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Introduction

Resilience, Vulnerability, and the Study of Socioecological Dynamics

Gyles Iannone

This volume examines the developmental trajectory of ancient Maya civilization, with particular emphasis on two themes: climate change, specifically droughts, and what are deemed to have been a series of periodic "collapses," including the infamous Terminal Classic collapse (AD 750–1050). The principal goal is to critical assess the drought-induced collapse models that have become increasingly popular of late—both within and outside of Maya studies—in light of our ever-more-comprehensive understanding of ancient Maya culture history. The aim is not to challenge the idea that severe droughts periodically impacted ancient Maya communities—this seems irrefutable given the multitude of data sets generated over the past three decades—but rather to better understand the timing and intensity of these droughts, and to provide a more nuanced understanding of socioecological dynamics, with specific reference to what makes communities resilient or vulnerable when faced with environmental change.

In order to achieve the aforementioned goal, the contributors to this volume strive to generate a better understanding of a number of issues, including the following: How useful is the concept of "collapse" and how can it be applied consistently in our studies of past societies? How severe was a purported drought episode in terms of duration, decline in rainfall, availability of potable water, impact on agricultural production, or shock to the economy? How do we accurately assess the effects of a particular drought given the range of climate change proxies that are currently available? How do we effectively articulate the environmental and cultural sequences so as to generate a better understanding of how droughts and the suggested periods

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of "collapse" correlate with each other? How vulnerable were ancient Maya communities to climate change, given their long-term adaptation to fluctuating environmental conditions? How much regional, subregional, and microregional variation is there in terms of the purported collapse sequences? Did a specific drought affect all segments of a community similarly? Is there evidence to suggest that other factors played a role in the various demographic and/or political downturns recognized by archaeologists? What can we learn from the past that will help us model the potential future implications of how we currently interact with our environment, construed in the broadest sense to include climate, landscape, and resources?

The purpose of this introductory chapter is twofold. To begin, I discuss some of the concepts that facilitate the study of socioecological dynamics from an archaeological perspective. This is followed by a brief summary of some of the more salient issues that emerge from the various chapters in the volume.

RESILIENCE THEORY AND COUPLED SOCIOECOLOGICAL SYSTEMS

In recent years there has been a growing concern with how climate change, declining resources, landscape modifications, food security, and the increasingly interconnected nature of the world economy might impact global society during the twenty-first century. This has stimulated ever-more-sophisticated research aimed at examining the reciprocal, coevolutionary relationship between societies and their environments (e.g., Bennett, Cumming, and Peterson 2005; Berkes and Folke 1998a; Berkes and Folke 2003; Gual and Norgaard 2010; Gunderson and Holling 2002; Janssen et al. 2006; Liu et al. 2007; Mainwaring, Giegengack, and Vita-Finizi 2010; Rosen 2007; Scheffer 2009; Turner 2011; Turner, Davidson-Hunt, and O'Flaherty 2003; Walker and Salt 2006; Walker et al. 2004; Walker, Anderies, et al. 2006; Walker, Gunderson, et al. 2006; Weisz et al. 2001; Whitehead and Richerson 2009; Zhang et al. 2011). The expressed goal of this rapidly expanding research program is to model the potential outcomes of our contemporary actions, or inactions, as they relate to issues surrounding *sustainability* (Costanza, Graumlich, and Steffen 2007; Costanza et al. 2007; Dearing et al. 2007; Walker and Salt 2006:38), defined here as "the use of environment and resources to meet the needs of the present without compromising the ability of future generations to meet their own needs . . . Sustainability is a process, rather than an end-product" (Berkes, Colding, and Folke 2003:2–4); it "is achieved in a long-term trial and error process and maintained by constant adjustment" (Winiwarter

2003:93). One result of this new emphasis has been a refocusing of the natural and social sciences toward transdisciplinary research efforts aimed at exploring, in detail, the dynamic nature of coupled socioecological systems (Costanza, Graumlich, and Steffen 2007a; Costanza et al. 2007; Turner 2010).

The concept of *resilience* has become a key conceptual framework within this new research program. "Resilience is the capacity of a system to absorb disturbance; to undergo change and still retain essentially the same function, structure, and feedbacks" (Walker and Salt 2006:32; see also Berkes and Folke 1998b:6; Scheffer 2009:357). According to Charles Redman et al. (2007:118), resilience is fundamentally about the "the capacity of an institution to adjust to perturbations . . . [It is not about] stability around a single state, but rather the possibility of multiple socioecological states that maintain the primary functional relationships of the socioecological system." The complexities inherent in the concepts of sustainability and resilience are readily apparent when one considers that resiliency is not always desirable, particularly if the system is currently in a stable, and highly resilient regime, but one that is unwanted; for example, a political regime that is firmly entrenched and totalitarian in operation may be highly resilient, but undesirable to the vast majority of the population (Walker and Salt 2006:37).

As indicated above, *systems*, from the perspective of resilience theory, differ in a number of subtle, but significant, ways from how they were viewed in some early archaeological applications (e.g., Binford 1965, 1972:106; cf. Weisz et al. 2001:121). For example, whereas the latter tended to emphasize "stability at a presumed steady-state, and . . . resistance to a disturbance and the speed of return to an equilibrium point"—which was an approach that was linear, tied to cause-and-effect relationships, and facilitated "predictive science"—the former focuses more on the capacity to absorb disturbance without flipping into an alternative regime, and assumes the existence of complex adaptive systems in which the nature of change is difficult to predict (Berkes and Folke 1998b:12; Redman et al. 2007:119). The "capacity . . . to manage resilience . . . to avoid crossing into an undesirable system regime or to succeed in crossing into a desirable one" is referred to as "*adaptability*" (Walker and Salt 2006:163).

Resilience Theory, Archaeology, and Importance of the "Long Term"

Although archaeologists have made some significant contributions to the study of long-term patterns of exploitation and overexploitation, generally referred to as *global change archaeology* (Benzing and Herrman 2003; Fisher, Hill, and Feinman 2009; Jacobsen and Firor. 1992; Redman 1999; Redman et al. 2004a, 2004b), resilience theory has not figured prominently in archaeology to date. Nevertheless, its potential was hinted at in some early discussions of the subject (Robert Adams 1978), and in recent years there has been a growing acceptance of the efficacy of the framework on the part of archaeologists studying in various parts of the world (e.g., Adams 2001; Blanton 2010; Costanza, Graumlich, and Steffen 2007a; Costanza et al. 2007; Dearing 2008; Delcourt and Delcourt 2004; Fisher, Hill, and Feinman 2009; Gabler 2009; Guttmann-Bond 2010; Hegmon et al. 2008; Janssen 2010; Kirch 2007; McAnany and Yoffee 2010a; Nelson et al. 2006; Peeples et al. 2006; Redman 2005; Redman and Kinzig 2003; Redman, Nelson, and Kinzig 2009; Tainter 2006), including the Maya subarea (Alexander 2010; Lucero, Gunn, and Scarborough 2011; McAnany and Gallareta Negrón 2010; Scarborough 2000, 2008, 2009a, 2009b; Scarborough and Burnside 2010a, 2010b; Scarborough and Lucero 2010). This call to arms has been encouraged by numerous scholars working within the new transdisciplinary framework, both inside and outside of archaeology, who have come to appreciate the crucial role that the discipline has to play in the future-looking modeling process, particularly with respect to examining issues of resilience and vulnerability over the long term (e.g., Costanza, Graumlich, and Steffen 2007a; Costanza et al. 2007; Guttmann-Bond 2010; O'Sullivan 2008; Redman 2005; Scheffer 2009:250–51; Smith 2010; Turchin 2008; van der Leeuw and Redman 2002; Wisner 2010; cf. Nash 2011). These researchers underscore the importance of archaeology's unique ability to generate and critically assess *parallel* or *integrated histories* for specific coupled socioecological systems (Costanza, Graumlich, and Steffen 2007:4–5; Kohler and van der Leeuw 2007; Wisner 2010:135). The importance of archaeology to this endeavor should be clear; given "its insight into tens of thousands of years of human activities in all parts of the globe, [it] is a tantalizing source of information on human-environmental relations" (Redman 1999:3–4). "Archaeologists, as purveyors of the past, are well equipped to bring this long-term perspective to bear on contemporary issues. Moreover, we are also trained to work in multiple scales of time and space as well as with scientists from various disciplines" (van der Leeuw and Redman 2002:597; see also Shryock and Smail 2011).

These detailed developmental sequences are required for the future-looking modeling exercise because (1) our models need to be broadly informed, and inclusive of the array of potential human-environment relationships that have existed in the past; (2) such sequences clearly enhance our ability to isolate significant developmental trends, and thus promote our capacity to understand the rationale behind human decision making as it relates to environmental change; and, (3) these sequences are essential if we hope to isolate the conditions under which environmental changes are likely to result in a more subtle "transition," or when they are liable to contribute to an actual *collapse*. Following Marianne Young et al. (2007:450), a "collapse is any situation where the rate of change to a system": (1) "has negative effects on human welfare, which, in the short or long term, are socially intolerable"; (2) "is more rapid and usually in the opposite direction to that preferred by at least some members of society," (3) "will result in a fundamental downsizing, a loss of coherence, and/or significant restructuring of the constellation of arrangements that characterize the system"; and, (4) "cannot be stopped or controlled via an incremental change in behavior, resource allocation, or institutional values."

Exploring Long-Term Developmental Trajectories: Some Key Concepts

With respect to building detailed, long-term sequences for coupled socio-ecological systems, it is not insignificant that "collapses in human-environment systems are often triggered by events or trends that have occurred long before, and thus the underlying processes can involve long time lags" (Young et al. 2007:449–50). Some of the more salient, and interconnected, concepts that aid in the examination of the long-term processes associated with resilience and vulnerability include societal metabolism, colonized ecosystems, niche construction, risk spirals, diminishing returns, path dependency, the sunk-cost effect, conformist social learning, rigidity traps, and poverty traps.

The concept of *societal metabolism* has ecological, economic, and social connotations, and specifically refers to the "material and energy flows which directly serve to sustain the human population or which are, to a very large extent, regulated and controlled by society" (Weisz et al. 2001:123–24; see also Fischer-Kowalski 2003; Haberl et al. 2011; Louwe-Kooijams 2003; Sieferle 2003). It therefore encompasses human nutrition, feed for livestock, and raw materials for construction and tool manufacture (Haberl et al. 2011:3). A society's *metabolic profile* will reflect its "mode of subsistence" (Fischer-Kowalski 2003:24). For example, whereas hunters and gatherers rely principally on the direct harvesting of biomass, agrarian societies are sustained by an elevated level of biomass that is obtained by colonizing and modifying natural ecosystems to generate higher yields (Fischer-Kowalski 2003; Haberl et al. 2011; Weisz et al. 2001:126–27). It is notable that "the larger (and denser) the population, and the larger its metabolism, the more natural systems have to be colonized in order to sustain this metabolism" (Fischer-Kowalski 2003:26).

Colonized ecosystems, also known as *artificial* or *cultural* landscapes, result from "the deliberate and sustained alteration of natural processes that aim at 'improving' them according to society's needs" (Weisz et al. 2001:123; see also Dearing et al. 2007:266; Fischer-Kowalski 2003; Haberl et al. 2011; Ponting 2007:67–69; Sieferle 2003; van der Leeuw 2007:214–15). Agriculture, for example, replaces natural ecosystems with *agroecosystems* that generate significantly higher biomass yields (Weisz et al. 2001:124). Nevertheless, as a result of efforts to maximize production by focusing economic attention and modes of intensification on certain key resources, these colonized ecosystems are less resilient because of the "weeding out" of diversity (cf. Sieferle 2003:134–35). In other words, "human beings initially adapt themselves to the dynamics of their environment, but over the long term societies' needs are best served by modifications to the environmental dynamics (Dearing et al. 2007:266; see also van der Leeuw 2007:215); this is also referred to as *niche construction* (Laland and Brown 2006; Laland and O'Brien 2010; Whitehead and Richerson 2009:269).

Returning to the idea of societal metabolism, it is significant that the reliance on such colonized systems may eventually force societies into what has been termed a *risk spiral* (Dearing et al. 2007:266; Fischer-Kowalski 2003:26; Müller-Herold and Sieferle 1997). According to Müller-Herold and Sieferle (1997:201–2): "a risk spiral is a dynamizing principle in the development of complex societies [wherein] the reduction of a particular risk leads to new types of uncertainty, which in turn require further (risky) innovations . . . [and a] permanent innovation pressure [that is] responsible for the restless transformations in complex societies." Risk spirals are particularly significant to our understanding of societies based on agrarian modes of subsistence, where the "minimization of risk" is a basic coping strategy (Müller-Herold and Sieferle 1997:205, 208). For example, the need to increase productive capacity—whether to feed growing populations or service expanding tribute demands—may lead to innovations such as agricultural terracing, but if this strategy is successful it may stimulate greater population growth because of the "relaxing of fertility controls" (Müller-Herold and Sieferle 1997:205, 208), and/or an increase in elite construction projects and overall consumption of surplus, both of which would eventually require further expansion of productive capacity and hence new innovation. One must also be aware of the potential unintended consequences that emerge as the result of new strategies for managing risk. For example, the shift to irrigated fields in arid regions may initially bring higher yields, but result in salinization and soil degradation over time (Haberl et al. 2011:3).

The growing dependence on colonized systems also spawns a cornucopia of new social institutions associated with "the organization of production, storage, and communication of knowledge" (Dearing et al. 2007:266; see also Ponting 2007:67–69; van der Leeuw 2007:214–15). The need to capture more energy to perpetuate these new institutions, to support the competitive status-building initiatives of the elite, and to feed the general populace—whose labor and tribute are required to uphold these institutions and elite lifestyles—requires societies to (1) increase their tax-collecting initiatives within their polities, (2) acquire more arable land by annexing new territory through warfare (to generate tribute), (3) expand into marginal lands and bring them under production, or, (4) develop new energy-capturing techniques. The problem is that all of these endeavors are expensive, and costs can eventually begin to outpace income, resulting in a period of *diminishing returns* (Tainter 1988), which is another characteristic of most agrarian societies (Sieferle 2003:134).

Unfortunately, as societies continue along the path of risk minimization and innovation, they often find themselves in a state in which "the people involved cannot stop investing knowledge and effort into the system that they have modified, because any reduction in effort will allow natural dynamics to take over and transform the environment into one to which society is no longer adapted . . . Once a garden has been created out of a wilderness, one is bound to keep gardening (van der Leeuw 2007:215). In other words, a society or community may begin to exhibit a certain *path dependency*, implying that there is a tendency to get "locked" into a particular developmental trajectory that ultimately limits the range of options that are available to deal with new risks.

A direct result of the aforementioned path dependency is that societies, or systems, can start to feel the impacts of what has been called the *sunk-cost* or *Concorde effect*, which refer to a situation in which agents "put more . . . effort into continuing with existing investments rather than exploring new ones," which results in a tendency to undermine innovation (Janssen and Scheffer 2004; Walker and Salt 2006:87). This situation is analogous to one in which *conformist social learning* becomes more prevalent than *individual learning*. This trend is problematic because the latter mode of learning is both more innovative and more adept at tracking environmental variation than is the former (Whitehead and Richerson 2009; see also Lucero, Gunn, and Scarborough 2011:487).

Both the sunk-cost effect and conformist social learning can lead to what has been called a *rigidity trap* (Hegmon et al. 2008), which is characteristic of many social formations, including those that appear wealthy, highly interconnected, and resilient, such as inflexible caste systems or "corrupt political regimes" (Holling 2001:400). In contrast, if a situation arises wherein the society is locked into a particular developmental trajectory that results in diminished potential and diversity, it can also be said to have entered a *poverty trap* (Holling 2001:400).

Exploring Long-Term Developmental Trajectories: Some Relevant Issues

When exploring the complexities of coupled socioecological systems over the long term, it is imperative that we remain cognizant of three key issues, all of which have a bearing on resilience and vulnerability. First, researchers must be more accepting of the idea that environmental change does not determine the nature of the resulting human response (cf. Gill 2000), but rather stimulates a range of potential reactions (Coombes and Barber 2005; Mainwaring, Giegengack, and Vita-Finizi 2010; McIntosh et al. 2000a; O'Sullivan 2008:46; Rosen 2007; Wisner 2010). This is crucial for our model-building exercises for two reasons, both of which relate to how we appraise past responses to environmental change: (1) an acceptance of historical contingency implies that individuals, groups, communities, and societies will respond to environmental change based on their own social memories of past environmental fluctuations and through the lens of their own culturally specific belief systems (i.e., their unique cosmologies and political ideologies; Rosen 2007; various papers in McIntosh et al., eds. 2000b); and (2) a logical corollary of the above is that what appears to have been an ineffective response to environmental change from the vantage point of the contemporary world, given our current level of knowledge and technology, may have been perceived by a specific society in the past as entirely rational given its own particular circumstances. For these reasons we should not judge the actions of past agents and groups based on how we, today, choose to engage with the world around us. Nevertheless, from our contemporary vantage point we can still isolate decisions and processes in the past as they relate to environmental change, and evaluate their possible positive and negative effects, with the explicit goal of using this information to better appreciate the implications of our contemporary actions and decision making.

The second issue underscores that researchers must remain conscious of the fact that all communities—large and small, past and present—are internally segmented. For this reason it is imperative that the case studies we generate through our archaeological research are representative of all segments of a particular community (at whatever scale we wish to operationalize the concept of "community"). This is the only way that we can build a holistic understanding of socioecological dynamics in the past. The significance of internally segmented communities for our model building is twofold: (1) it means that we must be mindful that there may be varying, often contradictory, responses to the same environmental crisis; and (2) it implies that different segments of a community may be impacted in diverse ways—both negatively and positively—as a result of varying perceptions of, and differential abilities to cope with, changing environmental circumstances (Rosen 2007).

Third, and finally, it is important to underscore that even though communities and societies are internally segmented, today as in the past, none of these subgroups live in isolation. The various segments of society are linked through a series of economic, social, political, and ritual relationships that begin on the microregional scale (e.g., on the level of single households, and expanding to include neighborhoods, communities, and individual polities), and extend upward to include the subregional (e.g., multiple polities and their affiliated settlements), regional (e.g., hegemonic federations or alliances), and transregional scales (e.g., broader alliance networks, sometimes empires). As a result, what are needed are archaeological data sets and analyses that are multiscalar in character, something that has been stressed by Costanza, Graumlich, and Steffen (2007b:17). Our ability to achieve this goal is aided by two related theoretical frameworks: adaptive cycle theory and panarchy theory. In combination they provide us with a set of heuristic devices that are particularly useful for investigating issues surrounding resilience and vulnerability over the long term.

Adaptive Cycles and Panarchy Theory

Adaptive cycle theory is based on the idea that four ideal phases characterize the developmental cycles of both ecosystems and social systems (Berkes, Colding, and Folke 2003:16–21, fig. 1.2; Gunderson and Holling 2002; Holling 2001; Holling and Gunderson 2002:32–33; Redman 2005; Redman, Nelson, and Kinzig 2009; Scheffer 2009; Walker and Salt 2006:80). The *r-phase* is typified by rapid movement into uninhabited or sparsely populated landscapes, rapid population growth, and new technologies and food acquisition strategies. The subsequent *K-phase* is characterized by slow growth; conservation, accumulation, consolidation, and sequestration; intensification of production; increased management over, and investment in, a smaller number of key productive strategies; and hypercoherence, which means there is a high level of integration. The following *Omega-phase* is distinguished by rapid, "creative destruction," declining construction, and abandonments. This phase is considered to be "a disturbance causing a chaotic unraveling and release of resources" (Walker and Salt 2006:163). Finally, the resulting *Alpha-phase* is exemplified by increased diversity, migrations (mobility), innovation, and rapid restructuring. Of note here is that there is a possible "leaking" away of potential or options as part of the shift from the Omega to Alpha phases (Gunderson and Holling 2002; Holling and Gunderson 2002; Walker and Salt 2006); in other words, the loss of capacity and capabilities.

Related to the concept of adaptive cycles is *panarchy theory*, which suggests that adaptive cycles of varying size—from the household to the empire—are interconnected to varying degrees (i.e., there are hierarchies of adaptive cycles), and they thus have the potential to influence each other in a positive or negative manner (Gotts 2007; Gunderson and Holling 2002; Holling and Gunderson 2002; Redman 2005; Redman, Nelson, and Kinzig 2009; Scheffer 2009; Walker and Salt 2006), as is also stressed in the theory of *complexity cascades* (Coombes and Barber 2005).

Summary

In the end, various issues must be taken into consideration in our efforts to elucidate the complexities of socioecological dynamics in the past. If our ultimate goal is to contribute to the success of contemporary, forward-looking model building—to practice what Sabloff (1998:872; 2008) has referred to as "action archaeology"—we must not only develop detailed, long-term sequences for specific coupled socioecological systems, but also examine, in a critical manner, the factors that contributed to both successful, and unsuccessful, responses to environmental change within our various case studies. In doing so we can be guided by Holling and Gunderson (2002:32–33), who suggest that three "properties" appear to play a key role in how humans will respond to perturbations, such as environmental change: (1) "the potential available for change, since that determines the range of options possible"; (2) "the degree of connectedness between internal controlling variables and processes, a measure that reflects the degree of flexibility or rigidity of such controls"—with greater connectedness (economic, social, political, or ritual) leading to increased rigidity, inflexibility, or both; and (3) "the resilience of the system, a measure of [the] vulnerability to unexpected or unpredictable shocks"—which reflects both the potential available for change and the connectedness of the system as a whole (see also Hegmon et al. 2008; Walker and Salt 2006:164).

From the perspective of archaeology, "What we know from investigations of the past is that there are circumstances when a society is resilient to perturbations (i.e., climate change) and others when a society is so vulnerable to perturbations that it will be unable to cope and may be severely affected or even collapse . . . To use this information to meet the challenges of the future, we need to construct a framework to help us understand the full range of human-environment interactions and how they affect societal development and resilience" (Costanza, Graumlich, and Steffen 2007b:10). In doing so, it is important to remain cognizant of the fact that the past cannot simply be "mined" for examples of precisely what our future will look like (Dearing 2007:23). Socioeconomic and sociopolitical transformations, and collapses, are historically contingent, and what happens to global society in the future will be unique—being based on a particular set of circumstances and being the result of a specific developmental trajectory (e.g., Nash 2011). Nevertheless, the past can still inform us as to some of the mistakes that were consistently made by those who did suffer through a "collapse," and such knowledge is crucial as we attempt to chart a better future for those who will follow us. The concepts and case studies presented herein are aimed at making a small, but not insignificant contribution to this enterprise.

THE CURRENT VOLUME

Versions of most of the chapters in this volume were initially prepared for a symposium I organized, entitled the Great Maya Droughts in Cultural Context, which was convened at the 2009 meeting of the Society for American Archaeology in Atlanta. In order to enhance the temporal coverage of the volume, I subsequently added the chapter by Ford and Nigh, and the chapter by Dahlin and Chase (at the suggestion of Chase, who admirably revised the chapter following the unfortunate passing of Dahlin). The current introductory chapter, which discusses some key concepts and definitions that are deemed useful for examining resilience and vulnerability from an archaeological perspective, was also added to help expand the focus of the volume so as to take advantage of the broader implications of the various case studies.

The volume itself is organized in two parts, followed by a concluding chapter. Part I—which includes the current introduction, along with Chapters 2–4—focuses on key issues, concepts, and definitions relating to the study of coupled socioecological systems, the "collapse" of complex societies, and the potential impacts of droughts. The current chapter has focused specifically on theoretical issues surrounding resilience theory, broadly construed. These ideas help frame many of the discussions found throughout the volume.

Chapter 2, by Aimers and Iannone, provides a critical evaluation of the concept of collapse, and useful suggestions as to not only what we mean by the term but how it can be applied appropriately, and effectively, in our research into the long-term dynamics of coupled socioecological systems. Adaptive cycle theory and panarchy theory are also discussed as a means to organize our diverse data sets over time and space. Chapter 2 then tackles the issues surrounding the purported drought-induced collapses in the Maya subarea by examining the broader cultural contexts of these declines. The lesson from these summaries is that the downturns that punctuate the ancient Maya developmental sequence are much more complex, in terms of causation, than is allowed for in most of the drought models that have been published to date.

Chapter 3, by Iannone, Yaeger, and Hodell, also provides a critical evaluation of the drought-induced collapse models, this time focusing on some of the key issues that currently inhibit our understanding of the degree to which specific droughts may have impacted past communities. These issues include (1) the difficulty in articulating the paleoclimatic and cultural sequences, given the resolution of our dating techniques; (2) the continued failure to confidently assess the effects of declining precipitation, with specific reference to whether droughts were meteorological (a decline in normal precipitation levels), hydrological (reduction in stream flow), agricultural (deficiency in soil water), socioeconomic (when declining precipitation impacts the supply of other goods, which negatively impacts communities), or a combination of all of the above; (3) the need for researchers from both the natural and social sciences to respect each other's findings and to work more closely together as part of transdisciplinary teams, in order to build a more comprehensive understanding of long-term socioecological relationships, with particular attention to what these sequences tell us that may be useful for modeling our future existence on this planet.

Chapter 4, by Griffin et al., presents the results of an important, ongoing modeling exercise that demonstrates how deforestation may not only exacerbate drought conditions, but also lead to the "patchy" nature of droughts across the Maya subarea. The authors conclude that extensive deforestation in the Late Classic may have been a significant factor contributing to the damaging effects of droughts leading up to the Terminal Classic collapse.

Part II of the volume consists of a series of Chapters (5–14) that are arranged in loose chronological order (i.e., some chapters focus on specific time periods,

Figure 1.1. *Map showing the location of key centers discussed in the text (for the location of other centers, consult the regional maps in the various chapters).*

whereas other present developmental trajectories encompassing multiple periods). In combination, these chapters allow for the long-term trends and processes crucial to exploring resilience, vulnerability, and environmental change, to be isolated within a broad, overarching developmental trajectory for ancient Maya civilization. At the same time, because individual chapters focus on different areas and time periods (Figure 1.1), they also demonstrate the variability inherent within specific developmental sequences on the regional, subregional, and microregional scales.

In Chapter 5, Ford and Nigh take a long-term view of the development of Maya agroforestry, and they conclude that the managed "mosaic" of different field systems and plant types constituting the Maya forest garden, and milpa cycle, emerged in the Preclassic, during a prolonged period marked by significant precipitation extremes. In some ways, this scenario reminds me of the variability selection process proposed by Potts (1996, 1998:93), wherein disparities in environmental conditions ultimately "enhance behavioral versatility." According to Ford and Nigh, the onset of precipitation stability in the Late Preclassic, and extending into the Late Classic period, facilitated the expansion and growth of Maya civilization. The authors contend that evidence for significant deforestation over this time is questionable, given that sediment cores do not provide any insights into the prevalence of important tree species that are not wind pollinated (i.e., the absence of pollen from these trees cannot be taken as evidence of deforestation). Citing dates from Mueller et al (2010), they also posit that another proxy for deforestation, the infamous "Maya clays" found in the Peten Lakes—which are also believed to represent deforestation during the Late Preclassic and Classic periods—may date to a much earlier time period and are therefore likely indicative of climate change, rather than anthropogenic factors.

This evidence is significant, considering the importance given to deforestation as a contributor to the decline of specific polities at different times during the Maya developmental sequence—as discussed by Dunning et al. in Chapter 6 (the Mirador Basin) and O'Mansky in Chapter 8 (the Petexbatun region) for the Late Preclassic—and considering that forest clearance may exacerbate drought conditions, as outlined by Griffin et al. in Chapter 4. Beach, Luzzadder-Beach, and Dunning (2006:69) do concede that dating the Maya clays has been difficult, but they also suggest that the evidence is strong enough to articulate multiple episodes of erosion with different periods of agricultural expansion (i.e., deforestation). My own suspicion is that Ford and Nigh are underestimating the level of deforestation and subsequent erosion, whereas others may be overestimating such anthropogenic impacts.

This topic is also addressed by Dunning et al. in Chapter 6. By assessing various forms of evidence from the Mirador Basin, and to a lesser degree a smaller zone on the Bahia de Chetumal, these researchers conclude that a combination of natural and anthropogenic factors likely contributed to the decline of a number of centers during the Terminal Preclassic period. It is interesting that neighboring communities are often unaffected. Depending on the circumstances, rising sea levels, climate change—specifically droughts—and erosion caused by agricultural expansion and deforestation, resulting in silting up of low-lying water sources, potentially played varying roles in the decline of specific centers.

With reference to the issue of deforestation highlighted in the chapters by Griffin et al. (Chapter 4) and Ford and Nigh (Chapter 5), Dunning et al. (Chapter 6) make the important point that though "deforestation" rarely leads to the complete removal of trees from a landscape—because economically valuable trees are left standing—the successful cultivation of maize and manioc, along with other crops, does require the removal of most trees, and this practice would have potentially contributed to erosion, as well as declining precipitation, given the processes outlined by Griffin et al. in Chapter 4.

Chapter 7 was originally conceived by the late Bruce Dahlin. Following his unfortunate passing, Arlen Chase agreed to carry out the final revisions, and he has done so admirably. The chapter itself deals with the "Hiatus," a period of apparent sociopolitical decline during the sixth century AD. The authors point out that the Hiatus is likely related to a global occurrence that is referred to as the "AD 536 event," a significant period of drought that may have been caused by an atmospheric disturbance resulting from a massive volcanic eruption, or the impact of extraterrestrial bodies. Key to the Chapter 7 analysis is that different polities were impacted in different ways by this drought. Tikal appears to have been ill prepared in terms of its poorly developed market exchange system and its lack of agricultural intensification. In contrast, Caracol—with its large-scale water storage facilities, extensive terrace agricultural system, wide-reaching road network, and overall higher level of food security—seems to have prospered. Finally, alongside its construction of a series of water management features, Calakmul seems to have adopted a program of warfare, conquest, and alliance building aimed at securing tribute in the form of food staples, which were transported using a far-reaching system of waterways. As a result, the Hiatus period was one of florescence at Calakmul. Dahlin and Chase conclude that these divergent preparations for, and responses to, climate change underscore that there is no simple cause-and-effect relationship between droughts and culture change (Chapter 7).

The next three chapters outline the results of long-term, multifaceted, regionally focused research projects in the western Peten. These studies—centered on Dos Pilas (O'Mansky; Chapter 8), Cancuen (Demarest; Chapter 9), and Piedras Negras (Scherer and Golden; Chapter 10)—marshal considerable evidence to suggest that droughts played a limited role, if any, in the demise of these riverine kingdoms. All three chapters emphasize that because of the centers' locations on large rivers and high annual rainfall, too much rain may have been more of a problem than not enough. Equally significant is that the problems in these kingdoms appear to have started earlier than the projected drought of the middle eighth century AD, as early as AD 730, if not before. These researchers also demonstrate that the collapse trajectories in these regions are marked by considerable warfare and by violence toward elite members of society, including ruling families. Ultimately, it seems that status rivalries, and the inability to fully accommodate the new forms of market and political economies that began to take hold in the eighth century, were the most significant factors leading to the demise of the Classic period political order. Droughts, and other environmental issues, were far less significant, if at all, in the western Peten collapses.

Chapter 11, by Repussard et al., provides some support for the idea that drought was not the primary cause of the sociopolitical declines in the western Peten, specifically at Piedras Negras. Employing a new climate change proxy based on the isotope analysis of deer bone—which appears sensitive to "severe," "extreme," and "exceptional" droughts lasting longer than 2.5 years—the authors carried out analysis of 77 samples from archaeological contexts, most of which derive from Piedras Negras ($N = 67$), with a smaller number having been collected from the site of Motul de San Jose ($N = 10$), in the Peten Lakes region. The authors conclude that there is no evidence for significant climate change at either center, though the climate appears to shift from drier to wetter from the Early Classic into the Late Classic, and it also begins to dry somewhat again the Terminal Classic. There is, however, no evidence for any prolonged droughts. They also argue that though Terminal Classic droughts may have "hastened" the collapse of Piedras Negras, sociopolitical factors were clearly the proximate cause of its decline. Finally, the researchers caution that their analysis is likely only representative of local climate conditions, and the results do not negate the possibility of more intense droughts elsewhere in the Maya subarea.

In Chapter 12, Valdez and Scarborough explore the role that droughts may have played in culture change in northern Belize. These contributors to the volume are the most supportive of the idea that droughts played a *significant*, if not *critical*, role in various cultural transformations over time, including what they consider to be significant site abandonments in the Terminal Classic. Nevertheless, they fall short of assigning drought *the* primary role in these transitions. Ultimately, Valdez and Scarborough invoke historical contingency as a key reason for the different impacts drought had on specific northern Belize polities. Thus, the range of behavioral responses include the abandonment of centers; ritual termination of elite architectural features; the massacre of elite or royal families, or both; and finally, in some cases, such as Lamanai, relative continuity.

Chapter 13, by Iannone, Chase, Chase, et al., summarizes decades of paleoenvironmental and archaeological research from the Vaca Plateau of west-central Belize. Specifically, two pale-climatic proxies—a speleothem from the Macal Chasm Cave, and isotope analysis of the fulvic acids from the soils in Reflection Cave—are used to examine the effects of climate change on the inhabitants of the large metropolis of Caracol and on the smaller centers of Minanha and Ixchel, as well as the changing ritual practices in Chechem Ha Cave. The results of the diachronic analysis demonstrate that though droughts sometimes contributed to declines, and wet periods often stimulated growth, this is not always the case. Communities and their different segments apparently had different levels of resilience or vulnerability over time and space. Even in the case of the Late Classic to Terminal Classic transition, severe droughts seem to have had variable impacts, with some communities being impacted harder than others (i.e., Ixchel), and certain segments of society demonstrating diminished levels of resilience (i.e., elites). This detailed, regional study clearly documents the complex character of socioecological dynamics and seriously undermines simplistic models wherein droughts automatically lead to some form of societal collapse.

In Chapter 14, Emery and Thornton again approach climate change using faunal remains, but through a very different method and over a far larger area than in the Repussard et al. isotope study (Chapter 11). Specifically, the authors use the presence of specific faunal remains in archaeological contexts as a proxy for the existence of certain water-related habitats. Their assessment of faunal assemblages from twenty-two archaeological sites—spread across nine drainages and covering much of the southern lowlands—suggests that species representing smaller water bodies (e.g., swamps) are more useful proxies for climate change than those normally associated with large water bodies (e.g., lakes and rivers). The former are considered powerful proxies for local climate conditions, as were the deer bone isotopes discussed in Chapter 11, and they can therefore be assessed against the much more coarse-grained proxies that have dominated the reconstructions of climate in the Maya subarea to date. Emery and Thornton conclude that the patterns for small water-body species across the twenty-two sites and nine drainages confirm the general wet/dry patterns that have emerged from other paleoclimatic studies, with a wetter Preclassic, drier Early Classic, wetter Late Classic, drier Terminal Classic, and wetter Postclassic. The study does point out, however, that the small water-body species (e.g., swamp species) are never absent from the record, and this suggests that even though droughts may have occurred, they may not have been as severe as has been suggested by others. It is important that the large-water-body species also suggest relative stability in river and lake levels, which discounts the possibility of more swampland being created as a result of the drying up of lakes and rivers.

Finally, in the concluding chapter, 15, Webster tackles a number of issues relevant to the volume and draws the ideas presented in the various chapters not only closer together but closer to the present, as he remarks on contemporary issues faced by agrarian populations and by those such as the people of Haiti, who have been impacted by multiple, devastating hurricanes in recent years. Webster operationalizes concepts such as niche construction, niche inheritance, and adaptive lag and highlights issues such as population growth, deforestation, erosion, and the protracted nature of soil generation, to suggest that the effects of droughts on ancient Maya communities would have been exacerbated because their negative impacts were, at least partially, human induced. In other words, the capacity to deal with unexpected perturbances, such as climate change, was limited by overreliance on artificial landscapes, the lack of available new land to move into, the already declining productivity of the agricultural system as a whole, and an archaic political system that was rigid and unresponsive to changing circumstances (i.e., the sunk-cost or Concorde Effect).

Although his ideas fit well with those outlined in the current chapter, Webster is admittedly uncomfortable with the concepts of resilience and sustainability. In my view, this discomfort partially reflects the fact that the definitions he employs for these concepts are somewhat dated and they are thus not as nuanced as those presented in this chapter. As an alternative to sustainability, Webster offers the idea of "copability," arguing that humans rarely, if ever, "sustain" anything but rather cope with things, which "involves a lot of messiness and unpleasantness" and the "outcomes are often unforeseen and fall short of our desires" (Webster, Chapter 15 in this volume). In my mind, this idea fits quite nicely with the notion that "sustainability is a process, rather than an end-product" (Berkes, Colding, and Folke 2003:2–4) and with the belief that sustainability "is achieved in a long-term trial and error process and maintained through constant adjustment" (Winiwarter 2003:93). It is this theme, I believe, that forms the spine that connects all of the chapters in this volume. With this idea in mind, we can now turn to other issues of theoretical and methodological importance so that we can better assess the various case studies that are presented in the second section of this volume.

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