of surrounding environments by non-human animal agents thus contributes to both stasis and change in ecosystems (see Laland and Boogert 2010). Today, the recognized importance of ecosystem engineering in the creation of habitats is exemplified by the deliberate introduction or reintroduction of some animals by conservationists to increase or manage biodiversity (Burney and Burney 2016; Byers et al. 2006; Derner et al. 2009).

Ecological inheritance is unique compared to genetic and cultural inheritance because it can occur among different types of organisms. For example, an insect-modified ecosystem will be inherited by subsequent generations of humans and vice versa. In this way, animal impacts on both human populations and other organisms become more complex through time. Ecological inheritance creates the potential for enhanced feedback and cascading interactions, creating more complex causal scenarios (see Laland et al. 2011). The process is cumulative and gives rise to far-reaching influences on evolutionary pathways in which the process of ecological inheritance may result in unexpected or unforeseen consequences of ecosystem engineering, which are just as important in structuring future behaviors as those that are intended or expected. While the time depth of such processes is generally unknown, Douglas H. Erwin (2008) has suggested that some effects of ecosystem engineering and other sources of niche construction activities can be felt across geological time on the scale of hundreds of thousands or millions of years.

Anthropologists have recognized the effects of these processes on humans, and Timothy Ingold (1995) specifically grappled with the implications of niche construction in his concept of "dwelling." He drew attention to the potential for long-term entanglements between humans and non-human animals through their mutual dwelling activities in the same location. Both contribute to the continual construction of the environment in which they dwell. Both respond to the impacts of the other, over short and long timescales. At any given time, one might be considered to be more important, but such importance is fleeting and difficult to untangle. It is within this context that we turn to the activity of agriculture and the complex contemporary entanglements recognized therein.

ANIMAL AGENTS IN CONTEMPORARY AGRICULTURE AND PLANT GROWTH

While the influence of anthropogenically modified environments on the long-term evolution of production systems is recognized (e.g., Kirch 1994), the impact of non-human ecosystem engineering remains under-appreciated. This is curious given the role played by a range of organisms in modern agricultural production systems. Landesque capital forms of agricultural intensification are classically defined as investments in long-lasting geomorphic alterations to the environment that improve production or reduce labor expenditure (Blaikie and Brookfield 1987). However, more recent theorizing has included reference to enduring biotic transformations as well (Morrison 2014). These modifications are inherited and manipulated by successive generations of producers. As such, ecosystem engineering and ecological inheritance are at the center of agricultural practice, and the combination of the two underpins the concept of landesque capital (Håkansson and Widgren 2014).

Few animals figure more prominently than earthworms in the vast literature that examines the effects of non-domesticated animals on modern agricultural strategies and productivity (Edwards and Bohlen 1996). For the most part, earthworm ecosystem engineering is beneficial for agriculture given its role in water regulation, soil structural stability, and nutrient cycling (Blouin et al. 2013). Earthworm activities reduce soil compaction and increase water infiltration, processes long known to be important in food production (Capowiez et al. 2014). Earthworms are also an important component of nitrogen (N) mineralization (Marinissen and Ruiter 1993). Still, research has also shown that earthworm ecosystem engineering can have a negative effect on plant productivity. Earthworm activity is known to increase soil erosion in some locations (Blanchart et al. 2004), which, especially in the tropics, could reduce biome productivity.

Birds provide another example of connections between the ecosystem engineering and ecosystem services of modern fauna and plant growth through insect predation, seed dispersal, and nutrient inputs through guano deposition. Birds are known to reduce insect species that prey on crops and other vegetation, thereby increasing crop yields by removing those pests (Johnson et al. 2010; Whelan et al. 2008). Bats also prey on insects, with bats and birds often working in tandem in tropical agroforestry landscapes (Maas et al. 2013). The avian ecosystem service of plant seed dispersal is more directly associated with environmental net primary productivity and human food production. This is especially true in the tropics, where 30 percent to 50 percent of plant species are dispersed by vertebrates (Wenny et al. 2011:3).

Removal of birds and other frugivorous animals from ecosystems can result in a reduction or risk of reduction of trees that produce large seeds or fruits, since they require large-bodied dispersers (Hansen and Galetti 2009; Meehan et al. 2002). This is apparent on remote islands where native and introduced plants rely on a small number of dispersal or pollinating agents because of the lack of agent redundancy (Kelly et al. 2010; McConkey and Drake 2015). In their study, Sandra H. Anderson and colleagues (2011) found that mammalian predation of pollinating birds in New Zealand resulted in an 84 percent reduction in seed output and a 54 percent reduction in regeneration of a native shrub (*Rhabdothamnus solandri*; taurepo), though generally, the impacts of mutualism disruption are still poorly understood and poorly quantified for both native and introduced species (Wenny et al. 2011).

Finally, the foraging behavior of seabirds that focus on aquatic species can redistribute key nutrients from marine to land-based ecosystems through guano deposition, especially nitrogen (N) and phosphorus (P) (Ellis 2005:234). Wendy B. Anderson and Gary A. Polis (1999) report six-fold increases in N and P due to increased seabird guano deposition in the coastal islands of California, which, in turn, increased the growth of long-lived cactus, short-lived shrubs, and annuals. Such results can be applied to the growth of economic crops. For example, an experimental study observed that maize fertilized with seabird guano resulted in higher crop yields and ^{15}N-enriched soils (Szpak et al. 2012). The long-term effects of changing seabird abundance will often cascade throughout entire ecosystems, impacting other organisms that have become dependent on seabirds' ecosystem services (Sánchez-Piñero and Polis 2000; Thoresen et al. 2017).

Relationships between human and animal agents are intertwined: human behavior (e.g., engineering, plant and animal introductions) impacts animal behavior, thereby disrupting, altering, or enhancing ecosystem services—which can then provide the background for changes in human behavior (e.g., agricultural practices). Such feedback loops can be positive or negative for the other species in an ecosystem; positive examples of such relationships are the human-constructed hedges or field margins in European agricultural systems, which serve as havens for myriad organisms that interact with and provide services for crop growth—including birds that pollinate plants, disperse seeds, and prey on field pests (Marshall and Moonen 2002). From the human perspective, the creation of artificial habitats promotes more stable long-term production by attracting organisms that provide ecosystem services beneficial for plant growth. However, some anthropogenic botanical modifications can reshape ecosystem energy flows in ways that are ultimately detrimental to human populations. For instance, the propagation of economic coconuts (*Cocos nucifera*) reduces N and P nutrient availability in tropical environments because the trees are avoided by nesting seabirds (Young et al. 2010). Similarly, limited comparisons between palm- versus non-palm-dominated ecosystems documented 10 to 20 times more N and 10 to 18 times more P in the non-palm ecosystems (Young et al. 2017), presumably because of differential guano deposition. Based on these differences, the long-term effects of introduced palms potentially include reduced productivity of arable land due to nutrient declines.

While scholars have long recognized the modern connections between animal activities and agriculture, the complexity of these relationships and their significance for archaeological study are not well explored, especially in terms of non-domesticated animals. Given the important and often complex relationships observed today, non-domesticated, non-human animals surely influenced the developmental pathways of food production systems in the past as well (see Leppard 2018).

OCEANIC CASES

Islands serve as model systems for the investigation of human-environment relationships (e.g., DiNapoli and Leppard 2018; Fitzpatrick and Erlandson 2018; Kirch 2007). Due to a degree of isolation and less complex biology and geology relative to continental systems, the effects of human-animal-environment interactions are

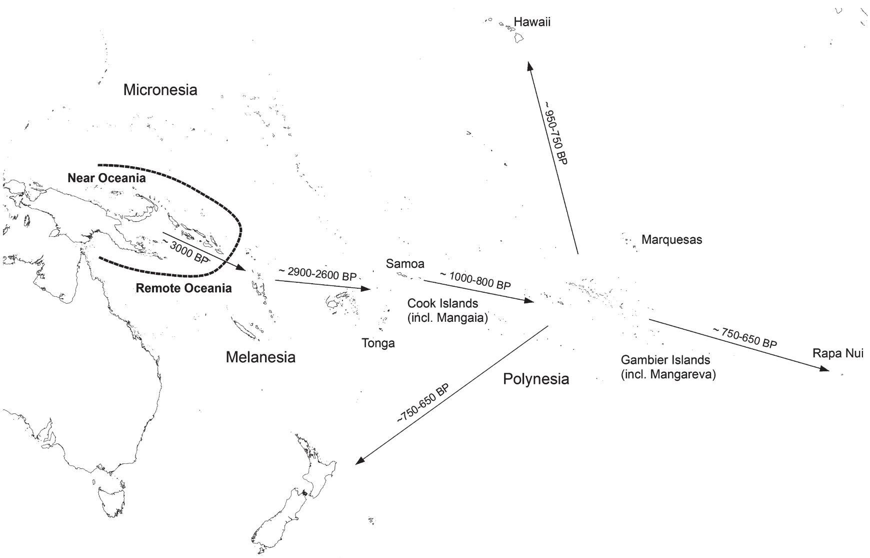

Figure 9.1. Distribution of case-study islands across East Polynesia (Rapa Nui, the Marquesas, Mangareva, and Mangaia) in relation to other islands and groups of islands. Arrows denote the timing and direction of initial island settlement in years BP (before present).

clearer or more apparent in these settings. In fact, islands have long been regarded as useful spaces to examine niche construction activities (Kirch 1980). This is especially true of the relationship between the environment and agricultural practices, where the bounded nature of islands presents opportunities for investigations of agricultural sequences that evolved—to some extent—independent of other island groups. The impact of species introductions (including humans) is often immediately visible on islands and can provide information on how the ecosystem engineering activities of introduced species resulted in impacts on long-term ecosystem functioning. Here, we focus on four case studies that demonstrate the importance of this theme: Rapa Nui, the Marquesas Islands, Mangaia (Cook Islands), and Mangareva (Gambier Islands). All of the islands in these case studies are located in the cultural area of East Polynesia (figure 9.1), and all were settled by humans in the last 1,000 years.

Rapa Nui: Behavioral Outcomes of Rat-Influenced Forest Decline

Rapa Nui, also referred to as Easter Island, is one of the most remote islands in the Pacific and one of the last to be settled (ca. twelfth–thirteenth centuries CE;

Hunt and Lipo 2008). The island is the most archaeologically investigated in the region, owing to its monolithic statues (*moai*) and accompanying narratives of the past that have long captivated archaeologists, ecologists, and the general public (see Diamond 2005). Substantial environmental changes occurred on Rapa Nui after human arrival (Flenley 1979; Flenley et al. 1991; Mann et al. 2008). Although Rapa Nui's pre-human environment was dominated by trees (Mieth and Bork 2010), only small trees and shrubs existed by the time Europeans arrived in the area (e.g., González et al. 1908:101). Significant forest declines such as this can have many cascading effects: the removal of tall vegetation increases wind prevalence and speed and also changes the environmental water balance. In some world regions, deforestation correlates with increased aridity (Cook et al. 2012), in part because the removal of trees decreases plant transpiration, which can result in reduced regional rainfall and water availability (Laurance and Williamson 2001).

The causes of environmental change are more nuanced than originally thought, such that the classic narrative of human-induced environmental and societal "collapse" on Rapa Nui is unlikely based on archaeological evidence (e.g., Hunt 2007; Mulrooney 2012). Forest contraction was a protracted process instead of a rapid event, spanning four centuries from roughly 1250 to 1650 CE (Hunt and Lipo 2018). The declines were most likely the result of multiple overlapping factors that included climate change *and* human land-use practices (Mieth and Bork 2010), but the Polynesian rat probably also played a role. As described by Terry L. Hunt (2007), rat populations had few natural constraints, and the apparent prevalence of palm seeds provided an attractive and ready food source. In fact, there is archaeological evidence of rats preying on native Rapa Nui palm tree seeds (*Jubaea* sp., syn. *Paschalococos disperta*) (Hunt 2007). Rat impacts on vegetation are known or hypothesized for other locations at other times, including case studies from the Pacific prehistorically (Athens 2009; Athens et al. 2002) and historically (Campbell and Atkinson 2002). In addition to their effects on vegetation, the introduction of rats had further cascading effects, as rat populations prey on seabird nests (Atkinson 1985). Decreasing seabird populations, evident in the island's archaeological record (Steadman et al. 1994), were followed by changes in nutrient cycling on the island, resulting in poorer soil fertility that necessitated alternative strategies of nutrient input (Hunt and Lipo 2009:605).

On Rapa Nui, human settlers developed a variety of cultivation techniques, including pit and walled cultivation (*manavai*) and lithic mulch gardens (Stevenson et al. 2002; Wozniak 1999). The latter technique is particularly extensive and forms an important component of the productive landscape (Ladefoged et al. 2013). The use of these techniques increased soil moisture retention and reduced variation in soil temperatures. These functions counteract the constraints of the Rapa Nui environment, which includes aridity caused by low precipitation and high wind speeds (Louwagie et al. 2006) made worse by deforestation. On the other hand, the inclusion of basalt in lithic gardens likely increased soil nutrient availability through weathering (Vitousek et al. 2014), and soil fertility was perhaps improved by human-mediated inputs of seabird guano (Commendador et al. 2013; Jarman et al. 2017:358).

Rapa Nui was always a challenging environment for cultivation, even before deforestation. Because of this, Terry L. Hunt and Carl P. Lipo (2009:606) argued that deforestation was not the only factor influencing the development of agricultural infrastructure because people likely practiced some moisture-saving techniques. Still, there are temporal correlations between the expansion of lithic mulch gardens and the sequence of deforestation for the island that hint at a causal relationship. The earliest dated examples of lithic mulch gardens on Rapa Nui were constructed in the fourteenth and fifteenth centuries (Bork et al. 2004; Stevenson 1997), with the most intensive use evident in the sixteenth to eighteenth centuries (Ladefoged et al. 2013; Stevenson et al. 2006). Based on this chronological sequence, Hans-Rudolf Bork and colleagues (2004:12) explicitly connected the development of lithic gardens to ecological change on Rapa Nui (see also Hunt 2007:498); and Christopher M. Stevenson and coauthors (2006) hypothesized a sequence that began with forest decline, was followed by open field cultivation, and was then replaced with the use of lithic mulches as aridity increased with forest contraction. The addition of nutrients through lithic mulches (Vitousek et al. 2014) may even have offset declines in nutrient inputs caused by seabird reductions through time.

While a lot remains unknown, at least some of the conditions that led to the development, use, expansion, and persistence of lithic gardens are documented for Rapa Nui. They include the impacts of static environmental conditions (Stevenson et al. 2015) and previous land-use decisions inherited by later generations of agricultural communities (Stevenson et al. 2006). The archaeological evidence from Rapa Nui (Hunt 2007; Hunt and Lipo 2009) and other Polynesian islands (Athens 2009; Athens et al. 2002) suggests that rats played a partial role in forest contraction by restricting the reproduction of vegetation, likely through predation on both palm seeds and seabird nests. As such, agricultural pathways were partially influenced by the ecosystem engineering capabilities of introduced rats. Important in this equation is the fact that the ecological impacts of rats accumulated through time and that the effects inherited by subsequent human population were exacerbated by other factors, including climatic conditions and human deforestation. Inheritance is the key mechanism by which rat impacts and their entanglement with broader ecological factors accumulated to influence change in human cultural practices. The sum of these modified ecosystems called for a response by human populations that led to the innovation and expansion of specific agricultural strategies, such as enclosures and mulching.

Marquesas Islands: What Occurs When Seed Dispersal Becomes Restricted?

The Marquesas Islands, initially settled ca. eleventh–twelfth centuries CE (Allen 2014), form part of the eastern boundary of Polynesia. These islands are rugged and known for their food production systems centered on the cultivation of introduced tree crops, particularly breadfruit (e.g., Crook 2007:73–74; Forster 1777:27; Krusenstern 1813:124–125). Archaeological research over the past twenty years illustrates the temporal sequence of forest transformations that resulted in these intensive arboricultural landscapes, particularly on the island of Nuku Hiva. The indigenous Marquesan lowland forests were irrevocably altered within two to three centuries of Pacific Islander arrival, and there is evidence that the productive tree-cropping systems observed at Western contact were in place by 1650 CE (Huebert and Allen 2016). While the creation of agroforest landscapes generated numerous anthropogenic environmental transitions, the crucial role played by birds in Marquesan vegetation change has also been recognized (Huebert 2014:265–267, 2015; Huebert and Allen 2020).

The development of an agronomic system focused on arboriculture helped maintain the forest structure compared to more open field cultivation systems created in other regions of the Pacific and, in turn, continued to provide a habitat for native fauna, including land birds. Even so, there are indications of drastic reductions in some avifaunal species due to hunting, particularly frugivorous native land birds such as pigeons and doves (Steadman and Rolett 1996). Once lost, these birds do not recover because recruitment from other islands is not feasible (Steadman 1995). These reductions would have inevitably led to further changes in forest composition. For example, Jennifer M. Huebert (2015) has found that arboreal members of the Sapotaceae vegetation family were extirpated early in the Marquesan cultural sequence. Genera of this family provide food for frugivorous birds in Polynesia (McConkey and Drake 2002:385) as well as in other regions (Snow 1981), and the fruits might have once made important contributions to the diets of larger Marquesan land birds. These plants might also have relied on birds as dispersal agents with few alternatives, with the declines in both organisms reflecting the dissolution of an important interconnected relationship.

The removal or persistence of avian ecosystem services had several implications. First, the reduction of native land birds may have decreased the spread of tree crops introduced by human populations, especially those with fleshy fruits. The importance of birds and bats in seed dispersals in modern tropical agroforestry systems (Maas et al. 2013) hints at this possibility. For example, *Cordyline fruticosa* (*tī* plants) and *Morinda citrifolia* (*noni*) are present in birds' diets elsewhere in Polynesia (McConkey et al. 2004:371; Steadman and Freifeld 1999). Bats, too, are known to act as dispersal agents and to play a role in the reproduction of economic trees such as Tahitian chestnut (*Inocarpus fagifer*) and *Pandanus* (McConkey and Drake 2002). In consideration of these activities, the retention of avian ecosystem services may have facilitated a more rapid expansion of human-introduced economic vegetation.

A follow-on effect is that the elimination of native vegetation communities, which may have been the outcome of the disruption of dispersal agents (e.g., land birds), may have facilitated more rapid establishment of novel forests, especially those propagated by humans. The opportunities provided by vegetation extirpations, such as the reduction and elimination of certain species of shrubs and trees, likely factored into forest transformation in the Marquesas. The loss of land birds may have also impacted soil nutrient cycling and hence the fertility of some spaces. Land birds, if they consume the fruits of land plants—which, in turn, take up nutrients from deep subsoil—contribute to moving deep subsurface soil nutrients to the surface soil. That mechanism is lost when those land birds become extinct, and this may have led to declines in soil nutrients. Finally, the observed economic importance of *Sapotaceae* species as fuel wood factored into its decline—a situation compounded by the loss of important dispersal agents. Over time, these declines necessitated the use of other plants as a source of fuel. The loss of land birds' ecosystem services, therefore, would have influenced the economic behaviors of human populations, which, in turn, had other long-term effects on the structure of forests. These processes are not unique to the Marquesas, as bird extinctions are well documented throughout the Pacific (Steadman 2006), and we expect that the reduction or retention of bat- and bird-associated ecosystem services played a role in the formation and continued maintenance of novel forests across the region.

A related concern regarding plant-animal interactions in this region is the impact of Polynesian rat predation on arboreal fruits and seeds, which, as previously discussed, has been attributed to the suppression and possibly even the extirpation of some plant species (rats can act as dispersers as well, but much more is known about their role as predators). Today, trees such as sandalwood (*Santalum* spp.) and *Nesoluma nadeaudii* (the latter a Sapotaceae) are severely impacted in French Polynesia by several types of rats; although researchers have concluded that they are probably not the main driver of modern-day extinctions, one study documents rats consuming up to 99 percent of sandalwood fruits (Meyer and Butaud 2009).

Mangaia and Mangareva: What Occurs When Bird Ecosystem Services Are Restricted?

Mangaia (Cook Islands) and the “almost-atoll” of Mangareva (Gambier Islands) are geologically old islands in Central East Polynesia, roughly 69 million years and 5 million to 6 million years in age, respectively (Kirch 2017; Kirch et al. 2010). Humans settled there in the eleventh century CE (Kirch et al. 2010; Niespolo et al. 2019). Extensive archaeological research conducted in both locations since the 1990s provides a substantial dataset from which to understand human-environment interactions. Each location features a complex local ecological history, but important similarities exist. Most notably, each region has a record of bird extinctions (including seabirds) and extensive vegetation change following settlement (Kirch 2007; Kirch et al. 1995). For each case, researchers have argued that prior to human settlement, birds provided a key ecosystem service by maintaining native vegetation through deposition of guano and associated nutrients (Conte and Kirch 2004:154; Kirch 2007:94; Kirch et al. 2015:36; Swift et al. 2017).

For the land mass of Mangareva, Jillian A. Swift and colleagues (2017) applied stable carbon (C) and nitrogen (N) isotope analysis of archaeological rat bone as a proxy for nutrient flows through anthropogenic food webs. Their results demonstrate a decline through time in $\delta^{15}N$ values across three of Mangareva’s islands. They associated these declines with reductions in seabird populations, caused by a combination of human and rat predation as well as contraction of native forest habitat. Elimination of seabirds from Mangareva would have had a twofold impact on rat $\delta^{15}N$: directly, through the removal of seabirds from the Pacific rat diet, as well as indirectly from the removal of ^{15}N-enriched seabird guano, which would lower baseline $\delta^{15}N$ values across the islands. While not detectable through rat bone isotope studies, Patrick V. Kirch (2007:94) similarly suggested that seabirds were essential for the maintenance of terrestrial ecosystems through inputs of P, a situation that exists elsewhere (see also Anderson and Polis 1999). While reductions in seabird populations generally are associated with human and rat predation, Kirch and colleagues (2015:39) also suggest that the removal of bird nesting habitat through the expansion of economic crop plants may have also contributed to seabird declines. Seabird reductions and nutrient losses are also evident for Mangaia, although they are not quantified. The record of seabird exploitation does, however, continue through much of the cultural sequence, and there was never a complete loss of seabirds on the island (Kirch 2017). Even though birds continued to be present, their reduction in the later temporal periods is thought to have reduced the net productivity of the environment (Kirch 2007).

The nutrient cycling transformations and loss of P and N through the decline in seabirds would have been particularly catastrophic for the geologically old and nutrient-leached islands of Mangaia and Mangareva. In combination with initial human-induced forest decline, the use of shifting cultivation, erosion, and reductions in avian-generated nutrient inputs would have resulted in lower agricultural productivity and limited capacity for forest regrowth (Kirch 2007:94; Swift et al. 2017). The most notable impact in each case was the loss of the viable productive landscape of the interior hillslopes because of the reduction of the ecosystem services of birds. It is not just the direct impacts of avian-derived nutrients that are significant, however, as such scenarios also had cascading impacts on cultural sequences.

While certainly lowering theoretical carrying capacity, landscape change did create some agricultural opportunities (see Walter and Reilly 2010:353, 367 for Mangaia). For example, the loss of soil-stabilizing tree roots on hillslopes resulted in the accumulation of sediments in valleys (Kirch 1994:282, 1996; Leppard 2018:57). In both cases, the suitability of valley ecosystems was improved for food production, especially irrigated agriculture and arboriculture (Kirch 2007:91, 95). Productive resource zones became more centralized, which resulted in differential productive capacity for different groups. Kirch (1994:276–279) and colleagues have argued that these ecological changes on Mangaia created conditions for chiefly control, resource defensibility, competition, and warfare manifesting in an interconnectedness between food production and warfare unlike anywhere else in Polynesia. Endemic warfare developed in Mangareva as well, related to the circumscribed nature of the productive environment following nutrient declines (Kirch 2007). In both locations, therefore, the reduction in seabird ecosystem services resulted in cascading effects that created contexts for circumscribed production and for political systems based on warfare and competition.

Mangaia and Mangareva provide case studies that demonstrate the wide-ranging effects of the removal of bird-associated ecosystem services. These case studies highlight the potential importance of these animals in other production systems in the region. If the removal of these birds had such an impact on nutrient dynamics and paths of agricultural change in these regions, it stands to reason that the inclusion of these birds is an important source for increased yields in environments where birds are still present (see Fukami et al. 2006).

DISCUSSION AND CONCLUSION

A complete understanding of any agricultural system requires a holistic evaluation of the pathways and processes of agricultural change (Morrison 2006). Often, such systems are the long-term outcome of socioecological circumstances that create novel landscapes and accumulate incremental change across generations. Human settlers encountered and created selective pressures that resulted in some agricultural techniques becoming more viable or less useful than others. These same human inhabitants counteracted pressures by actively constructing their environments, which resulted in intended and unintended consequences feeding back into a sequence of cause and effect (Quintus and Cochrane 2018). Humans are affected by the behaviors of other organisms as well, especially when those organisms modify or disrupt the environmental context around human activities. The reality that such modification should have an effect on human behavioral strategies is predicted by niche construction theory and supported by modern analysis of ecosystem servicing.

In each case analyzed here (table 9.1), the impacts of non-human agency were significant because of their cascading effects across ecosystems as well as their pronounced influence on important ecosystem services on which humans rely. Islands tend to have low species redundancies in which few species perform the same ecosystem services as others, such that even small-scale species reductions or losses can lead to dramatic consequences (McConkey and Drake 2015). In addition, disruption of plant-animal mutualisms can lead to escalating changes that compound to impact human populations. The importance of these animal impacts becomes more visible as temporal scales increase and as the webs of organism connectivity that maintain ecosystem functionality become more historically entangled. The accumulation of effects over time and their interaction with other ecological and anthropogenic changes create opportunities for incremental ecological shifts to influence the direction and rate of human behavioral strategies such as crop rosters, techniques of cultivation, and other social and ecological approaches.

Niche construction is a multi-agent process that is cumulative and emergent, although the specific consequences of niche constructing behavior on any organism are largely unpredictable. Environments extend beyond the sphere of humans, and the agency of other animals need not be seen only in their interactions with humans but also in their interactions with other animals, whether indigenous or introduced. For example, all four case studies presented here highlight the role rats played in transforming ecosystems through seabird predation (see also Leppard 2018), which is a well-documented process in contemporary times (Jones et al. 2008). These rats played a part in removing key ecosystem services through their predatory behavior on birds, which then modified processes of nutrient cycling important for ecosystem functioning (Fukami et al. 2006) and human strategies of resource procurement.

While ecosystem engineering can be difficult to quantify on archaeological timescales, recent isotopic analyses of commensal fauna present opportunities for tracing and measuring the long-term impacts of human-animal-environment interactions on island food webs and nutrient flows (Swift et al. 2018). In the Marquesan

TABLE 9.1. Summary of non-human impacts on agricultural trajectories in Polynesia

Animals	*Ecosystem Service/ Activity*	*Compounding Factors*	*Outcome*	*Case Study Highlighted*
Rats	Predation of vegetation and avifauna	Low static soil fertility, human forest removal	Deforestation, changing nutrient cycle, human agricultural innovation	Rapa Nui, Marquesas, Mangaia, Mangareva
Seabirds	Loss of bird-derived nutrient deposition	Human predation, rat predation, human agroforestry	Deforestation, changing nutrient cycle, circumscription of production	Rapa Nui, Mangaia, Mangareva
Land birds	Negation or persistence of seed dispersal and loss of nutrient cycling	Human predation, rat predation, human agroforestry	Forest restructuring, manipulation of mutualisms, changing nutrient cycling	Marquesas
Bats	Negation or persistence of seed dispersal and loss of nutrient cycling	Human predation, human agroforestry	Forest restructuring, manipulation of mutualisms, changing nutrient cycling	Marquesas

case study, birds and bats dispersed seeds in ways that affected the distribution of trees and other vegetation. Impacts on this process might be measured by examining the distribution and development of novel economic landscapes in places where those ecosystem services are still intact and comparing that to locations where they are lost. If ecosystem services such as bird-mediated seed dispersal played a critical role in these sequences, variation in final outcomes should be identifiable.

The environment, including its flora and fauna, is often viewed as a backdrop of human resource exploitation, including cultivation. However, as Brendan J. Doody and colleagues (2015:126) and Harper Dine and coauthors (chapter 7, this volume) have shown for weed species in gardens, the presence and impacts of flora and fauna often play important roles in constraining and presenting opportunities for certain behaviors among all the species participating in the system. It is the characteristics of these relationships formed among humans, plants, and non-human animals that dictate the nature of agency. The concepts of niche construction, ecosystem engineering, and ecosystem services are manifested in actions by all parts of an ecosystem. Engaged actions of farming, hunting, and resource collection on the landscape scale create human, plant, and animal entanglements, in addition to the sedentary actions of what Timothy Ingold (1995) has called "dwelling." The resultant persistence of ecosystem functionality, on which humans and other organisms rely, is contingent on webs of relationships that are at the core of understandings of agencies (see Murdoch 1997). Recognizing these entanglements is important to appreciate how agency is materialized as well as how that materialization is embedded within and persists through landscapes to influence future generations of the same and other organisms, including but not limited to humans.

Pathways of agricultural change are the product of multiple factors that interact temporally and spatially. No single factor directs these trajectories, though they may influence strategies in part, as historical contingencies are one component of causation. An important consideration is the role non-human animals play in constructing the environments within which cultivation is conducted. As demonstrated here, various non-domestic animals both in contemporary times and in the deep past influenced pathways of agricultural change and agricultural strategies. This was largely accomplished by making the practice of one technique more likely than another through ecological change, which was subsequently inherited by future generations.

Acknowledgments. We wish to extend our gratitude to the editor of this volume, Monica Smith, as well as to two anonymous reviewers. Comments from these individuals on earlier drafts of this chapter have certainly improved the final product.

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10

Animal Agents in the Human Environment

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ABSTRACT

Humans' increasingly close relationship to animals constitutes one of the most important cultural, social, and economic developments of the past 10,000 years of our history. Animals have been and continue to be important sources of food, labor, and secondary products in many societies. As relationships with animals intensify, processes such as domestication ensure that humans are potentially able to control the behavior and deployment of large numbers of animals, altering ecosystems and creating an anthropogenic landscape. However, these types of relationships are heavily structured by the innate attributes of the animals involved: pre-evolved characteristics create the set of possibilities on which human agents can act, and actions undertaken by animals have major impacts on human as well as conspecific behavior. The agentive actions of wild and commensal animals are evident in trajectories of domestication and are further brought to the fore through the process of ferality, which is an agentive re-imagination of the domesticated niche and not always controllable by human actions.

All animals interact with other animals that share their environment, not only through predator/prey relationships but also through a variety of biological symbioses. One type of symbiosis is a mutualism in which individuals of both species benefit from the interaction, such as cleaner wrasse eating the parasites of larger fish: the larger fish benefits from a reduced parasite load, and the wrasse benefits by

https://doi.org/10.5876/9781646423521.c010

Figure 10.1. Birds exploiting the disturbance caused by the cow to improve hunting success for insects. Author photo.

having an easily procured meal. Relationships in which individuals of one species benefit from the relationship while individuals of the other are neither helped nor harmed are known as commensalisms. Examples of this include cases where an animal benefits from the environment created by another, such as birds exploiting the disturbance caused by cattle to improve their success at hunting for insects (figure 10.1). A relationship in which individuals of one species benefit to the detriment of individuals of another is known as parasitism; this includes relationships in which members of one species feed off hosts of another species (such as ticks or lice feeding off mammalian hosts), but it can also encompass more complex interactions, as in the brood parasitism of a parasite that tricks or coerces the host into rearing its young. An amensal relationship is the opposite of a commensal one: members of one species are neither helped nor harmed by the interaction, while members of the other are harmed. An example of this could be the relationship between a swarm of locusts and a prairie dog colony. When the swarm of locusts denudes the vegetation from the colony's location, the prairie dogs are left with nothing to eat (causing harm) but the locusts are indifferent to their presence or needs. A final type of symbiosis is neutralism, in which species share the same landscape but don't directly benefit from one another's presence, as in mixed herds of zebra and wildebeest.

Humans likewise have always maintained various types of relationships with the animals that shared their environment. Early hominins were poorly equipped to defend themselves from large predators, so a feature of this interaction would have been avoidance of becoming prey. Early hominids such as *Australopithecus afarensis* were frequently preyed upon by large cats, dogs, hyenas, bears, and even raptors. The relationship of humans as prey is not only represented in our early evolutionary history but continues today (albeit much less frequently; Hart and Sussman 2018). Our human ancestors also took advantage of changes to the environment created by other animals, such as scavenging the kills of other predators (Shipman 2010) and exploiting trails made by large animals (Haynes 2006). The development of tools by human ancestors was motivated at least in part by the need to process animal carcasses and to aid in the capture of animals for consumption (Shipman 2010). The importance of animals to early humans is shown by the preponderance of animal imagery in early figurative art (for more on the symbolic importance of animals, see Bishop, chapter 8, and Tomášková, chapter 11, both this volume). As human relationships with their environment became more complex, animals were relied on as sentries, as walking meat larders (Clutton-Brock 2012:35), and as living tools, as well as a source for power (Shipman 2010). While we tend to conceptualize these interactions as driven primarily by choices made by humans, the agency of animals also plays a large role in defining these relationships, particularly with reference to domestication as a clear symbiotic partnership.

Starting at least 11,000 years ago (Zeder 2012a), humans began experimenting with a strategy that involved closer relationships with animals, and some species of animals started to take advantage of closer relationships with humans. We now recognize this as the early stages of the process of domestication. Over many generations, animals that found reproductive success through these relationships manifested the evolutionary effects of this changed strategy via the physiological, behavioral, and genetic changes we associate with domestic animals (the so-called domestication syndrome; Larson and Fuller 2014; for the limitations of this concept, see Lord et al. 2020). Of the multitude of animal species co-occupying environments with humans, only a few went on to become domesticates. Is this small sample size the result of unwillingness on the part of humans to domesticate other species (lack of need) or the result of other species not having a suitable temperament for domestication?

In the process of domestication, the agency of animals to enter into a social contract with humans (giving subservience and docility in exchange for food and protection; figure 10.2) drastically altered survival strategies. For many domesticated species, this new survival strategy has resulted in much greater reproductive success compared to their wild progenitors. The domestic cow is one of the most plentiful large animals on earth, while its ancestor, the wild aurochs, is extinct (Felius et al. 2014). The same is true of the domestic horse; its wild ancestor, the tarpan, is extinct.

Figure 10.2. Domestic animals rely in part on humans to fulfill their needs for safety and shelter. Author photo.

The wild progenitors of sheep and goats, the Asiatic mouflon and Asiatic bezoar, are both listed as vulnerable by the International Union for Conservation of Nature (IUCN 2019).

ANIMAL AGENCY

Agency relates to the ability of an organism to impact its environment by selecting among options for how to fulfill basic needs of food, shelter, and reproduction. The fields of cognitive psychology and philosophy provide a framework for thinking about animals, which can move and act autonomously, as agents. Shaun Gallagher's (2000) attempts to reconcile philosophy and cognitive science lead him to divide the self into two levels, the more basic of which is a "minimal self." The "minimal self" is "a consciousness of oneself as an immediate subject of experience . . . One does not have to know or be aware of this to have an experience that still counts as a self-experience" (15). The minimal self is the part of the self that understands that something is happening to you. The concept of the minimal self allows the ideas of a "sense of agency" and a "sense of ownership." In this definition, agency is the sense of being the causative initiator of an action, whether a movement or a thought. Agency in this context is a causative phenomenon rather than a manifestation of volition, or as Stephanie Spengler and colleagues (2009:290) put it, "was it me or was it you?" Agency as a causative phenomenon is different from the sense of ownership, which refers to the sense of participation in an experience, this experience being voluntary or involuntary (sense of ownership applies when someone else moves my hand—I know it is my hand that is moving, but I did not *cause* the motion). In applying Gallagher's concept to the "was it me or was it you" definition of agency, most animals are capable of meeting his definition of "minimal self" and being self-aware.

Being self-aware is one condition for animal agency, but it is not the only requirement. The philosopher Helen Steward (2009) developed a four-point definition of agency, in which three of the points are manifestations of Gallagher's minimal self. She suggests that animal thought may not consist of circumscribed, causation-based units of ideation in the way human thought does, but this "human" way of thinking is not necessary for the animal to possess agency. Her four-point definition of agency as it specifically applies to non-human animals is:

1. An agent must be capable of independent movement. If something is unable to move, it cannot act upon other components of its environment.
2. An agent must be "a centre of some form of subjectivity" (Steward 2009:226) while being self-aware as an entity—aware of a difference between itself and its environment. Without self-awareness, there can be no purpose to any movement: it is either purely reactive or random.
3. An agent has at least some basic intentional state (e.g., in the shape of wanting, trying, awareness of its surroundings). In other words, the action must be toward some purpose.
4. An agent has some kind of directed control over the actions it takes to cause outcomes; the motion the agent undergoes to fulfill a need is the result of internal impulse, not external stimuli or triggers—in other words, "it was me." While this criterion is similar to (1), which only requires the agent to be able to move independently, it also requires that movement to be (a) controlled by the agent and (b) aimed at achieving a purpose.

Importantly, this definition of agency allows room for instinct to influence the animal's needs and desires. As long as the animal selects from a number of possible actions to fulfill these instinctual imperatives, it is acting as an agent. This definition excludes actions over which no control is exerted by the animal (i.e., reflex), but it does attribute agency to some of the actions taken by wild, commensal, domesticated, and feral animals.

Below, I make use of concepts that provide an explanation of the self that does not rely on a socially constructed understanding of selfhood or free will but focuses

Figure 10.3. Beaver dam as an example of niche construction. Author photo.

instead on individual action, in which the agency of animals leads them to alter the landscape where they live through a process known as niche construction (cf. Lewontin 1983; Quintus et al., chapter 9, this volume). Perhaps the most striking example is the dams beavers build to create a water impoundment that supplies them with food and protection from predators (figure 10.3), although all animals engage in niche construction to some extent. Whether it is the burrow of a gopher, the nest of a bird, or the wallow of a bison, the presence of animals has an effect on their surroundings. Some effects are due to intentional action, but in other cases the actions of animals have unintended and sometimes even detrimental impacts on their environment. When a herd of elephants forages through a forest region, it creates a new environment for grasses to grow and at least temporarily replace the woody plants of the understory. This new growth is not a preferred food for elephants, instead competing with elephants' favored shrubberies.

Another manifestation of animals' agency is seen in the defensive mechanisms they adopt to avoid becoming prey (whether and how to flee, hide, or fight). Tactics that may have worked well as defense against four-legged predators were not always successful when facing hominids that had a different hunting strategy and a different set of weapons that replaced tooth and claw. Whether behaviors to counteract these human threats were individually learned or the result of evolutionary pressure is unknowable, but the outcome is the same—individuals and species with better defense strategies fared better than those with insufficient ones. As humans intensified their hunting behaviors over the past million years or so, prey animals' agency led them to new defensive techniques that had a feedback loop with human hunters. Animals' attempts to evade human hunters led to changes in hominid hunting techniques, and the natural migration of animals (both large-scale and local) forced hominid hunters to follow.

Wild Animals

Regardless of whether humans are present, wild animals' agency has an effect on an individual member of a species, on their group, on the other species with which they interact, and on their environment. An animal's behavior has an impact on everything around it: when a herbivore eats, the nutrition it receives from that particular source has a primary effect on the individual; mate selection has an effect on the future of the species through the combination of genetics imparted to the offspring produced; a carnivore's agentive selection of prey also has an effect on the prey species; and even something as simple as moving along a habitual pathway has an effect on the environment by creating a trail. To show animal agency in the natural environment, consider that any animal's desire for self-preservation will motivate it to escape from its predators. However, for many smaller prey animals, escape can be accomplished in a variety of ways; and a selection is made among the options of hiding, fleeing, or fighting. In the predator/prey interaction between a coyote and a hare from the perspective of the hare: (1) the hare is obviously capable of motion; (2) the hare is aware that the coyote is a threat to its safety; (3) the hare's desire to escape predation is to avoid being caught; and (4) the hare has control over which actions to take to effect that escape. The hare is therefore exhibiting the four hallmarks of agency outlined by Steward (2009). The action the hare will take depends on its awareness of the environment. If it is close to a haven (such as a pile of boulders), it will likely choose to run to that haven. If it is in an area with sufficient cover, it may remain motionless in an attempt to keep the coyote from detecting it. If fleeing or hiding are not options or are not successful, the hare can forcefully defend itself in an attempt to convince the coyote that other prey may be less trouble.

Within a population of animals, some individuals will be more prone to one strategy than another (for avoiding predation, finding food, or exploring their environment) as a function of the individual animal's temperament. Field observations of wild animals have shown that the personality traits that can be observed range from passivity to curiosity, skittishness to boldness, and submissiveness to aggression. Acting based on these personality traits can be beneficial or detrimental, depending on the circumstance, in ways that can impact the reproductive fitness of wild animals. For example, Phylis C. Lee and Cynthia J. Moss (2012) suggest that differences in temperament are a deciding factor in social leadership among elephants. Peter A. Biro and Judy A. Stamps (2008) have shown that behavioral tendencies or personality traits such as boldness and aggression have a positive correlation with life history successes (including increased growth rate, increased adult size, and fecundity) in a wide variety of animal species, from insects to mammals. Because some elements of temperament are heritable (van Oers and Sinn 2013), when one temperament leads to enhanced fitness, the population will be skewed toward that temperament (McDougall et al. 2006). Within captive populations, tests have been developed to measure various aspects of temperament and demonstrate the variability that exists among individuals. Russell Greenberg and Claudia Mettke-Hoffman (2001) discuss methods for assessing neophobia in birds, such as placing a new object adjacent to a food source and measuring the time it takes for the birds to come to the food. A study on the behavior of captive spotted hyenas showed the reliability of five general personality traits (assertiveness, excitability, human-directed agreeableness, sociability, and curiosity) in quantifying the differences in behavior among individuals (Gosling 1998).

Animals in a Commensal Relationship with Humans

Animals in a commensal relationship with humans are those that take advantage of human-modified environments and live in close proximity to humans. Although humans are not necessary for animals to exhibit agency, their presence provides new opportunities for animals that are willing and able to exploit them. The relationship between commensal animals and humans may be one of true commensalism, mutualism, or parasitism. Evidence of animals exploiting new niches created by increased human sedentism dates back at least to the time of the Natufians (~15,000 BP), one of the earliest known sedentary populations. Here, the common mouse (*Mus musculus*) was able to create its own niche within this environment and out-compete the Macedonian mouse (*Mus macedonicus*), another small rodent native to the Near East that was less adept at exploiting the new conditions created by human niche construction (Weissbrod et al. 2017). The relationship continues today, and the common mouse has exploited the relationship so well that it is now a globally distributed species that lives everywhere humans do (even in outer space; Neff 2017).

As human populations have grown and their niches have diversified, so too have the number of commensal species that take advantage of human niche construction.

Cities, as heavily constructed environments with high concentrations of people and a wide variety of microhabitats to be exploited by commensal animals, represent the ultimate arena for human-commensal animal interactions; animals that are successful in urban environments must be well adapted to tolerating the presence of humans. However, even in non-urban environments, a commensal strategy that makes use of human-created niches is adaptive for a wide variety of species. A good example can be found in modern exurbs with relatively low housing density: in these regions, there is ample space for animals as well as a plentiful supply of food in the form of enhanced foliage, garbage, food placed out for domestic animals, and purposeful feeding of wildlife (e.g., birdfeeders). In North America, white-tailed deer, raccoons, and opossums (among others) live in proximity to humans and take advantage of these resources. The commensal coyote takes this niche adaptation one step further by directly consuming some human-provided resources *and* by preying on the other species drawn into the niche—all the while benefiting from the human removal of the large predators such as wolves, mountain lions, and bears that previously provided competition.

Commensal animals are frequently so successful in human environments that their increased population sizes lead them to become nuisances. One example is the rhesus macaque in India, which, according to Charles H. Southwick and M. Farooq Siddiqi (1994:223), "is probably the world's best example of primate commensalism." Commensal rhesus macaques flourish in disturbed habitats and in close contact with humans in locations such as cities and villages (including temples and railway stations) and in agricultural zones, adeptly taking advantage of human niche construction. These commensal macaques depend on humans for food provision by raiding crops, causing significant economic damage (Rattan 2011, cited in Southwick and Siddiqi 2011; also personal observation, Talapada, India). This problem is "highly seasonal and location specific" (283), as it is related to the abundance or lack of foods depending on seasonal agricultural cycles. In urban areas, macaques often harm property in their pursuit of food (Saraswat et al. 2015) and have been known to resort to direct contact and antagonistic behavior, such as biting people or snatching mobile phones, glasses, or bags and returning the objects only when they are threatened or offered food (Chauhan and Pirta 2010). Moreover, temple visitors and tourists voluntarily feed the macaques, exacerbating the animals' reliance on human-derived foodways (Rattan 2011, cited in Southwick and Siddiqi 2011).

Domesticated Animals

Domestication is a process involving groups and occurring over multiple generations. The actions of a single animal (or a single human) will not lead to a domesticated species; rather, the collective action of groups of animals and people brings about this result through interactions over a prolonged period of time. Melinda A. Zeder (2012b) describes three pathways to domestication: commensal, prey, and directed. Each of these different pathways can be understood in terms of the agency animals exerted in their development.

COMMENSAL DOMESTICATES

Commensal domesticates are animals that became domesticated through a process of habituation, such as the dog, cat, pig, Guinea pig, golden hamster, chicken, duck, and turkey. These species were able to successfully exploit the niches created by human activity and became associated with humans in the initial stages of their domestication. In the commensal pathway to domestication, animal agency is obvious: the animals chose to be in close contact with humans and chose to remain with the humans; no enclosures or capture devices were used. There were, however, at most a few locations where this kind of domestication took place, compared to all the possible locations in which the wild progenitors of commensal domesticates were in the vicinity of humans. Was there something unique about the temperament of the individual animals within the particular groups that continued down the commensal pathway to domestication, or was there something unique about the group of people that took advantage of the animals' agentive choice to stay nearby?

The story of pig domestication provides a distinct example of mutualistic commensal accommodation. Wild boars were widely distributed throughout Eurasia and northern Africa during the Mesolithic and early Neolithic periods. The process through which these wild boars became the domestic pig took place over a long period of time and probably in more than one location. Early evidence of domestication comes from eastern Anatolia, where pig remains from the sites of Hallan Çemi and Çayönü Tepesi show signs of domestication (e.g., morphological changes and changes in kill-off patterns) from ~10,000 BP (Hallan Çemi) and ~9,000 BP (Çayönü Tepesi) (Rosenberg et al. 1998; Ervynck et al. 2001). Studies of ancient mitochondrial DNA by Greger Larson and colleagues (2007) suggest that early domestic pigs came from the Near East, but other domestication events could have taken place in Europe and did take place in East Asia. Analyses of 2,000 years of pig remains at Çayönü Tepesi suggest a long process of domestication (Ervynck et al. 2001), and analyses of pig remains from a variety of sites in southern Anatolia and the northern Fertile Crescent support a long-term process of morphological change following the initial period of domestication (Price and Evin 2019).

Wild boar are omnivorous; therefore, this process could have begun with boar exhibiting agency and coming to early sedentary habitation sites to feed on human refuse or early agricultural products—a truly commensal relationship with humans.

The close proximity to humans and the change in diet could have led to the initial stages of domestication, both behaviorally and morphologically; but for the relationship to progress to full domestication, there had to have been a benefit to the humans from having the boar in close proximity (a mutualistic symbiosis). The exact details of early pig husbandry are not clear from the archaeological record, but a modern analog in New Guinea may provide one possible process. In this case, domestic females are kept but no breeding males; instead, the females mate with wild males. The piglets are born in the village and are coddled within households, so they imprint on their human owners. All of the male piglets are castrated, so humans only control the female half of the breeding pair. When the piglets are 4–5 months old. they are allowed to forage throughout the village for food (Rowley-Conwy et al. 2012). There are no physical barriers keeping the pigs in the village, and only their own agentive actions—taken because of the benefits they obtain from close interaction with people—keep them where they are beneficial to humans.

Modern zooarchaeological techniques have been applied to faunal collections in an effort to clarify the transition from commensalism to domestication in ancient pig populations. For example, examination of stable isotope ratios in purported early animal domesticates can provide insights into dietary differences from their wild progenitors. Thomas Cucchi and colleagues (2016) used this method to determine that early domestic pigs in China were foddered on cultivated millet grain, which was absent from the diet of wild boar. The ready supply of the millet may have provided the incentive for the pigs to remain in association with humans in the earliest part of the domestication record, similar to New Guinean practices in more recent times.

PREY DOMESTICATES

Human practices such as selective hunting and game management constituted a process toward domestication for cattle, sheep, and goats in the Old World and for llamas and alpacas in the New World. As an example, bezoars (wild goats) were widely distributed throughout the Near East during the Mesolithic and early Neolithic periods (Makarewicz and Tuross 2012). Demographic profiling shows selective harvesting of wild goats in southeastern Turkey and northwestern Iraq, which may have begun as early as 12,000 to 13,000 BP (Zeder 2012b) with the selective harvest of large adult males. This game management demographic pattern is different from that shown in early domestic herd management, which favors the killing of young sub-adult males, as documented in the Zagros Mountains of Iran at about 10,000 BP (Zeder and Hesse 2000). Mitochondrial DNA analyses of goats and wild bezoars indicate that the domestication process probably consisted of at least two independent events, one in eastern Anatolia and the other in the southern Zagros Mountains/Central Iranian Plateau. Most modern domestic goats are descendants of those domesticated in eastern Anatolia (Naderi et al. 2008).

Using stable isotope analysis, Cheryl Makarewicz and Noreen Tuross (2012) showed an intermediate step between game management hunting strategies and herd management domestic strategies in the Southern Levant about 10,000 BCE. In this scenario, humans selectively foddered goats and influenced their pasture sites to promote the health of goat populations as a beginning of a mutualistic symbiotic relationship. The selective foddering was shown by differences in the isotopic mixture of the goats' diet compared with that of gazelles, whereas in the wild these two species would have had diets with similar isotopic mixtures. The influence on pasture location was evidenced by differences in hydrological regimes used by manipulated goats versus unmanipulated gazelles. Whether the goats studied were fully domestic or at an intermediate stage in the domestication process is not clear, but what is clear is that humans were attempting to make use of the agency of goats by providing them with an alternative to wild foods and directing their grazing locations.

A similar process of transitioning between wild herd management and domestication was used for reindeer, a process that can still be seen in the management style of Sami herders in the Kola Peninsula of northwest Russia. Herders only occasionally round up strays and move herds to fresh pastures, but at certain times of year tighter control is exercised, such as during the calving season (Baskin 2000). Within this loose-control strategy, there is ample opportunity for interbreeding between wild and domestic populations of reindeer. Knut H. Røed and colleagues (2008) determined that in some locations, there is little difference between the gene pools of wild and domestic herds. Part of the reason for this is likely because reindeer are a very recent domesticate (probably the most recent prey domesticate), having only entered into a mutualistic relationship with humans 2,000 to 3,000 years ago (Zeder 2012b). Unlike other prey domesticates, the wild population of reindeer is still extensive (see Tomášková, chapter 11, this volume).

While the directed action of animals plays less of an obvious role in the prey pathway to domestication than in the commensal pathway, animal agency still contributes to the way the domestication process unfolds. The agency displayed by animals and the differences in temperament and behavior between individuals and among species influenced which of the many prey species exploited by human hunters successfully made the transition into fully domestic animals.

DIRECTED DOMESTICATES

Once humans had domesticated animals such as goats, resulting in a template for how to obtain benefit from animals without having to hunt or trap them, other animals became domesticated. Directed domesticates include the horse, donkey, Old World camelids, buffalo (American bison), ferret, mink, silver fox, chinchilla, emu, ostrich, and fish. These species were domesticated not only for food but also for other benefits they could supply, such as transportation or tractive power (horses, donkeys, dromedaries, yaks), furs (mink, chinchillas), and fibers (silkworm) (Larson and Fuller 2014). The decision to domesticate animals that were not entirely intended for use as food stemmed from the utilization of domesticates for these purposes in the early stages of the secondary products revolution (Sherratt 1981). For example, the use of cattle (originally a prey domesticate) for new activities such as traction or milk production could have been the impetus for the domestication of the dromedary and the yak, as these species thrive in arid and high-altitude environments unsuited to cattle.

IMPLICATIONS OF DOMESTICATION: AN ANIMAL PERSPECTIVE

Considering all the wild animals that could provide benefit and the relatively small number of species that have been domesticated over time, the choice of domesticates was certainly not entirely up to the human domesticators. Further, domestication does not diminish animal agency; anybody who has a pet dog or cat realizes the degree of control they exert over their owners and the ways they rely on a strategy of human interaction as part of their problem-solving strategies that also have measurable physical consequences (e.g., Kaminski et al. 2019). Bradley Smith and Carla A. Litchfield (2010) report on experiments comparing dingo and dog problem solving in which the two groups have a very different approach to solving the problem placed in front of them. In the experiment, a V-shaped fence was constructed; the subject was placed either inside or outside the V, and food was placed on the other side. To get to the food, the subject had to go around the end of the fence. While dingoes would tend to go around the fence to retrieve the food prize, domestic dogs attempted to look to the experimenters for guidance rather than independently completing the task. While this may appear to suggest that dingoes are quantitatively more intelligent than fully domestic dogs, I would suggest instead that this demonstrates a response evolved by domestic dogs to choose collaboration with humans for the purpose of problem solving. Notably, both the dog and the dingo performed actions in response to a challenge, demonstrating that both retain agency. Every individual possesses a suite of possible reactions to a problem, from which a response is selected. In other words, the domestic dog exercises its agency to select an approach that relies on its evolved symbiosis with humans.

In general, domestic animals have developed a great deal of reliance on humans to fulfill their survival needs, and if humans had failed to supply those needs during the domestication process, the pathway would have hit a dead end. Even in cases where the domestication pathway is long and well established, however, there are instances where an animal may elect or be forced to reduce its reliance on human interaction, an agentive process that leads to feralization.

FERAL ANIMALS—A DIFFERENT KIND OF AGENCY?

Feral populations arise from the reproduction of domestic animals that have abandoned a human-based survival strategy (animals that are in the first generation to leave human control are strays, while their descendants are feral; cf. Slater 2001). While many feral populations continue to live in commensal relationships with humans, they no longer have an intimate social connection with them. Feralization, therefore, is an evolutionary trajectory that comes as a direct result of an application of agency by domestic animals: feralization is an additional stage of the process of evolution, not an undoing of domestication.

Domestic pigs, camels, and goats are all good examples of species that have sometimes successfully abandoned their close ties with humans and developed large feral populations, mostly in regions where the domestic population's wild precursors are absent and to which a domestic population has been introduced. An excellent example of this is the feral dromedaries of the Australian Outback. Dromedaries were initially domesticated in Arabia around 3,000 years ago (Almathen et al. 2016) and were introduced into Australia in the mid-nineteenth century for use as draft animals. The climate of the interior of Australia is well suited to camels, and approximately 20,000 of them were imported (Saalfeld and Edwards 2008). By the mid-twentieth century, motorized vehicles had made the use of camels obsolete, and many camels were released into the wild. From this initial stock of probably fewer than 10,000 individuals, the population of feral dromedaries in Australia had expanded to nearly 1 million animals by the early twenty-first century (Saalfeld and Edwards 2008). Clearly, the domestication process did not impact the dromedaries' ability to survive without human intervention. The success of the feral camels has established them as a pest species over much of their range, where they are outcompeting native animals for food and water.

The survival strategy to abandon close contact with humans may not be the preferred option for domestic animals, but it is one they are not always evolutionarily excluded from using. If this abandonment is not a successful strategy, the population of strays will not reproduce and rear young with enough success to become a self-sustaining feral population (this failure to create a self-sustaining feral population is frequent, for example, in populations of stray and feral dogs; Zeder 2012b), so the fact that there *are* sustained feral populations of some species indicates at least a moderate level of success and a forward movement along the evolutionary pathway.

CONCLUSION

Acknowledging the importance of animal agency reorients our understanding of human cultural strategies as part of broader ecological and environmental systems. Animal agency has had an influence on many, if not all, human-animal interactions and therefore on the development of all the systems in modern human society that are reliant on those interactions. The ramifications of this agency become even clearer when exhibited by the domestic animals that share the most intimate relationship with humans. The agency exerted by domestic animals in any given situation depends not only on the human-created environment but also on the temperament of the individual animals (and eventually the predominant temperament selected for the population by the domestication process) when exposed or introduced to that environment. Some species of animals have ranges of temperament that better position them to enter into relationships with humans, and for the most part, these are the species that have continued down the various domestication pathways to the present.

The domestic animals we have today are as much a result of the agency of animals as they are of human action. While many animals could be useful as domesticates, the number of domesticated species is relatively small. The animals that have entered into a social contract with humans through the long-term evolutionary process of domestication have certainly had meaningful impacts on every facet of human life: from the nutritional impacts of having readily available sources of meat to the economic advantages of harnessing the strength of animals to providing us with clothing materials (leather, wool, silk, felt, furs) and providing companionship. While domesticated animals have thus contributed much to economic and physical health through their engagement with human-created ecological niches, they have also contributed to negative impacts when serving as vectors for zoonotic disease transmission (see Juengst et al., chapter 6, this volume).

An interrogation of the actual ramifications of these relationships reveals a much more complex ecological tapestry in which animals contribute to and shape the direction of human niche construction and human culture. Perhaps the term *symbiotic* more accurately reflects the nature of these relationships, suggesting a broad spectrum of possible relationships between humans and animals that for either party can be harmful, beneficial, or neutral. Aspects of the symbiosis between humans and animals can vary over time and space, even for a single individual. For animals that live in environments heavily shaped by human activity, some aspects of human niche construction may provide benefits, such as a reduction of predators or greater access to food, while other aspects simultaneously introduce new dangers, such as automobiles, pollution, and slaughter. If the net benefit of these relationships to humans and animals outweighs the harm, these relationships persist or even intensify. If the net harm to both humans and animals is greater than the benefit, these relationships diminish or end. The overall effect is generally perceived at the population level, but the benefit or harm plays out on an individual basis where agency influences the reactions taken. For individuals, behaviors vary temporally on a daily basis (night versus day), on a seasonal basis (migration or crop availability), and on the scale of a lifetime (long-term resource depletion or accretion). These same dynamics play out for domestic animals, which for certain parts of the day, year, or lifetime may have varying degrees of interaction with humans and may play a greater or lesser part in human lives. Because of this, one animal may exist in a variety of niches and experience a variety of different types of symbiosis with humans over the course of its life. The agency of individual animals is a key factor in establishing these changing relationships.

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11

Reindeer as a Toggle

Animal Agency in Domestication

Silvia Tomášková

Def.: A toggle, a part of a harness for a dog or reindeer, used to change direction of movement or to force a stop.

Abstract

The chapter describes the importance of reindeer in the lives, histories, and prehistories of Indigenous people of Siberia. The multifaceted, commensal nature of the relationship and the persistent coexistence of wild and semi-tame reindeer offer an opportunity to understand the process of domestication in a more nuanced way. The diversity of reindeer is coupled with the diversity of northern Indigenous people through intersecting agencies. Historical actors—be they Indigenous people of Siberia, colonial officials and prisoners, reindeer, Arctic landscapes, or parasites that inhabit skins and furs—all play an active role in long-term processes. Pieces of nature, persistence of culture, and lasting moments of history should urge archaeologists to interweave difference and agency of nature in more creative ways so as to grapple with the notion of domestication in distinct corners of the world.

Siberian Indigenous communities have been used for centuries as a stand-in for various Western categories, mostly as a contrast to "civilized," developed groups or as an imagined evolutionary stage en route to modernity (among many, see, e.g., Grant 1995; Gray et al. 2003; Jordan 2011; Tomášková 2013; Vitebsky 2005).

https://doi.org/10.5876/9781646423521.c011

Geographically placed somewhere between Asia and Europe as well as between temperate and Arctic climes, Siberia and its native people—if thought about at all—usually serve as a generic placeholder for larger forces moving to some other location (see Bassin 1991, 1999). Yet the long history of human-animal relationships in the region, particularly the commensal nature of living closely with reindeer, offers us an opportunity to approach the various Indigenous Siberian groups to think about prehistory, and domestication in particular, in more complicated ways. Reindeer are not only the region's principal animal and an inseparable symbol of the native groups but are also creatures with more obvious agency than most because they are a species that has tolerated human presence without becoming fully domesticated. I therefore place reindeer at the center of histories of the northern regions to work through concepts of domestication and human-animal relations as experienced across millennia. The recent inclusion of non-human actors in archaeology is an exciting development (Conneller 2004; Coole and Frost 2010; Miller 2005; Olsen 2010; Overton and Hamilakis 2013; Robb 2015; see also Ammerman, chapter 10, and Bishop, chapter 8, both this volume). It allows us to position animals in prehistory and history as agents rather than merely targets of human action.

This chapter proposes to approach reindeer as a "toggle" of sorts, referring to an old device used in a harness to transmit a rider's signal for redirection or a pause (figure 11.1). I mean to invoke a mental equivalent for archaeological analysis when approaching questions of domestication in prehistory. Here, this pause takes the form of the case of Siberia, encouraging us to take species, regions, and people more seriously when considering domestication. Reindeer may indeed be a unique animal in the history of human-animal relations, but it is one that can also serve as a toggle for thinking about other species and their places in human history.

ARGUMENTS AND AGENTS

This work is based on my previous research in Siberia, specifically in the historical archives of German and Russian explorers and ethnographers of the region (Tomášková 2013). In reading these rich sources, I found myself repeatedly reminded that historical and ethnographic evidence remains ever situated in a specific social context. Historical actors were never blank slates when they carried out treks through the vast expanses of Siberia, whether driven by exploratory, scientific, or commercial motives. Each journey into an unknown place—ethnographic and archaeological fieldwork included—evokes a geography of imagination. Colonial encounters between explorers and native men and women, along with unfamiliar landscapes and animals, often resulted in a desire for knowledge interspersed with

Figure 11.1. Reindeer harness consists of lines and a toggle. A toggle was usually made from a piece of bone or an antler carved to represent an animal, a pattern, or a recognizable motif. Leather or skin line is threaded through two circular holes at the center of the toggle. The ends of the line form a loop, and each end is threaded and knotted through a hole at one end of the toggle. When pulled, the toggle tightens the line, which stops the animal's movement or turns its head to look back. *Courtesy*, Division of Anthropology, American Museum of Natural History, New York, NY, Catalog #70/3100.

a complicated alchemy of fear, curiosity, and aggression. Siberia was no exception, but the colonial project in this part of the world possessed particular qualities that merit close attention. The history of Russian colonial expansion into the vast land to the east has only rarely been featured in the history of European science, and it is not frequently referenced in discussions of European colonial endeavors (Boeck 2009; Khodarkovsky 2002; Slezkine 1994). Yet historical threads tied to Siberian natives interlace the texts of disciplines such as anthropology, geography, and botany (Balzer 1995; Gingrich 2005; Krupnik and Fitzhugh 2001; Penny and Bunzl 2003; Shternberg and Grant 1999). Moreover, the histories, observations, and notes about the state of Siberia, its Indigenous people, and the animals that live with them do not neatly line up along a path to greater knowledge about the region and its people, let alone provide a template for understanding prehistory in general (for comparison, see, e.g., Anderson 2000; Appleby 2001; Argentov 1857; Bogoras 1904a, 1904b; Grant 1995; Willerslev 2007). Instead, we get a shifting mosaic, built from various pieces of information collected by successive travelers and scientists (Gray et al. 2003; Kivelson 2006).

In the course of my research, I came to see all of these historical actors as active agents whose very diversity enriches our images of Siberia, Arctic spaces, and the Ice Age, along with providing a wealth of notes on reindeer. Amid the remnants of strange and distant worlds, the traveling scientists projected their own assumptions and anxieties alongside the things they took as evidence. We should embrace those continuities and discontinuities, in both these ethnographic narratives and the archaeological record. I will make this point by describing the varied, even contradictory historical accounts of Siberian Indigenous reindeer herders. It is not my goal to highlight these ethnographies and descriptions as flawed, inaccurate, or useless for a discussion of prehistoric behavior. Rather, I offer a multiplicity of accounts of reindeer, people, and the relationships their proximity generated. These stories remind us that accounts of the prehistoric past can benefit when archaeologists stretch their imaginations and include margins and out-of-the-way places, when they do not follow only the well-trodden, previously accepted paths to such topics as animal domestication.

Before I describe in some detail the habits and characteristics of reindeer that lead to the suggestion that this particular species is better understood as "less than domesticated" or even periodically as "undomesticated," I offer the rationale for such an argument. First, I draw attention to one of the perennial problems and solutions archaeologists have been dealing with for well over 100 years—that of analogy. Yet I am not inclined to scold or to claim that the analogies many of us use are simplistic, incorrect, or misleading. To the contrary, I want to restate the seemingly unremarkable case for analogical reasoning and ethnographic analogies. They are essential tools of archaeologists, part of both the justification *and* the interpretive process we regularly engage in. However, I suggest that the particular comparison on which any one analogy is based has far greater potential than we usually recognize. A point of comparison does not have to be the end station of our train to prehistory. Rather, it could prove a transfer stop to a richer and more imaginative understanding of both the prehistoric past *and* the state of the discipline of archaeology.

Here, I offer a discussion of reindeer in Siberia and the nature of their relationship with the native groups over many centuries as a path toward thinking about agency and difference, particularly different kinds of relationships humans have with nature (figure 11.2). In the classic mode of ethnographic analogy, I would like to expand the circuit in which comparisons travel to include the ethnographic present alongside the prehistoric past. Siberia boasts numerous examples of travelogues, scientific descriptions, and ethnographic accounts that provide impressions about a place, its peoples, its natural histories, and their intertwined relationships. I propose to amplify the focus on particular agents of the past and the present,

Figure 11.2. Yakut reindeer. *Courtesy*, Division of Anthropology, American Museum of Natural History, New York, NY, Catalog #12572.

specifically animals. Throughout history and prehistory, reindeer in Siberia had far more agency and autonomy; they allowed humans to create a commensal form of relationship not well captured by the terms *game keeping* or *domestication*. Thinking through reindeer, I suggest, would encourage archaeologists to look for other analogies, entertaining a larger variety of potential relationships among people, animals, plants, ice, and rocks that might otherwise escape notice. I use ethnographic accounts and historical travelogues from Siberia to make two points:

1. Animals, be they wild or domesticated, have agency that can exceed human-centered visions. Many anthropologists and archaeologists have begun to work across the boundary between humans and animals or between nature and culture (e.g., Alberti et al. 2011; Conneller 2004; Kohn 2013; Overton and Hamilakis 2013; Stépanoff 2012; Vivieros de Castro 1998; Willerslev 2007). However, for the most part, archaeologists position animals in relation to humans and can still learn quite a bit from rethinking these relationships from other perspectives. To illustrate such an argument, I draw attention to reindeer to describe how people can exist on the margins of an animal world or create a new mode of existence co-produced by animals and humans. Siberian Indigenous stories and ethnographic accounts over the centuries provide abundant material to support such a claim.
2. Histories, ethnographies, and the archaeological record consist of long and short strings out of which we create the fabric of the past and the present. Parts that fail to fit a given pattern often fall to one side, particularly when we strive to weave a seamless, linear account. By contrast, focusing on these scraps of narratives and stories collected along the way presents an opportunity to recognize other possible patterns to explore, ones that might alter the end product in unexpected ways.

GEOGRAPHIES AND ANALOGIES, HUMANS AND ANIMALS

The Neolithic Revolution, featuring the domestication of humans, animals, and plants into a settled village life, has constituted one of the central topics of archaeological research and debate since the inception of the discipline in the late nineteenth century. For an august figure such as V. Gordon Childe, the "individual expression of human activity" (1925:1) could be manifested only after the successful mastery of domestic animals and cultivated plants:

> Throughout the long paleolithic period which reaches back far into geological time, man remained in a state of helpless barbarism, a mere food gatherer dependent for his livelihood on the products of the chase and fishing supplemented by such wild nuts and berries as mother Nature might provide. Paleolithic man had no domestic animals, save the dog and that only late in the epoch, practiced no agriculture, was ignorant of pottery, and did not polish stone or flint. The Neolithic period saw man master of his own food supply through the possession of domestic animals and cultivated plants and shaking off the shackles of environment by his skill in fashioning tools for tree-felling and carpentry, by organization for co-operative labour, and by the beginnings of commerce. The study of the paleolithic period belongs to the history of humanity as such. European civilization as a specific and individual expression of human activity only began to take shape during the Neolithic epoch. (1)

In this scenario, the persistent and conscious control of the immediate natural environment proved the essential building block, the stepping-stone of European civilization (Childe 1926). Childe was a meticulous and impressively erudite archaeologist; fully immersed in the humanistic philosophical thought of the day, he was convinced of the centrality of human reason in history and in progress of civilizations through the mastery of nature. Whether one considers Childe's early publication, *The Dawn of European Civilization* (1925), or the work at the end of his career, *The Prehistory of European Society* (1958), it is clear that in his view it was the domestication of animals and plants, rather than chasing wild deer or catching fish, that provided the path to progress that led to the richness of European civilization (Harris 1994; Trigger 1980).

Archaeological methods changed dramatically over the span of the twentieth century, especially in the post–World War II period when we became the beneficiaries of military equipment and scientific techniques. Yet many of the central archaeological research questions *and* the geographies of their framing have changed far less. While the term *Neolithic Revolution*—coined by Childe in the early 1920s—may have a different resonance today, the counterintuitively labor-intensive process of animal and plant domestication continues to carry as much cachet as it did in the early twentieth century (see, e.g., Colledge and Conolly 2007; Watson 2009; Zeder 2015). Furthermore, I suggest that the specific geography of the discipline's early focus on the fertile Eurasian "hilly flanks" (Young et al. 1983; Watson 2009) had a determining and lasting effect on the understanding of the process and on what counts as evidence in the search for origins of domestication and control of nature. The early villages, which turned into urban centers and led to civilization, located the beginnings of modernity in southwest Asia—the "Fertile Crescent" of prehistorians' imaginations, as close to the historically presumed location of the Garden of Eden as possible. As Ofer Bar-Yosef (2007:x) pointed out, "The interest in the archaeology of the Near East was and is common among European and American scholars, and appears to be related first and foremost to the teaching of the Bible." The specific animals and plants present in the cradle of early farming and subsequent settled village life presented paradigmatic examples of the dramatic change in human control of nature. Domestication of goats and sheep, unique and particular as it may have been, came to serve as the foundational referent for a universal process, subsequently mapped onto other geographic regions.

The puzzle of the "birth of civilization" attracted over a century of attention to southwest Asia and the Mediterranean. On one hand, we now have a wide range of impressively detailed accounts of individual sites, large settlements, dispersed villages, and urban centers (e.g., Adams 1965; Hammer and Arbuckle 2017; Smith 2019; Zeder 2008, 2011). Archaeologists accumulated vast amounts of data on the changes as well as the lasting practices of people who lived in the region for millennia (Arbuckle 2014; Hodder 2017). On the other hand, this unwavering geographic fixation on a particular ecological setting channeled research questions and the evidence collected in their pursuit toward a specific range of human practices, toward particular species native to the region. As T. P. O'Connor (1997:150), in rethinking the ancient relationships between humans and animals, has noted: "Perhaps if the archaeological discussion of animal domestication had begun with elephants, we might have arrived at a different model."

The Neolithic narrative, located in the Fertile Crescent of southwest Asia, confirmed the revolutionary nature of the adoption of agriculture and its long-lasting consequences. However, the success of this synthetic interpretation also reinforced the Eurocentric view that such crops as wheat, barley, and pulses or such companion species as sheep, goats, cattle, and pigs were model citizen specimens to represent a larger mass (see, e.g., Young et al. 1983; Flannery 1983). As O'Connor (1997:150) stated, "The domestication debate has largely centered on the emergence of caprines as domestic livestock in that relatively small region between the eastern Mediterranean and the Caucasus mountains in the early Holocene." The ensuing socioeconomic transformation from foraging societies to settled farmers subsequently served as a model that archaeologists followed in other parts of the world for most of the twentieth century (for a historical overview of the research, see O'Connor 1997; Russell 2002, 2007; Zeder 2008, 2011, 2012). The process of domestication of these particular species took the form of a sacred bundle of interconnected parts: changes in the size of the animals, their attachment to and dependence on humans, and their irreversible change into "domesticates" due to genetic breeding manipulated by humans. Animals, following their human "masters," were not only domesticated; they, too, settled, no longer simply mobile or only migrating.

Not all human-animal encounters measure up equally when placed within the Neolithic template derived from southwest Asia. David G. Anderson and colleagues (2019:1) describe the implications of following the same Mediterranean model for both reindeer and the northern herders: "Within this framework, the domestication of reindeer by Eurasian Arctic peoples has been portrayed rather poorly, with reindeer being characterized as being 'deficiently' domesticated or at best in 'an early stage' of domestication. Siberian hunter-herders have been left out in the cold, as it were, since their pastoralist skills also place them outside of the debates on hunting and gathering adaptations." After archaeologists working in other regions of the world joined the domestication debate, it became clear that other plant and animal species had had a sustained yet distinct relationship with people in prehistory; for example, as Patty Jo Watson (2009:3) noted, "evidence for a very different food-producing system was emerging in the Eastern Woodlands of North America." Neither corn and squash nor llamas and turkeys behaved like wheat or goats. These plants and animals responded to human overtures and pressures quite differently than the initial prototypes from Eurasia.

In what follows, I focus on reindeer precisely because they do not fit the traditional domestication model. The species can thus guide us through a different relationship between people and animals in their prehistoric interactions. My intent is to complicate the debate about domestication and connections between animals and humans in several ways. First and foremost, as with all the chapters in this volume, I underline the agency of nature, specifically animal behavior in the history of human-reindeer interactions. Charles Stépanoff (2012:290) best captured the complex relationship between wild and domesticated reindeer: "The paradox of reindeer herding is that, compared to other domesticated species, humans can domesticate reindeer only if they keep them (in the) wild. Therefore, the reindeer retain an element of choice: even in the most controlled systems, they can find opportunities to abandon humans and go live without them in the tundra or the taiga."

However, by paying attention to the degree to which reindeer have been domesticated or remained wild, turned feral or tame, whether they were migrating on their own or as companions to people, I pivot to a larger theoretical point. Specific species of plants and animals recovered in archaeological contexts provide the basis of analogy, a comparison drawn from a range of sources in which archaeologists routinely rely on historical and ethnographic accounts (for a discussion of analogy, see Watson 1999; Wylie 1985, 1992). Yet analogies archaeologists choose when discussing domestication or a transition from foraging to farming and settled village life are not simply neutral case studies, waiting to be picked. They have their own histories and lives and should therefore be treated with more explicit care and attention to the particulars. Specifically, I point to the geographies of our thinking and suggest that when engaged in model building, archaeologists rarely venture far from certain foundational places, to the detriment of areas deemed marginal or extreme such as the northern edges of continents. The herds of reindeer in northern Eurasia have been the exception to traditional models of domestication (Anderson et al. 2019; Stépanoff 2012; Vitebsky 2005; Vitebsky and Alekseyev 2015). But they also serve as useful cautionary guides to other species, other regions, and possibly more complicated prehistoric relationships between people and animals in varied kinds of landscapes, including the margins, be they northern or elsewhere. In effect, the very difference of reindeer from common domesticates of southwest Asia nudges us to consider other potential exceptions and geographies of human-animal relations.

REINDEER ON THEIR OWN IN THE WORLD

Reindeer define the northern latitudes and serve as both a major signifier of the environment and a symbol of the imagination and politics of place (Stammler-Gossmann 2010). For centuries, they have acted as a proxy for the different ethnic groups of the Arctic, their cultures, their relationships, their subsistence practices, and their way of being. The animal stands in for the frozen North, to tell us about Indigenous peoples who herded them in our imagination. In discussions of animal masters, the reindeer has regularly functioned as a toggle, a creature that redirects attention by enabling talk about shamans, sacrifice, and hunting rituals in debates about the shift from hunting to domestication. Here, however, I want not only to take reindeer as a signifier of all things social and human but also to follow them in prying apart the terms *game* and *keeper* in gamekeeper, to consider the reindeer as a keeper rather than game.

Reindeer have a particularly complex relationship to humans in that they continue to exist in wild, domestic, and feral forms. Moreover, their domestication appears to have been a complicated process that did not follow the common logic of animal husbandry (Bjørnstad et al. 2012; Røed et al. 2018; Stépanoff 2012). According to archaeologists and biologists, reindeer were domesticated 3,000 years ago in the southern regions of Siberia and adjacent northern Mongolia (Anderson et al. 2019; Røed et al. 2018; Vitebsky 2005). Nevertheless, they were only partly domesticated in the Eurasian Arctic and the process never took place in North

America, where the species goes under the name caribou (Røed et al. 2018). For all the images of Santa Claus coming from the North on a sleigh pulled by reindeer, the domestic caribou found in Alaska and the Canadian North were brought there only recently (in the 1880s; Vitebsky 2005). To complicate matters further, molecular analyses have brought to light several lineages of domestic reindeer across Eurasia, suggesting different origins for Fennoscandian and Siberian reindeer domestication (Bjørnstad et al. 2012).

According to prior studies, we are thus not dealing with one kind of reindeer but instead with animals that behave rather differently depending on their habitat: "The tundra reindeer is more gregarious and has evolved a more sophisticated social organization than the forest dwelling types, making them more prone for domestication" (Bjørnstad et al. 2012:107). Moreover, early attempts at domestication, which were clearly dependent on the animals' social organization and chosen habitat, were not for the purpose of "animal mastery or even husbandry but instead to get closer to wild reindeer" (Vitebsky 2005). Reindeer are speedy herd animals; unlike deer, they are the earliest crowd-sourcers, which makes hunting them difficult. Reindeer keep each other company at all times; when under threat, they form a circle and pick up speed, running dizzyingly with no point of entry for a predator such as a human or a wolf: "Reindeer can run for many hours at twenty or thirty miles an hour and in bursts at double the speed . . . a wild tundra herd can travel 700–800 miles, a greater distance than any other land animal" (23). Only a sick or hurt animal finds itself in isolation, a potential dinner but not the best candidate for taming or breeding.

Historically, Indigenous people in Siberia partially domesticated a few reindeer so they could ride them and be able to get close to and hunt wild reindeer. The relationship between domesticated and wild reindeer clearly required a separate name for animals in each role—as the ancient Tungus, Samoyed, Yukaghir, and Koryak had assigned them—since they became one with the hunter but also remained the prey (Miller et al. 2009). To add to the complexity of the species, gender is a determining factor in the herd structure because a senior female is the lead animal among tundra reindeer when they move a long distance. Indigenous Siberians exploited this pattern and captured the senior female to disrupt group cohesion, thereby setting up a distinct negotiation of human and animal gender dynamics. Despite the patriarchal social structure of most Siberian groups, with male herders serving as the heads of households, women always tended the domestic reindeer. And yet they never succeeded in having a close relationship with the domestic reindeer in the same way they did with other tame or domesticated animals. A wild herd of reindeer may at any point sweep in at high speed and lure away the kept animals, turning them back into an undomesticated species in one fell swoop: "Siberian oral traditions recount cases of groups of herders that starved to death because their herds were driven away by huge wild reindeer herds" (Gurvich 1977:49–50, cited in Stépanoff 2012:289). To add to this complicated gender picture of human-animal relations, male reindeer of the domesticated kind were often neutered to increase their docility and to use their strength for digging the ground for pasture the remaining animals in the herd could rely on (Vitebsky 2005). These interventions fall somewhere closer to animal modification in the process of domestication, yet they did not lead to genetic changes, and they benefited the animal keepers only temporarily.

It is worth paying attention to what historical accounts tell us about the different Tungus and Samoyed terms for wild and domestic reindeer. As the terms suggest, in the eighteenth century they indeed were, and still are, different animals, even if deemed the same species in terms of biological classification (Miller et al. 2009). The native, far more intimate distinctions between different kinds of reindeer are a reminder of the messiness and the challenge of taxonomy in general. It is then worth asking, if we are to use reindeer in analogies for prehistoric behavior or in reconstructions of belief systems that involved supernatural gamekeepers, do we mean the domesticated or the wild reindeer? In some early ethnographies of Siberian Indigenous religious practitioners, a reindeer carried the shaman's robe and a drum but was not used for riding or pulling a sled (Bogoras 1904a). As Piers Vitebsky (2005:25) points out, "Even transport reindeer may become uncooperative and recalcitrant if left unattended for a few days, and any domestic reindeer may revert to the wild if left unattended for longer." The terms *game keeping* and *domestic animal* become only more fascinating and complex in this context.

The agency of reindeer, as impressive and convincing as it sounds, is complicated even more by the presence of other, much smaller, persistent companions. While reindeer coexist with humans in the world in a state of seeming truce or negotiated cohabitation, the warble fly (*Hypoderma tarandi*) and the reindeer nose botfly (*Cephenemyia trompe*), so-called obligate parasites, truly cannot exist without reindeer as the host animal. The warble fly lays eggs in the animal's skin during the brief summer months, and the hatched larvae feed on the host's proteins. Once they are too large to live under the skin, the larvae crawl out and drop to the ground where they mature into flies (Bogoras 1904a:80; Curtis 2015). The reindeer nose botflies behave similarly, but, as their name suggests, they use the reindeer's nose as a point of entry through which to travel into the animal's breathing passages. The larvae's mature size becomes so unbearable that the desperate reindeer forcefully sneezes it out, thereby allowing it to complete the cycle and live its brief existence as a fly.

From the reindeers' perspective, the arguably unpleasant natural cycle repeats itself annually and literally drives their behavior. The closer together they stay, the less the chance for a warble fly to get into their fur. Only the outlier reindeer are attacked and invaded, punishing the less-than-social and the weak. Females, young males, and calves are protected by their propensity to huddle and rub against each other; it is the senior males whose standoffishness leads them to become the most subject to fly attacks (Folstad et al. 1989). The botflies, in contrast, do not care for wind, inspiring reindeer to engage in high-speed dashes during the summer months in an effort to escape their tormentors. The faster the speed, the fewer nasty flies can invade or stay inside the reindeer's nostrils. This leads to marathon summer runs in distances of hundreds of miles (Bogoras 1904a:80; Folstad et al. 1989; Vitebsky 2005). Herders, keepers, and owners of reindeer can only hope their domestic herds do not join the stampede and vanish for weeks, months, or forever.

In recognizing the role of flies in inspiring reindeer behavior, I do not intend to paint an image of an all-powerful, static natural cycle. Rather, the evidence suggests an intricate dance of coexistence, as people are not entirely helpless in the relationship with reindeer and their parasitic companions. They light fires to generate smoke that deters flies, and reindeer come close, crowding nearby. However, the bond remains loose, as the animals can easily walk off during the night or venture away once the summer fly torture is over. Many Siberian reindeer-herding Indigenous groups have another trick to play. Reindeer seek out salt, and herders attract them by offering it to lure the wild animals close to their settlements. While there are natural sources of salt that animals frequent, human urine seems to be a particularly delicious source, irresistible to reindeer. Men, not women, walk out in winter nights and mark the snow, which quickly turns into ice that reindeer lick: "Tozhu men are used to urinating near the house, often on a hollow stump, or even in a urinal specially constructed for reindeer: a tree trunk with a trough carved in it, adapted to [the] height of reindeer mouths" (Stépanoff 2012:293).

These gendered, intimate relationships between humans and reindeer suggest a different order of closeness between them than the terms *domestication* or even *herding* might suggest. The connection between species remains fluid and plural, without a single, stabilized state. When pursuing analogies in accounts of domestication, archaeologists might benefit by expanding the range of geographic, species, and relationship boundaries between the people and animals they consider throughout history. The reindeer in the Arctic is a wild animal but also a domesticated beast of burden (Anderson et al. 2019; Vitebsky and Alekseyev 2015). Therefore, the "ways of being a reindeer" stress the coexistence of humans and animals, not just co-dependence but actual living with, where the term *keeping an animal* may not always prove an apt description. Reindeer in the Siberian context were, and to a great extent still are, often the driving force in their relationships with people. At the same time, it would not do them justice to describe them as singular lead actors, any more than would positioning the human at the center of the universe. Rather, they are co-producers of the world—partly on their terms, even if not always exclusively of their own making (see Stépanoff 2012).

REINDEER HISTORIES

I offer three brief examples from Siberian historical descriptions of the seventeenth, eighteenth, and nineteenth centuries. I do so to defend their usefulness as historical curiosities, as stories of the biased, prejudiced folly of colonial endeavors, but also as information that could inspire us to think laterally in new directions. Over the past several decades, literature in anthropology, sociology, and the history of science has urged us to adopt a far more complicated understanding of the emergence and popularity of specific theories and interpretations (Marchand 2009; Marchand et al. 1996; Penny and Bunzl 2003). Archaeology, seen through this lens, may be more than a progressivist discipline that dispenses with past theories as either misguided or simply wrong. Historical accounts are a useful reminder that every travel or ethnographic description is located in a specific time and place. As fanciful or strange as they may seem, such accounts can also serve as both a mirror of the larger scientific milieu and a reminder of our own positionality. Colonial, missionary, and military expeditions all impacted Indigenous peoples in Siberia in dramatic ways but with varying degrees of severity, rupture, and readjustment. It is therefore imperative that we see animal keeping and, more generally, animal relations among different Indigenous peoples of the region through the lens of such colonial history, not as unchanging and frozen in time. Reindeer in Siberia have been used to explain Indigenous ways of being in myriad ways, presenting a transfer point into other directions of inquiry. These animals stare at us, encouraging us to think more broadly and not simply to discount their stories.

Siberian tales and histories that stretch over several centuries feature a range of actors—some well represented and prominent, others in the background. Reindeer in many of these stories are equal partners and players. This may seem like an obvious point to those interested in animism, especially the kind championed by Victorian-era anthropologists such as Edward B. Tylor (1870) or the more recent return to the term in discussions of mimicry and the blurring of boundaries between human and natural worlds or bodily and spiritual realms (e.g., Willerslev 2007). Yet I would like to take reindeer even more literally and give them more agency, not merely personhood and human-like qualities. Tim Ingold's inquiry "what is an animal" (1994b) and the even more specific query by Piers Vitebsky and Anatoly Alekseyev of "what is a reindeer" (2015) are serious questions, which suggest that the place of reindeer in the world of humans in Siberia was far greater than we imagined and worth close attention (see also Ingold 1980).

During the seventeenth century, Siberia already served as a place of banishment for prisoners of war conflicts, and it is in some of these early memoirs that we meet both Indigenous people and reindeer. Writing in 1658, Polish prisoners led to exile described their encounter with the Indigenous group of Tungus: "The Tungus were very generous to the prisoners, fed them and provided them with meat and furs for their journey. They were polygamous, some had as many as nine wives. Their reindeer herds were in the thousands or more" (Tugolukov 1985:42). From the perspective of the prisoners headed into exile, the natives lived in abundance, free to act as they wished and to move anywhere in this vast space. The nomadic lives of reindeer and Tungus were the embodiment of that which was denied to prisoners. The fact that the Tungus were described as men with numerous wives and plenty of animals is a reflection of the state of mind of the Polish captives—homo-sociality for years to come, if not the rest of their lives; men in the company of only men, deprived of any ability to grow food or to farm. Reindeer stood in for freedom to move away, for wealth and a lack of human company and domesticity for the prisoners and an abundance of freedom for the natives. Whether the Tungus actually owned thousands of heads of reindeer or merely lived in their company we do not know, but their presence is not disputed. Whether the reindeer were truly domesticated or merely grazed close by cannot be established either. Prisoners who arrived from Poland would have only been familiar with herds of cows, sheep, or goats known from any European village. Herds of large animals near a settlement would have been perceived as a highly desirable ownership of abundance. The supernatural nature of the relationship would not have been a part of the picture; rather, the material existence of plenty was what mattered most.

In 1730, a strikingly different yet equally insightful account of reliance on reindeer appeared in Gerhard Friedrich Mueller's (1764) description of his multi-year travels through Eurasia.[1] As a historian, Mueller tried to trace geographic diffusion as well as linguistic affinities to explain how the different tribes found themselves in their locations. In his description of Indigenous ownership and husbandry of reindeer, Indigenous peoples had entirely different words for domestic and wild reindeer, as if they were completely different kinds of animals (Miller 2009:223; table 11.1).

Mueller suggested that in their ancient homeland, they must have been accustomed only to wild reindeer and that domestication occurred after they arrived in their current lands. Mueller's history of Siberia has been valorized in Russian science as "the first scientific study of Siberia" and in German sources as the proof of German scientific superiority (Mueller 1732; Miller et al. 1996). Whichever of these national sentiments one accepts, he contributed to the knowledge of Indigenous people of Siberia by treating each group as its own distinct linguistic entity. Moreover, he

Table 11.1. Indigenous peoples' words for domestic and wild reindeer

	Wild Reindeer	*Domestic Reindeer*
Tungus	Schókdscho	Óron
Samoyed	Kédere	Týa
Yukaghir	Légouf	Áatsche or Ílwe
Koryak	Öllewet or Karngúgui	Chojánga

offered one of the earliest known insights into wild and domesticated reindeer. As a historian and a scientist in the eighteenth century, his awareness of the migration of peoples and the progress from wild to domestic animals is impressively modern, a view that would have held up into the twentieth century. The linguistic (and ontological) distinction between wild and domesticated reindeer persists among some groups to this day, as noted by Stépanoff (2012:291) in writing about the Tozhu people in the Tuva region of southern Siberia: "Although domestic reindeer have a different name (*ivi*) from wild reindeer (*taspanan*) and are called *mal* (or 'cattle'), Tozhu partly treat them as wild beasts. For instance, Tozhu say that only wild game (*aŋ*) liver must be eaten raw. However, when they kill a domestic reindeer, they eat its liver raw as well. They would not eat the liver of cow or a sheep in this way."

The final account I would like to highlight is that of the 1890s Siberian revolutionary exiles. They were firm believers in the possibility of a "different society" in terms of hierarchy, social inequality, and material possessions. At the same time, they were aware of the centuries of Russian expansion into Asia and the impact it had on the Indigenous groups of Siberia. Waldemar Bogoras (1904a, 1904b), Waldemar Jochelson 1910, and Lev I͡Akovlevich Shternberg and Bruce Grant (1999) used reindeer in their writing as a proxy for social ties, for caring for and being with others, as well as the possibility of other worlds that could be. The herds the Reindeer Chukchee had were an expression and a mechanism of community care; among reindeer, there was never a single, isolated animal, just as there was no abandoned person or a poor family left alone. Reindeer both represented and embodied wealth, care, mobility, and stability; the constellation of the stars; and the material embodiment of spirits, as Bogoras (1904b:624) noted in his account of the Reindeer Chukchee: "All families of the Reindeer Chukchee are connected among themselves by ties of relationship. Thus, a poor family without relatives is almost impossible."

At the same time, the animals and their spirits were co-producers of this world and had power over the people to withhold not just resources but also tranquility, peace of mind, and health. The exiles reported a spirit known as the Reindeer Being, represented with one eye closed as a sign that it has lessened the supply of reindeer. When it closes its other eye, all reindeer will vanish (Bogoras 1904b:316). In this understanding, the boundary between humans and animals is absent; the seamless transition between a reindeer and its all-powerful spiritual avatar that can grant or withhold the presence of the species indicates the power reindeer had in the company of people:

> Picvu'čin is a special "owner" of wild reindeer and of all land-game. He lives in deep ravines and stays near the forest-border. From there he sends reindeer-herds to the hunters; but when he is angered, he withholds the supply. He is especially strict in demanding the performance of all ancient customs and sacrifices connected with the hunt and resents every slight neglect of them. He is represented as very small, not larger than a man's finger, and his footprints on the snow are like those of a mouse. Picvu'čin rides the largest bucks in his herds: therefore, wild reindeer bucks are found with the hair on their shoulders all roughened up. (286)

Yet Bogoras makes it very clear that the beliefs, stories, and practices are not Indigenous traditions in any simple sense as timeless practices unchanged for centuries. Rather, they are the result of colonialism, conflicts, and impressive adjustments to regimes of power. Even reindeer and their "masters" change with time:

> "Masters" of the forest are, in the Russo-Yukaghir conception, exceedingly fond of drinking brandy and of playing cards. Even now those hunters who are most successful in trapping are reputed by the Russianized natives to have bought their luck from the "master" of the forest with brandy and packs of cards . . . The best material for sacrifice is tobacco. On the whole, the natives in many cases prefer to sacrifice imported provisions, Russian or American, supposing that the local "masters" and deities need them much more than ordinary food, which is abundant. (287–288)

THE NATURE OF AGENCIES

Judging from ethnographic, biological, and historical accounts, reindeer have occupied a central place in the lives, imaginations, languages, religious practices, and ways of being of herders of northern Eurasia for millennia. What, then, are archaeologists to do with such stories in attempts to interpret prehistoric materials using analogy? A recent spirited exchange between Rane Willerslev and colleagues (2015) and Tim Ingold (2015) rested in a disagreement over the nature of the relationship between domestication and hunting among northern peoples (in reference to Ingold 1994a). Ingold (2015:27) pushed back against Willerslev's notion of hunting as a distinct form of sacrifice and argued that there were two potential perspectives: "The [first is the] patriarchal model, applicable to Near and Middle Eastern pastoralism as

Figure 11.3. Offering of reindeer horns. *Courtesy*, Division of Anthropology, American Museum of Natural History, New York, NY, Catalog #1480.

represented in biblical accounts and associated with the proximate power of ancient kingdoms. The other is the northern circumpolar model, where the control of the pastoralist over his herd is not at all like that of a ruler over his subjects but very much like that of the spirit master over animals which are really just refractions of his own being."

The transition to domestic animals is of great interest to archaeologists, who regularly draw on ethnographic analogies to support their interpretations of the archaeological record. My brief review of diverse historical accounts that span several centuries suggests that the example of reindeer in Siberia reminds us that there is more to the animal and to the perceived relationships with Indigenous people than is generally thought. Reindeer in Siberia were a source of wealth for humans, the embodiment of mobility and freedom, the essence and spirit of relationality, and a critical tie between the worlds of people and animals (figure 11.3). But reindeer remained partly wild, encouraging people to follow their migrations and mimic their sociality. In this sense, they were co-producers of that same world, keeping humans who lived alongside them as much as they were kept by them. Other animals in different parts of the world may have played larger cohabiting roles that similarly do not fall easily along the domestic-wild divide. Domesticating an animal may have entailed a broad range of practices, beliefs, and relations. In this respect, the reindeer from Siberia offers a good proxy for agency, acting on the world where categories of humans, animals, wild, and domestic are not easily separated and need to be thought through from other perspectives. Like the toggle in a harness, their very existence can nudge us in the direction of thinking otherwise.

NOTE

1. Mueller's name was Anglicized in different ways and appears variously as Mueller, Müller, and Miller.

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12

The End of the World (Again)

JOHN ROBB

ABSTRACT

Humans live in a world of crises and catastrophes. Usually, we understand them simply as random "acts of God" that wreck human lives and plans. But this common-sense, worm's-eye view masks important questions. Do catastrophes just happen randomly, or do humans create them? Do they change history, or do they just facilitate it? Are they a patterned evolutionary force or just random noise? As an example, we turn to the bubonic plague epidemic of 1347–1350—the so-called Black Death, in which up to half the population of England died. What does it teach us about the experience of historical crisis?

It's time to talk frankly about the end of the world. Even if we've made it to the present day, we may not be out of the woods yet. Should we worry about it?

How many of our crises and catastrophes are really important? When we are in the thick of things, every thread that connects the past to the future is vitally important, a fiber of our being that feels every change. But look at the newspaper headlines from a hundred, fifty, even twenty years ago: painstakingly hammered-out laws regulating long-dead industries, treaties negotiating long-vanished borders, protests and riots over things we now take for granted. Deadly little wars over territories that no longer exist. Assassinations of now-forgotten people who would have been dead in a few years anyway. Heresies cleansed with fire that are now not even a footnote to history. Did any of this really matter? And yet, to the

https://doi.org/10.5876/9781646423521.c012

people of the time, some of these things presaged the end of the world, at least as they knew it.

Were they wrong, and is most of what they—or we—worry about not really so important? Are our crises going to look as dusty in a couple of decades? How do we know what the important crises in history are?

BRING OUT YOUR DEAD . . .

If you want to look at a disaster that seemed like the end of the world, the Black Death is an obvious candidate. It was an epidemic of bubonic plague, *Yersinia pestis*, that swept through Eurasia in the period 1347–1350 (Benedictow 2004; Horrox 2013). Bubonic plague is a virulent bacterial infection that painfully kills most people who get it within a few days. The Black Death was the kickoff event for the "Second Pandemic," a series of recurrent plague epidemics throughout Eurasia that lasted until the early eighteenth century. The first wave struck Britain in 1348 and within a year wiped out 40 percent to 50 percent of the population—perhaps 2 million people. Nobody knew how to explain it. Doctors thought it might be spread by bad air; priests said it was punishment for humanity's general sinfulness. During the epidemic, as well as fear and grief, there was panic and confusion; many people seriously thought the world was ending or at least that the social world was unraveling into anarchy.

Like the people who endured it, historians have regarded the Black Death as a huge disaster. One traditional view, found in many popular books, is that the Black Death completely transformed European society (McNeill 1998; Herlihy 1999; Cohn 2002). This is the "pathogen as protagonist" model; you only have to explain how the pathogen arrived there and the rest happens mechanically. Its most commonly quoted example of social transformation is that because peasants moved around more after the epidemic, the plague broke the bonds of serfdom and ushered in a modern world of free labor working for wages. But there is a more nuanced historical tradition that sees the plague as ecologically and socially contextualized. Some pathogens are always present; what effect they have depends in large part on their context—for instance, whether the population is healthy or biologically compromised. In this model, most recently expressed in Bruce Campbell's (2016) socio-ecological model, by about 1300, most of Europe was overpopulated and under severe demographic pressure. Any event—the late medieval climatic downturn, for instance—could create crises, and the fourteenth century was a century of crises, such as the Great Famine of 1315–1320 in which over 10 percent of England's population died. The Black Death arrived at a vulnerable and compromised society and developed into the perfect storm. It proved a trigger for some changes; for others, it accelerated changes that were happening anyway.

This usefully poses three key questions:

1. What defines a crisis?
2. Why does rapid or traumatic change have the effects it does?
3. How do crises form a part of historical process? Are they exceptional "acts of God" that intrude upon an otherwise orderly unfolding, or are they an integral part of change?

What Is a Crisis? The Micawber Definition

Is a crisis what feels like a crisis? What people experience as a crisis is notoriously unreliable. What we fear isn't the result of a careful risk analysis. People live with things that cause very high levels of suffering and death—divorce, car accidents, gun crime, heart disease, or in medieval times, tuberculosis—if they can familiarize them, routinize them, or rationalize them. They fear the unknown, things that erupt unpredictably, dramatically, and incomprehensibly; the traditional Four Horsemen of the Apocalypse were Death, War, Famine, and Plagues, not the Chronic Disease and Social Inequality people lived with every day. They fear things that disrupt the world as they know it. Even as I write, there are people writing angry letters to the *Times* (or blogposts and tweets) about how teaching schoolchildren that not everybody is heterosexual, or the result of a presidential election, or belonging to the European Union, or any number of other things will bring about the end of civilization as we know it. The emotional politics of the present and future may be a very poor guide to whether important change is actually going on. Humans are resilient; we've lived through things much bigger than any of these. And our attention gets captured by particular issues, often (perhaps usually) the wrong ones: in the 1950s, for example, Americans should have worried much less about global communism and much more about racial injustice. Indeed, crises can be manufactured for political needs. The muckraking journalist Lincoln Steffens once created a crime wave simply by reporting every routine crime that happened in New York, and factions from fascism and McCarthyism to today's right-wing extremists have entirely invented threats to society to motivate repression. The point is obvious: just as mashing your finger in a door hurts a lot more than cardiovascular disease, there isn't necessarily a correlation between how much immediate pain change causes and how lethal it is.

Systemically, we can define a crisis as a moment when change happens faster than the system's ability to cope with it without disruption. This definition recalls Mr. Micawber's dictum (in Charles Dickens's *David Copperfield*) that spending sixpence less than your income leaves you in prosperity, while spending sixpence more than your income means a financial crisis. This definition, which clearly involves a sliding scale (when does "reasonable adjustment" become "disruption"?) sometimes depends entirely on practicalities and capacities: if a town's system for dealing with deaths can cope with ten per day, when the plague strikes and the death toll reaches a hundred, it's time to dispense with labor-intensive individual funerals and start digging big pits. One of the most intriguing questions is whether processes and structures of different kinds have inherent paces of change—an idea familiar in biology but rarely explored in history. Institutions may have reaction speeds tied to their structure: heterarchy and democracy are slow politics, hierarchy is fast politics. For cultural systems, the speed of crisis ties into Pierre Bourdieu's (1977) idea of hysteresis, or an inherent lag time for cultural change based on how deeply people are enculturated with habitus; if change goes faster than this, it may cause a traumatic emotional dislocation (as in many colonial encounters).

The Black Death: What Happened—and What Didn't Happen

The consequences of the Black Death are generally acknowledged. To generalize briefly, in England (Platt 1997; Hatcher 1986; Aberth 2010):

- The epidemic caused massive countrywide suffering and psychological trauma, both for people dying and for survivors.
- Population fell to half its earlier level, from around 5 million in England to around 2 million–3 million, and remained low and static for two centuries. Some settlements shrank; others were deserted entirely.
- By removing half the population at a stroke, the epidemic rebalanced population, labor, and land. Wages and mobility rose for working men; land values fell for propertied people.
- Accompanying this, the feudal labor dues workers owed to landowners were increasingly replaced by cash payments, hastening the demise of feudalism as a system whereby people were tied to the land and paid in-kind from their labor on that land.
- More land was used for pastoralism, fueling the late fourteenth–fifteenth-century boom in wool and cloth, the economic motor of England's trade.

But in some ways, it is more interesting to consider a counterfactual history and ask about effects that never were. Disasters can cause a lot of historical effects: psychological and cultural trauma, political change, economic restructuring, regime change, war, economic collapse, and the disappearance of entire groups and societies. At the time of writing, after 15–18 months of pandemic, Covid-19 has killed about 1 in 500–1,000 people in many countries while causing chaos in daily life, paralyzing international travel, and partly helping to bring down at least one head of state. The Holocaust killed 6 million–7 million people; generated an enormous literature of genocide, memory, and healing; contributed to structuring international politics for at least a generation, and gave rise to an independent nation. World War II killed 3 percent–4 percent of the world's population and punctuated twentieth-century history. Given such precedents, can you imagine the consequences for our society if a disaster killed one person in two or three, like the Black Death did?

In this light, it is surprising what *didn't* happen with the Black Death:

- The practices of economic production, daily life, health, and well-being show much more continuity than change.
- There was no major technological change or loss of traditions or cultural knowledge bases.
- There is almost no plague literature or art (analogous to, say, Vietnamese literature) that might show a culture working through a major trauma.
- In religion, there were florescences of popular piety in things such as religious guild membership, endowing charities, and flagellants; but the Black Death in general did not engender new forms of religious action. In addition, the existential challenge of the plague did not lead to major theological discussions, reformulations, new doctrines, or new religions.
- The epidemic had very little major direct political effect. It loosened the bonds of feudalism, but this may have been happening in any case; and it has been credited rather vaguely with contributing indirectly to the Peasant's Revolt in 1381, perhaps by creating a generation of working folk with higher expectations and a sense of the value of their own labor. But there was no "regime change," no reordering of social classes or property relations, no international realignments or change in the balance of power.

This is the great paradox of the Black Death. Why didn't mortality on such an unimaginable scale have much greater effects? Why did so many of the historical consequences other disasters have not happen?

Some of the answers are obvious. If the Black Death had decimated one part of Europe and not another, it might have shifted an international balance of power or started wars, but it struck most areas equally. If it had obviously killed the rich but not the poor or the poor but not the rich, it might have shifted internal social relations more than it did. The predominant human experience was grief and anguish, but Medieval Christianity was a near-hegemonic belief system and already provided an elaborate way of dying that responded to these emotions and disposed of existential questions. The pre-Reformation heresies of the fourteenth century such as Lollardism had no relation to the plague, and the great religious shift of Protestantism occurred much later, starting with Martin Luther's declaration in 1517. Overall, religion channeled psychological responses into stability, reinforcing rather than undermining institutions. Knowledge was widely distributed among communities and institutions such as religious orders, so even with a massive loss of life, no knowledge bases or traditions were lost. And, of course, one reason why there was so little institutional change was simply that the emergency was so far beyond humans' abilities to deal with it in any way. No vaccination drives, no mask campaigns, little systematic attempt even at social distancing: there was little they could do besides pray.

One big reason—with possible lessons for resilience today—was the structure of medieval society. If you remove half the biomass from a ton of elephant, it dies; if you remove half the biomass from a ton of yeast, it simply grows back. If producing a bowl of food requires high-tech machinery, petroleum, electricity, shipping, insurance, banks, chemical factories, supermarkets, and a supply chain of diversely skilled people spanning several continents, it is fragile. Relatively small perturbations can stop the economy dead. If basic production is low-tech and local and involves skills most people have, even a much larger disaster won't incapacitate it. The medieval productive economy was basically cellular, centered around the rural village and manor, with a few necessary specialists such as priests and imports such as metal. Even with half the population lying dead, a local group could survive, pick itself up, and regenerate the system. In a highly specialized, hyper-integrated, globalized society such as ours, a much smaller disturbance can cause much greater chaos.

It is not only the nature of the society but also the nature of the disaster that matters. Epidemics such as the Black Death are like forest fires: sudden, traumatic, devastating, and visible. The day after a fire, the landscape looks like scenery from hell. But if the ecosystem is healthy and fire-adapted, five or ten years later it's green again and normal forest succession is under way. Other medieval problems such as tuberculosis were more like climate change: less dramatic, less visible, but always present and tirelessly at work; less likely to look like the end of the world, but more likely to actually push us toward it.

WHAT DO CRISES DO?

The point is not to trivialize the Black Death but just to highlight that the human experience of a crisis is different than its historical effects. And the historical effects may be greater or less or different than we might expect. Given this, how do crises play a particular role in historical processes or in evolution?

Much of the "collapse" literature in archaeology is surprisingly uncritical on this question; it tends to be built on a progressivist view of social evolution; to take things such as towns, political hierarchies, and elite culture as inherently advanced;

and to assume that their disappearance inherently constitutes a "crisis" and is somehow a mark of failure. For all I know, most Mesoamericans, Mississippians, Mesopotamians, Harappans, Mycenaeans, and so on were actually happy to see these things "collapse" and to watch the step pyramids or citadels gather dust in the desert. There has been more consideration of what disasters do in other literatures. Catastrophism—seeing disasters as major agents of change—was important early in evolutionary thought but was sidelined by Darwinian gradualism for over a century until revived in Niles Eldredge and Stephen J. Gould's (1972) "punctuated equilibria" model. In this view, catastrophes can break up periods of evolutionary stasis, cause mass extinctions, and provide space for adaptive radiations. Similarly, in orthodox Marxist thought, revolution—abrupt, traumatic transformation—is needed to accomplish the real, major change that will bring about the end of capitalism; gradual change is not big enough and inevitably involves too much complicity with existing institutions (Marx and Engels 2017 [1848]). In both Marxism and evolutionary thought, disasters create alternative spaces of history in which other rules of change apply. They thus can accomplish things—for better or worse—beyond the potential of ordinary historical process, such as:

- Focusing awareness. Gradual change often passes unnoticed; crises attract attention and, potentially, social response—a fact often exploited in labeling something a crisis to generate action on it (such as branding obesity an "epidemic"). As politicians say, you should never waste a good crisis.
- Converting quantitative process to qualitative change, forcing decisions, and triggering new chains of action. The real culprit may be poor original design and years of accumulated stresses rather than the last truck going across the bridge, but the collapse is what actually forces rebuilding the bridge or rerouting the road somewhere else. This may result in unforeseeably different outcomes—going in new directions rather than simply ramping up existing ones.
- Making the unthinkable thinkable. The first mandate of any social order is to protect and perpetuate itself. Thus, all proposed policies have the unspoken corollary "if, of course, this doesn't upset the way we do things too much." During times of crisis, it may become clear that ordinary practice isn't working and ordinary reality is suspended, and things previously unimaginable may be thinkable—even necessary. There's a war on—we need women in factories. And, as the USA discovered in World War II, the experience of joining the workforce may have changed women's self-images and attitudes, making it difficult to push them back into the kitchen . . .
- Breaking through constraints: the productive crisis. A city's structure can become a straitjacket—until an earthquake, fire, or war levels it and offers a blank

canvas for a new century. The Great Fire of 1665 let London grow from crowded medieval lanes into Georgian squares and Wren churches; a lot of modern(ist) housing throughout Europe was built in the wake of World War II's urban bombings. Similarly, a social order can get trapped in layers of self-protection that prevent any movement toward change, even when the system is creaking with the effort of trying to stop history. A crisis may open spaces for movement, allowing it to break free and develop in new ways.

- Directing change. As an evolutionary force, crises may change internal structures in specific, perhaps predictable ways. For instance, they may focus attention and resources on core needs. In many examples of the "fall of civilization," peasants and their productive structures continued intact; what "fell" were elite institutions. Similarly, if complex environmental settings change, specialized organizations that are adapted to them may be knocked back into more generalized components. Crisis, thus, can push a society toward particular forms.

Do different kinds of disasters have different effects? The answer is probably yes, though it would be pedestrian to formalize the typology of monsters. Epidemics reduce population and freeze interactions, but they don't destroy infrastructure; if the population rebounds, plagues may fade into memories relatively rapidly, as the Spanish Flu of 1918–1920 did and Covid-19 may do. This may be aided by the sense that they are impersonal, effectively random events, unless they are politicized as AIDS was and Covid-19 may also be. Physical events (earthquakes, hurricanes, tsunamis, fires, floods) mostly destroy landscapes and infrastructure and dislocate people, but that occurs mostly locally. Volcanic eruptions cause local destruction, but their potential for global reach really comes from their ability to send dust around the world and lower atmospheric temperatures. Wars potentially combine wide-ranging physical destruction, loss of life, dislocation of populations, and restructuring of politics and memory. But wars are contextualized within larger political movements that take decades or centuries to break out in conflict (indeed, politics may be history-as-process and war its alternative historical space of crisis). But to really change the course of history, we probably need to address the less dramatic and visible parameters that provide the context for all of these—large-scale climate and environmental change.

No crisis ticks all the boxes. As noted above, the Black Death was, by and large, a missed opportunity for political change. Further, it did not generally breach taboos of thinkability except in a few minor theological ways (such as new, temporary forms of burial and regulations allowing non-clergy to administer sacraments to the dying). In hastening mobility for serfs, the epidemic may have brought to action tensions over the nature of land tenure that had been building up for some time. And in clearing (albeit cruelly) an overpopulated society, the epidemic may have allowed scope for economic innovation and maneuver—for instance, expansion of pastoralism and the cloth trade—in a way impossible in the packed landscape of 1300.

As this suggests, there is no single recipe for how a specific crisis will unfold; too much depends on circumstances. To take a big issue—inequality—the forces of crisis pull in contrary directions. On one hand, crises offer an unparalleled opening for increasing hierarchy. As an organizational form, hierarchy allows fast, decisive response to emergency conditions much more readily than horizontal organization does; indeed, many systems make provision for invoking emergency dictatorships or martial law during crises. And crises offer an unparalleled opportunity for would-be leaders to sow confusion, fear, and doubt; seize control; and wrestle society in previously unthinkable directions—so much so that inventing crises is almost an obligatory part of a demagogue's playbook. On the other hand, crises may exert leveling effects. They may involve jettisoning the less necessary components of society, which rarely include actual producers redeveloping local self-sufficiencies of basal units, and adding moral pressure for change. Even in modernity's class-divided societies, major benefits to workers may result from or follow social spasms—universal suffrage in Britain following World War I, the American New Deal during the Great Depression, and the American GI Bill and the British National Health Service following World War II.

THE ZOMBIE APOCALYPSE: THEORETICAL CONSIDERATIONS

Crises are events, and events are linked into ideas about causation. We want to think linearly: Circumstances A caused Event B, which caused Consequences C. This desire for simple linear narrative is exemplified in those *Nature* headlines that are the bête noire of serious historians: "My Cherry-Picked Climatic Wiggle Caused the Fall of the World's Most Famous Civilization." But at the risk of restating the obvious, this isn't really how history works. History is multi-causal: any event has a lot of different causes. As historians have argued since Braudel (Bailey 2007; Robb and Pauketat 2012), history is multi-scalar, a palimpsest of processes going on at different scales and speeds. So these causes are embedded in both short-term surface histories and deeper histories going back a long time. All of this implies that we can, and indeed must, write multiple histories at multiple scales. Moreover, as a general rule, anything important enough for us to want to explain it will also influence other processes, and anything important enough for us to call it a cause will also be affected by other things. In such an approach, "causality" becomes a narrative way of holding everything else equal so we can highlight particular relationships within a complex web of relationality (Robb and Harris 2013).

What defines a crisis? It is clear that what people experience as the end of the(ir) world isn't always the same thing as real historical change. Nobody would downplay the human tragedy of the Black Death, but its historical effects were much less sweeping and more subtle than we might expect from the sheer scale of death. Instead, crises are times when the pace of change outstrips our ability to deal with it. What their consequences are depends on the specific historical context and the nature of society. The Black Death didn't result in widespread unemployment and starvation in part because of the locally self-sufficient nature of medieval society; a much smaller disruption would have much greater effects in our world today. But it is clear that crises also create a different mode of historical time in which different kinds of things can happen. Crises as a form of historical time may have special effects distinct from processual change. These potentially include galvanizing people and groups to new actions, pushing social organization in specific directions, making previously unthinkable possibilities become thinkable, and clearing away the past to allow new things to emerge.

Evolutionarily, history is all about balancing change and continuity. Both stasis and change require deliberate action (Smith 2010:23–24). Humans are attached to the past, and we usually assume that the narrow way we have lived is "normal," inevitable, and necessary. This shared commitment to a shared social world is part of culture and evolutionarily important for acting together. But change is the state of the world, and humans can live in a huge variety of ways. This creates complexities. If you refuse to change or change too slowly, extinction looms. In the midst of the Italian War of Unification, a character in Tommaso di Lampedusa's *The Leopard* remarks ambiguously "If we want things to remain the same, things will have to change." Thus, change is never total. The future is rooted inextricably in the past through our institutions, our landscapes, our bodies, and our habitus. It can never be entirely new. As frustrated revolutionaries inevitably learn, even if you build a completely new system, you still have to populate it with the same old people, with all their virtues and defects.

The conclusion this leads us to is that crisis is relational, not absolute. The effects of a catastrophe depend not only on how severe it is and how long it lasts but also on how people are organized and relate to the world around them. With the Black Death, for example, we see how a social world made of cellular units with generalized capabilities is more resilient than one made up of highly specialized, integrated units. This leads to an obvious question: are some ways of organizing our social world more crisis-prone than others? The answer has to be yes.

It has to do with how you cope with change. The world around us is constantly changing. The masters at dealing with this are hunter-gatherers in a world of other hunter-gatherers. They typically live at low population levels in highly flexible ways. You just map yourself onto whatever new conditions emerge. If rising sea levels drown your territory, you move somewhere else; end of problem. In contrast, the more demands you place on the world around you, the more you have to fix it stably at optimum levels to continue to live in the way you are accustomed, and the more the mere fact of change becomes a threat and a crisis. Subsistence farmers are not too bad off, as long as they don't live in a desert or in too crowded a landscape and can move when they need to. In contrast, capitalism positively manufactures crises, particularly when combined with rigid political borders that rule out movement as a response to change. The capitalist system of production and consumption depends on finding a golden moment of maximum productivity and fixing it there stably, so that change itself becomes an existential threat. (As an American politician recently stated when discussing climate change, "The American Way of Life is non-negotiable.") For example, once you turn land into high-investment ownable capital, a lot of wealth, housing, and food production becomes tied up in specific, non-movable places that must remain dry land; and your options for dealing with rising sea levels are much more circumscribed. Given the futility of arguing with long-term historical change, taking such an attitude is probably setting yourself up to fail.

Of course, it is probably not a realistic option for all of us to quit our jobs and grow potatoes in our gardens. But there may be ways to design societies that are more change-friendly. Maybe we should take thought about how to build societies that do less to conserve yesterday's world and more to welcome change. For instance, rather than specializing to maximize any single objective (particularly productivity) or to fit any single, particular configuration of circumstances that then have to be fixed stably for survival, one can develop generalized capacities that provide multiple modes of operating under different circumstances. A system with flexibility and diverse organizational possibilities is able to operate in multiple modes as circumstances require. And we should conserve diversity of all kinds as a resource, nurturing kinds of people, ways of doing things, knowledge bases. We might not need it now, but you never know what the future will need.

Ultimately, we don't live in a world of crises. We live in a world of change. In some ways, the end of the world is always happening; every day sees the end of yesterday's world and the birth of tomorrow's. Whether it becomes a crisis is up to us.

Acknowledgments. I am grateful to my colleagues on the "After the Plague: Health and History in Medieval Cambridge" project (Craig Cessford, Jenna Dittmar, Ruoyun Hui, Sarah Inskip, Toomas Kivisild, Piers Mitchell, Bram Mulder, Tamsin O'Connell, Alice Rose, and Christiana Scheib) for many stimulating discussions; the views expressed here are not necessarily theirs. I thank Monica Smith for insightful comments on the manuscript. Funding was provided by the Wellcome Trust (Medical Humanities Collaborative Grant 200368/Z/15/A).

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