Archaeology of Overshoot and Collapse

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Abstract

The literature on sustainability and the human future emphasizes the belief that population and/or mass consumption caused resource degradation and collapse in earlier societies. Archaeological literature proposing overshoot and collapse appears in current debates over resource conservation versus continued economic growth. The prominence of this debate, with its national and international dimensions, makes it important to assess whether there is evidence in the archaeological literature for overshoot and collapse brought on by Malthusian overpopulation and/or mass consumption.

Overshoot: the outcome when a trajectory is unsustainable for environmental, technical, or social reasons

Collapse: rapid loss of an established level of social, political, and/or economic complexity

INTRODUCTION

Overshoot is a term and concept in the wild. Like a computer virus in the wild, it proliferates in the public arena. It mutates like a biological virus, assuming altered forms and new meanings. Overshoot is part of contemporary politics, ideology, and public discourse. Many believe that humanity has overshot the carrying capacity of some resource or other (e.g., Rees 2004). Conversely, neoclassical economists and the politicians they influence argue that resources, and the concept of overshoot, can be left out of economic calculations. As a resource becomes scarce, they believe market prices will signal that there are rewards to innovation: A new resource or technology will emerge. This debate tinges public life and international relations. It also means that academic discourse, including archaeological and historical research, about overshoot has political connotations.

The concept of overshoot is often traced to Malthus' (1798) *Essay on the Principle of Population*. Malthus believed that whereas agricultural production increases linearly, population tends to grow geometrically. Population will overshoot food supply. Malthus was influenced by Wallace (1761), who argued that progress would undermine itself by filling the world with people. Stimulated by Malthus, Jevons (1866 [1865]) wrote *The Coal Question*, in which he proposed that Britain's industrial development would outrun the coal supply. Ehrlich (1968) brought Malthusian overshoot to public attention in *The Population Bomb*. The concept was systematized by Catton (1980) in *Overshoot: The Revolutionary Basis of Ecological Change*. Catton defines overshoot as follows:

> (v.) to increase in number so much that the habitat's carrying capacity is exceeded by the ecological load, which must in time decrease accordingly; (n.) the condition of having exceeded for the time being the permanent carrying capacity of the habitat (p. 278).

The concept of overshoot clearly depends on that of carrying capacity, which Catton (1980) defines as follows:

> the maximum population of a given species which a particular habitat can support indefinitely (under specified technology and organization, in the case of the human species) (p. 272).

Catton did not seem to realize that this qualifier may make the concept moot for humans. As an ecologist he emphasized population, whereas today's concerns are about both population and consumption.

Collapse, too, is in the wild, as shown by Diamond's (2005) popular book *Collapse: How Societies Choose to Fail or Succeed*. The term collapse has many meanings. Colloquially, collapse means everything from what happened to the Soviet Union to what a worker may do at the end of a hard day. Societies collapse, but then so do bridges, levees, and cardiovascular systems. Academically, the problem is not that definitions vary, but that scholars sometimes discuss the collapses of societies without defining the term. Authors assume that we know what it means, without individual, cultural, or temporal variation.

Where authors fail to define collapse, I use my own definition (Tainter 1988). Diamond (2005) does explicitly define collapse, giving priority to population: "By collapse, I mean a drastic decrease in human population size and/or political/economic/social complexity, over a considerable area, for an extended time" (p. 3).

The interest in Diamond's book suggests that, in the popular imagination, collapse results from overshoot. The belief that previous collapses did result from overshoot (Rees 2004) contributes to the debate over our own future. While recognizing a wider range of writings about resources and collapse, I concentrate on literature pertinent to the contemporary debate. Is there evidence in history or prehistory that population and/or mass consumption overshot carrying capacity and degraded resources, causing societies to collapse?

Although we commonly consider overshoot to be an excess of population and/or consumption relative to natural resources, overshoot may take several forms. A common theme in the study of early states is whether elite demands for taxes and/or labor exceeded the peasants' tolerance or capacity to produce (e.g., Lowe 1985). Agrarian empires may overshoot a sustainable size within the constraints of transportation and communication—a province too far, so to speak (e.g., Tainter 1988). Government costs may grow to the point that they undermine a state's ability to respond to crises (Phillips 1979). More broadly, social and political complexity carry costs, which may increase to the level of becoming unsustainable (Tainter 1988). These topics merit their own reviews.

STUDIES IN OVERSHOOT AND COLLAPSE

In 1931, Cooke proposed that the collapse in the southern Maya lowlands (Classic period ca. A.D. 250–830) was caused by soil erosion and land scarcity, encroachment of grasses, silting of lakes with attendant destruction of water transportation, decline in water supply in dry years, and an increase in mosquito populations along with the introduction of, or increase in, malaria. Thirty years later, Sanders (1962, 1963) conducted an extensive study of lowland ecology and reached similar conclusions. He argued that swidden agriculture in this region leads to soil depletion, weeds, and savanna formation. Between the times when Cooke and Sanders wrote, Betty Meggers (1954) proposed her environmental limitation theory: More productive environments can sustain more complex societies. Cultural complexity is limited by environmental potential, especially for agriculture. Meggers considered tropical rainforests to have insufficient agricultural potential to support much cultural complexity. This raised the problem of the Maya. Her solution was that Maya civilization must have been introduced from elsewhere. By this circuitous reasoning, the Maya overshot the limits of the environment in which they found themselves, and so collapsed.

Culbert (1988) argues that the Maya could not achieve equilibrium because they "were a growth system" (p. 77). Population may have reached 200/km^2. Intensive agriculture could have supported such dense populations, but at a cost of grass invasion, fertility loss, and erosion. Sustaining such a system required high levels of continual labor. Yet labor was diverted into monument construction and warfare, depriving the agricultural sector of necessary maintenance. The resulting environmental degradation ultimately created the conditions for a collapse.

The most widely accepted archaeological cases of overshoot and collapse were proposed by Jacobsen & Adams (1958; Adams 1981). In ancient southern Mesopotamia, intensive irrigation could produce growing prosperity. The Third Dynasty of Ur (ca. 2100 to 2000 B.C.) expanded the irrigation system and encouraged growth of population and settlement. It established a bureaucracy to collect taxes and tribute. Unfortunately, after a few years of overirrigating, saline groundwaters rose and destroyed the basis of agricultural productivity. The political system lost its resource base and was destabilized. Large irrigation systems that required central management were useless once the state could not maintain them.

In the Early Dynastic period (ca. 2900 to 2300 B.C.), crop yields per hectare averaged 2030 liters. Under the Third Dynasty of Ur this declined to 1134 liters. Ur III farmers had to plant an average of 55.1 liters per hectare, double the previous rate. The Third Dynasty of Ur pursued intensification that yielded diminishing returns.

The Third Dynasty of Ur hung on through five kings and then collapsed. The consequences were catastrophic for the population. By 1700 B.C. yields were down to 718 liters per hectare. Of the fields still in production, more than one fourth averaged only about 370 liters per hectare. The labor to farm

Intensification: increase in the inputs to a productive system to obtain higher gross outputs a hectare of land was constant, so for equal efforts cultivators took in harvests about one third the size of harvests in the previous millennium. Soon southern Babylonia was extensively abandoned. By a millennium or so after the Third Dynasty of Ur the number of settlements was down 40%, and the settled area contracted 77%. Population did not rebound to Ur III densities until the first centuries A.D. (Adams 1981).

The fullest development of Mesopotamian agriculture began in the sixth century A.D. Under the Abbasid Caliphate (750–1258) the needs of the state took precedence over peasants' ability to pay. Tax was fixed whatever the yield, so peasants had to cultivate intensively. Taxes were no longer remitted for crop failure. Fifty percent of a harvest was owed under the Caliph Mahdi (775–785), with many supplemental payments. Sometimes taxes were demanded before a harvest, even before the next year's harvest.

As the irrigation system grew in size and complexity, maintenance was no longer within local capacity. Communities depended on the government, which became unstable. Fields again developed problems of salinization. Peasants lacked reserves, and revolts were inevitable. Civil war meant that the hierarchy could not manage the irrigation system. Mesopotamia experienced an unprecedented collapse. In the period from 788 to 915 revenues fell 55%. At the center of the empire, the Sawad region had supplied 50% of the government's revenues. This dropped within a few decades to 10%. Most of this loss occurred between the years 845 and 915. In many areas there were revenue losses of 90% within a lifetime. State control contracted, which diminished any chance to resolve the agricultural problems. By the early tenth century irrigation weirs were limited to the vicinity of Baghdad.

In portions of Mesopotamia the occupied area had shrunk by 94% by the 11th century. Population dropped to the lowest level in five millennia. Urban life was eliminated for centuries in 10,000 square kilometers of Mesopotamia.

Chew (2001) has employed the framework of World Systems Theory to explore ecological degradation between 3000 B.C. and the present. Chew believes that the relations between culture and nature are exploitative and that the outcomes include "civilizational collapse" (p. 1). More broadly, "[i]t is the interplay between the limits of Nature and the trends and dynamics of social, political, and economic relations that ultimately defines the historical tendencies of transformation and evolution of societal systems" (p. 2). Collapse is one kind of societal transformation and also an environmental interlude: "[D]ark ages should be appreciated as periods for the restoration of the ecological balance . . . " (p. 10). Chew believes that during the Bronze Age of Mesopotamia and the Indus Valley, excess consumption produced environmental degradation that led to collapse.

In the Tigris and Euphrates valleys, argues Chew (2001, pp. 20–26), wood requirements for manufacturing, urban consumption, construction, implements, and shipbuilding caused deforestation in northern Mesopotamia. Combined with overgrazing, the result was siltation of irrigation systems. Canals had to be cleaned regularly. When there was unrest, agriculture declined. This decline was exacerbated by the problem of salinization. Overall, core-periphery relations coupled with high consumption to degrade the environment (p. 26). This problem was exacerbated when peripheral elites tried to emulate the lifestyles of core elites.

But human action was not the only factor. Between 3100 and 1200 B.C., Mesopotamia experienced declining precipitation (Chew 2001, pp. 36–39). This decline was combined with increases in evapotranspiration and salinization. Agriculture was intensified nonetheless. In Chew's assessment, the eventual decline in agricultural production brought collapse to southern Mesopotamia and a shift in power to the north.

The Harappan Civilization of the Indus Valley and beyond, asserts Chew (2001), had the same culture-nature relations as southern Mesopotamia (pp. 26–36). Demand for wood, including wood needed to manufacture fired brick, led to "extreme deforestation of the Harappan landscape and its hinterland" (p. 27). Increased aridity between 1800 and 1500 B.C. stressed the Harappans, as did a decline in Mesopotamian imports. Tectonic shifts diverted water courses. By ca. 1700 B.C., "overcultivation, overgrazing, salinity, deforestation, and flooding contributed to the decline of the Harappan urban complex" (p. 35). As southern Mesopotamia declined simultaneously, Harappan exports to the Gulf fell. People migrated to the north and south, until even small trading towns "merged into the countryside" (p. 36).

Chew sees the same processes in the Minoan and Mycenaean collapses (2001, pp. 41–61). Population on Crete increased until ca. 1600 B.C. Large volumes of wood were needed for construction and shipbuilding. Chew argues that deforestation led to erosion and flash flooding. Crete imported wood from Mycenaean Greece and metals from various places, in turn producing value-added exports. The environmental problems on the island weakened Cretan manufacturing, and also the island's political and economic strength, by the 15th century B.C.

Chew postulates that similar transformations occurred in Mycenaean Greece. Cretan wealth was transferred to the mainland in exchange for Mycenaean wood. But the Mycenaeans had to undertake extensive environmental engineering to combat erosion and siltation caused by deforestation. As with Mesopotamia and Harappa, "ceaseless accumulation of capital, core-hinterland relations, urbanization, population growth, deforestation, and intensive land use, ultimately led to severe constraints on the continued expansion of socioeconomic communities of the Aegean" (Chew 2001, p. 56). But other factors were involved: natural catastrophes, changes in climate, external invasion, and perhaps internal rebellions. Mycenaean Greece ultimately had to import food and metals. The Hittite collapse disrupted the trade routes on which Mycenaean imports depended. Notwithstanding such exogenous factors, Chew concludes that "[e]cological scarcity required a downscaling of material and cultural lifestyles" (p. 60).

Chew (2001) continues his narrative into the Roman era. Forest loss was "predominant all over the Roman Empire" (p. 93). During 400 years of silver smelting in Iberia, some 500 million trees were cut. Morocco lost five million hectares of forest in the Roman period. Yet Chew refrains from linking this loss to the Roman collapse. Other scholars are less reticent. Hughes (1975) indicts the Romans for failing to establish harmonious relations among economy, society, and the environment. He believes that this was a major contributor to the Roman collapse. Deforestation led to erosion, the most accessible minerals were mined, lands were overgrazed, and agriculture declined. Food shortages and population decline sapped the Empire's strength. In later writing, Hughes & Thirgood (1982) focused particularly on deforestation as a cause of collapse.

Deforestation has also been implicated in the collapse of Cahokia in the American Midwest. A high volume of wood went into Cahokia's construction and occupation, and land was cleared for planting. Lopinot & Woods (1993) point out that in the Stirling phase (A.D. 1100–1200) wood use came to be increasingly localized and diversified. Intensified local cutting increased runoff and caused floods to become more frequent, severe, and unpredictable. Milner (1990) notes that after 1050 the area experienced rapid soil deposition, and he suggests that it was caused by increased runoff from cutting bluff-zone forests (p. 7). It appears that flood levels were increasing and that this increase reduced the area of bottomland suitable for farming and habitation (p. 7).

The most wide-ranging attempt to draw contemporary lessons from past ecological crises is Diamond's (2005) recent work. Diamond's working model is overshoot, followed by degradation and collapse:

> It has long been suspected that many of those mysterious abandonments were at least partly triggered by ecological problems: people inadvertently destroying the environmental resources on which their societies depended.... Unsustainable practices led to environmental damage.... Consequences for society included food shortages, starvation, wars among too many people fighting over too few resources, and overthrows of governing elites by disillusioned masses.... The risk of such collapses today is now a matter of increasing concern (pp. 6–7).

Diamond realized early on that collapses are more complex than simple overshoot. So he developed a more nuanced framework involving environment, climate, hostile neighbors, friendly trade partners, and societal responses. Yet slips of the pen betray his conviction that environmental deterioration is really to blame. A modern collapse would be "triggered ultimately by scarcity of environmental resources" (Diamond 2005, p. 7). Environmental problems "undermined preindustrial societies" (p. 35). "The Anasazi and Maya were... undone by water problems" (p. 490). "Deforestation was a or *the* major factor in all the collapses of past societies described in this book" (p. 487, emphasis original). Today's Third World trouble spots all suffer from environmental deterioration: "[I]t's the problems of the ancient Maya, Anasazi, and Easter Islanders playing out in the modern world" (p. 516).

Diamond discusses six archaeological cases: Easter Island, Pitcairn Island, Henderson Island, the Anasazi (especially Chaco Canyon) of the U.S. Southwest, the Maya, and Norse Greenland. Some of these are places where subsistence producers could not have survived long-term and are thus unsuitable for deriving broader inferences, let alone lessons for the future. Pitcairn and Henderson islands, for example, are small, remote, and lacking critical resources. They could not be occupied for long without obtaining resources from elsewhere. The failure of attempts to occupy them (which I do not consider collapses) is attributed by Diamond as much to problems plaguing trade partners on Mangareva as to anything done by the occupants of Pitcairn and Henderson islands (pp. 120–35). For comparison, if the resupply of the International Space Station were to fail, future historians would not wonder at the fate of the astronauts, nor draw broader inferences. The cases of Pitcairn and Henderson islands are no more compelling.

Norse Greenland is not an enduring lesson for the same reason: Local resources could not indefinitely support a medieval European society. Add to this the problem of low-frequency events—rare but inevitable adverse climate fluctuations—and it is clear that the Norse settlements were temporary (although the Norse themselves did not recognize this). Although the Norse did put the local environment to use, and thereby degraded it, the great problem they faced was the Little Ice Age (e.g., McGovern 1994). As McGovern noted, the dilemma is not that the Greenland Norse went extinct or left, but that they need not have done either. The continued occupation of the area by the Inuit shows that alternative subsistence strategies and ways of life would have allowed the Norse to survive in Greenland. The Norse failure, argues McGovern, lay in not adopting Inuit ways. Diamond, like McGovern, wonders at the inflexibility of the Norse. Whatever the answer to that conundrum, Norse Greenland is not a simple example of overshoot and collapse. It may illustrate a limited kind of overshoot—overshoot in respect to extreme conditions.

Diamond's (2005, pp. 136–56) account of the Anasazi is a confused muddle, including Chaco Canyon as "the Anasazi capital," a Chaco "mini-empire," and perhaps "provincial capitals" elsewhere (pp. 148–49). Diamond alternates between discussions of

Chaco Canyon, "warfare-related cannibalism" (p. 151), and Long House Valley, with mention of other places that "also underwent collapses, reorganization, or abandonment at various times within the period A.D. 1100–1500" (p. 154). This includes the Mimbres, Mesa Verdeans, Hohokam, Mogollon, and others. One wonders what society, over a period of 400 years, would not experience some process that could be labeled "reorganization." Diamond concludes that Chaco Canyon was abandoned in the twelfth century because of human impact and drought. With centuries of population growth, demands on the environment grew, resources declined, and people lived precariously. The proximate reason was a drought beginning in A.D. 1130, which "pushed Chacoans over the edge" (p. 156). At a lower population density they might have survived it.

Diamond (2005) also considers collapses in the Maya region (pp. 157–77). The Maya damaged their environment, of course. They also fought among themselves over farmland, and, Diamond believes, emphasized "war and erecting monuments rather than . . . solving underlying problems" (p. 160). But climate also played a role. A drought beginning around A.D. 760, and peaking around 800, was "suspiciously associated with the Classic collapse" (p. 174). Diamond concludes that one strand in the Classic Maya collapse was population overshoot. This contributed to deforestation and erosion. More and more people fought over fewer and fewer resources. Elites fiddled while the lowlands burned. Drought then came to a system at the margins (pp. 176–77). Diamond's analysis of the Maya places them with the Anasazi and Norse Greenland: a society that overshot the level of population, consumption, and political complexity that could be sustained under rare, extremely adverse circumstances.

Thus Easter Island is Diamond's best case of overshoot, resource degradation, and collapse. It is not Diamond's case alone. "Easter Island," wrote Kirch (1984), "is an example of a society which—temporarily but brilliantly surpassing its limits—crashed devastatingly" (p. 264). Many have come to regard Easter Island as a metaphor for "Spaceship Earth" (e.g., Flenley & Bahn 2002; Ponting 1991). Easter Island now figures in economic theory. Brandner & Taylor (1998) use the Lotka-Volterra predator-prey model to simulate overshoot and collapse on the island, whereas Dalton & Coats (2000) explore whether markets and a private-property regime could have saved Easter Island. Erickson & Gowdy (2000) use Easter Island to evaluate the consequences of substituting human for natural capital. Easter Island is in the wild.

Islands are useful laboratories for the study of some ecological processes. Cut off to varying degrees from the influence of larger land masses, islands permit ecologists to study such things as invasion, population growth, and extinctions in a more controlled environment than is otherwise possible. For this reason, and because scholars have recently discussed it at length, Easter Island merits review in some detail.

We do not know when Easter Island was first occupied. Flenley & Bahn (2002) cite a date of A.D. 690 ± 130 (p. 77). This is from a large platform, so it cannot record the earliest settlement. Kirch (2000) notes what may have been human forest clearance as early as 1630 ± 130 B.P. (p. 271). Initial settlement sometime in the first few centuries A.D. seems likely.

The settlers found an island that was poor in resources by the standards of Oceania. Its latitude is subtropical, so the climate is cool compared with the rest of Polynesia (Diamond 2005, pp. 83, 86). The ocean is too cold in winter to support a coral reef, so the population of marine fauna is depauperate (McCoy 1979, p. 140). Around the island there are 126 species of fish, compared with 450 species around Hawai'i and 1000 around Fiji. Sea mammals and turtles may never have been abundant (Flenley & Bahn 2002, p. 19). As happened elsewhere in Polynesia, the settlers (and the rats that they introduced) destroyed a diverse community of nesting birds (Steadman 1989, 1995).

An early faunal assemblage from the Ahu Naunau site was analyzed by Steadman et al. (1994). Radiocarbon dates ranged between 660 and 900 B.P. Dolphin was the most common marine species. Bones of the Polynesian rat (introduced for food where Polynesians settled) were second in abundance, and chicken bones were outnumbered by those of native birds. Overall, marine mammals, seabirds, and native land birds were more common than in later prehistoric sites, and bones of fish and chickens were much rarer.

The settlers found a forest dominated by a now-extinct palm that is related to the Chilean wine-palm (Flenley & King 1984). Historically this forest no longer exists. Its disappearance plays a large role in overshoot-and-collapse interpretations of Easter Island and in contemporary imaginings of humanity's future (e.g., Diamond 2005; Flenley & Bahn 2002).

Easter Island is known, of course, for its statues. The cessation of statue carving figures prominently in the idea that Easter Island underwent a collapse. Statues were placed on *ahu*, elongated platforms parallel to the shore. *Ahu* and statues may have been built over a period of 700 years (Kirch 1984, p. 271), starting probably no earlier than A.D. 900 (McCoy 1979, p. 152). Many statues were standing in 1722, when a Dutch ship commanded by Roggeveen made the first recorded European contact. A Spanish ship in 1770 saw much of the island but reported no fallen statues. Only four years later Cook found many statues toppled, and the *ahu* were no longer maintained. Subsequent visits continued to report toppled statues (Flenley & Bahn 2002, p. 150).

Society was hierarchical. The island was unified sufficiently to allow transport of statues from the Rano Raraku quarry to all coasts. The high-ranking Miru clan occupied the western and northern parts of the island. As is common in Polynesia, this group had a monopoly on fishing in deeper waters, where marine mammals and larger fish could be found (Kirch 1984, pp. 270, 272).

Estimates of maximum population, reached most likely in the sixteenth century, range from 7000 to 10,000 (Van Tilburg 1994, p. 52), up to 15,000 (Diamond 2005, p. 91). Population declined to ~2000 by 1722 (Flenley & Bahn 2002, p. 169).

This decline in population qualifies under Diamond's definition as a collapse (2005, p. 3). Archaeologists point to concomitant changes in subsistence, and in the social, political, and economic spheres. In these realms, the essence of collapse is a marked reduction in complexity (Tainter 1988). The complexity of Easter Island society seems to have changed significantly after ~1500. Labor was no longer organized for corporate group projects. Rights to move statues across the island ceased to be exercised, along with the interclan political and/or ceremonial relations that this implies. Island-wide exchange and cooperation declined. The hereditary status system lost influence. Chiefs lost economic power, including the right to surplus production, and a rigid class structure gave way. Warfare became chronic. A warrior class emerged, largely supplanting the hereditary rank system. Late in prehistory the island had no high chief. Instead, the island's descent groups coalesced into opposing factions of the east and west (Flenley & Bahn 2002; Kirch 1984, 2000; McCoy 1979). The loss of organizational capacity makes it appropriate to label this a collapse.

Late in the island's occupation there was conflict over land, and defeated people risked dispossession or enslavement. Many lived in fortified caves. Late middens have a high frequency of fractured and charred human remains, many from juveniles. This is interpreted as cannibalism. In time the statues were overthrown and many were destroyed (McCoy 1979).

The Easter Islanders themselves ascribe the end of statue construction to the outbreak of war. Mulloy (1970) proposed that war resulted from overpopulation, which led to "competition for agricultural land and fishing rights.... With warfare came considerable cultural decline" (p. 5). In 1983, Flenley & King (1984) cored deposits in the three main craters and showed what had long been suspected: The island was once forested. Deforestation occurred since ca. 990 ± 70 B.P. The findings "do not conflict with the hypothesis that the decline of megalithic culture was associated with total deforestation" (p. 50). Mann et al. (2003), undertaking soil analyses, found that the island's primeval soils began to erode severely by A.D. 1200 and that there was forest clearance and erosion everywhere between 1200 and 1650. Deforestation presumably occurred as a result of cutting wood to build canoes, using wood for structural elements, fashioning wood into implements, cooking, cremating, perhaps moving and raising statues, and possibly early swiddening.

Several authors see the deforestation as the start of a cascading process that led to a decline in fishing and farming; changes in farming technology; increases in warfare and insecurity; changes in settlement patterns; population decline; and sociopolitical collapse. Forest depletion, in this view, led to a shortage of wood for canoe construction, and thus to a decline in the consumption of fish (especially deep, pelagic fish) and marine mammals. Soils eroded, and the fertility of forest soils was lost. Crops were exposed to the winds that blow at Easter Island most of the year. Soils lost moisture. Crop yields declined. Springs and streams dried up. People responded with agricultural intensification. Stone dams diverted water, while lithic mulch was employed to retain soil moisture. Stone-lined pits were created to shelter plants from the wind. Rocks were stacked to create windbreaks. Stone chicken houses up to 20 meters long were built to prevent theft. Fires were fueled by herbs and grasses (Ayres 1985; Diamond 2005; Flenley & Bahn 2002; Kirch 1984, 2000; McCoy 1976, 1979).

Easter Island, in this account, is the paradigmatic case of overshoot and collapse, the prototype Spaceship Earth. Diamond (2005) sketches the parallels between Easter Island and our own potential future:

> Polynesian Easter Island was as isolated in the Pacific Ocean as the Earth is today in space.... Earthlings have [no] recourse elsewhere if our troubles increase. Those are the reasons why people see the collapse of Easter Island as a metaphor, a worst-case scenario, for what may lie ahead of us in our own future (p. 119).

EVALUATING OVERSHOOT AND COLLAPSE IN ARCHAEOLOGY

The past is contested in many ways, including whether Malthusian overshoot caused earlier collapses. We can gather more data, refine chronologies, and develop new techniques to reconstruct paleoenvironments, but none of these will resolve the question of whether past collapses provide analogues for possible future ones. Fundamental beliefs and short-term well-being are at stake. Still, one can try to make the debate as rational as possible. To that end, this section evaluates whether those who see overshoot and collapse in past societies have made their case.

Betty Meggers' (1954) environmental limitation theory never found widespread favor and is today rarely discussed. In the Amazon Basin, where Meggers' own work stimulated her theory, we now know that some societies had levels of complexity that her theory predicted would be impossible (e.g., Heckenberger et al. 2003). Meggers did not consider the role of intensification in raising the productivity of land.

Intensification also undercuts the arguments of Cooke (1931) and Sanders (1962, 1963) regarding the consequences of swiddening in the southern Maya Lowlands. We have learned that the southern cities were not supported by low-production swiddening, but by a landscape that managed to give high agricultural yields (e.g., Turner 1974). It is sometimes suggested that this landscape was unsustainable (Culbert 1988), but that question cannot be divorced from the costs and consequences of sustaining urban centers, elites, monumental construction, and interpolity warfare, coupled perhaps with drought. The Maya collapse cannot be explained by the simple overshoot of Cooke and Sanders.

Culbert (1988) believes the dramatic population loss of the Maya collapse suggests agricultural failure. Yet if, as he suggests, agricultural breakdown came from inept decision-making, what ultimately was the problem: population, competition, public construction, mismanagement, disaffection, or all these? If Maya elites had allocated labor better, would scholars today discuss overshoot? Culbert (p. 100) compares the Maya to Mesopotamia and reaches conclusions similar to those of Adams (1981). As with Mesopotamia, if the southern lowland cities collapsed from resource degradation, the main questions involve decision-making rather than procreation. This would mean that the Maya collapse is not an example of Malthusian overpopulation but of elite-driven intensification.

The Third Dynasty of Ur and the Abbasid Caliphate are two of history's best candidates for overshoot, degradation, and collapse. Powell (1985) questions the role of salinization in the Ur III collapse on textual grounds. Whether Powell's objections undermine the case, Ur III is poorly known. The political situation in Iraq has prevented archaeologists from acquiring data to address the questions that the case raises. This consideration applies also to the Abbasid Caliphate, but its collapse was more recent and is better documented. Still, both Mesopotamian cases have limited potential to give a broader understanding of overshoot and collapse. Neither is a Malthusian overshoot, nor an overshoot brought on by excess production for mass markets, today's primary concerns. The agricultural problems in both cases can be traced to elite mismanagement. The critical questions then involve not merely the resource, but the more fundamental question of why rulers would undermine the agricultural regime on which they and their societies depended. We cannot yet answer this question. For the Abbasid Caliphate, though, some pertinent factors can be discussed.

One factor in Abbasid tax policy may have been the need to fund the frequent wars with the Byzantine Empire. Another factor was that the Abbasid Caliphate was a costly regime. Under the Abbasids there was unprecedented urban growth. Baghdad grew to five times the size of tenth-century Constantinople. The capital was moved often, and each time built anew on a grand scale. The Caliph al-Mutasim (833–842) built a new capital at Samarra, 120 kilometers upstream from Baghdad. In 46 years, he and his successors built a city that stretched along the Tigris for 35 km. It would have dwarfed imperial Rome (Hodges & Whitehouse 1983, pp. 151–56).

Overshoot in these cases resulted from the failure of feedback loops. Negative feedback, which dampens excesses in a system's behavior, operates by feeding back information about the system's state or behavior to the control, which responds by altering its own state or behavior. The thermostat is a simple example. The Mesopotamian collapses resulted from a failure of this mechanism. Information about the deteriorating state of agriculture either failed to reach the government or was ignored. As agricultural yields faltered, these regimes demanded yet more production. What should have been a negative feedback system, dampening departures from sustainability, instead became a positive feedback system. The government responded to agricultural problems in a way that made the problems worse. Positive feedback forced the agricultural system, the regime, indeed the complexity of the society as a whole, into a downward spiral toward collapse.

The interpretation of overshoot and collapse in Bronze Age societies advanced by Chew (2001) is empirically weak. Chew provides no data, merely sweeping assertions, on the extent of deforestation or erosion in northern Mesopotamia, the Indus River watershed, Minoan Crete, and Mycenaean

Greece. In southern Greece, erosion does not correspond temporally to the Mycenaean collapse (van Andel et al. 1990). Paleoenvironmental studies may someday provide further data to test Chew's ideas. These cases have not yet been demonstrated to be examples of overshoot.

Deforestation did not cause the Roman collapse. To the end, Roman mints consumed tons of charcoal to produce millions of coins, even in places like North Africa. Builders fired millions of bricks to build the walls of Rome in the 270s. There is no evidence of wood shortages. Indeed, forests were regrowing in the late empire (Tainter 2000a).

It is unlikely that deforestation and flooding caused the collapse of Cahokia. The rulers of Cahokia had demonstrated extraordinary capacity to move people, relocate settlements, mobilize labor, and build massive earthworks (Dalan 1997). If flooding was a threat to Cahokia, the elites could have moved political centers, villages, agricultural production, and population to higher ground a short distance away. They had already accomplished similar feats of organization.

Diamond's inclusion of Pitcairn and Henderson islands, and Norse Greenland, illustrates problems in his conception of collapse. There was no loss of sociopolitical complexity in these places, with a less complex society succeeding. The occupants either died or left. Apparently any place that was abandoned is potentially, to Diamond, a collapse. When he includes Rwanda in his cases, he equates genocide with collapse. There is no logical consistency among these cases. Diamond's approach was seemingly to find cases where (*a*) bad things happened, and (*b*) he could construct a plausible environmental reason. The outcomes, however diverse their nature, are lumped into the category "collapse."

Diamond would have liked to have shown that Chaco Canyon, the Anasazi and other Southwesterners, and the Maya overshot the capacity of their environments, degraded them, and collapsed. In each case, though, he was confronted with the potential roles of climate and other factors. These were not Malthusian overshoots. In Diamond's formulation, these cases may illustrate overshoot in reference to extreme climatic conditions. If the extreme conditions had not occurred, the societies in question might not have collapsed. Sheets (1999) has argued that the ability to withstand extreme events (volcanism in his cases) varies with the complexity of the society. This idea suggests that the many archaeological studies that focus on extreme events such as drought merit their own review.

Easter Island again requires discussion: It is the last candidate for an overshoot resulting from excess population and/or consumption. Diamond (2005) considers Easter Island to be "as close as we can get to a 'pure' ecological collapse" (p. 20). Yet there are many questions about deforestation, deep-sea voyaging, social organization, agriculture, and statue production in the Easter Island collapse.

Diamond (2005) writes, "I have often asked myself, 'What did the Easter Islander who cut down the last palm tree say while he was doing it?'" (p. 114). In fact some scholars suggest that remnants of the island's forest may have survived in the volcano craters into the nineteenth century (Flenley and Bahn 2002, pp. 86–87; Ponting 1991, p. 5), after which the last trees may have been killed by sheep and goats (Flenley & Bahn 2002, p. 160). Seeds of the extinct indigenous palm have been found. These are important: Every seed discovered had been gnawed by the Polynesian rat and could not have germinated (Flenley & Bahn 2002, pp. 160–61). The rats ate these nuts systematically, and the Polynesians ate the rats. Once the Polynesian rat was introduced to Easter Island, the palm forest may have been doomed. Human use merely sped up the inevitable. This could explain why practices of sustainable forest use were not successful, if they were attempted.

The extinct palm was not uniformly useful. Palm wood is porous and would have been undesirable for fashioning canoes. The forest did contain other trees. Even so, "larger trees suitable for canoe construction may have been sparse or lacking" (Kirch 1984, p. 268). Diamond observes that canoes in the historic period were small, flimsy, and leaky. Yet when Roggeveen approached the island in 1722, a canoe came nearly 5 kilometers out to the Dutch ships. The marine zone where the Easter Islanders could obtain delphinids and pelagic fish was well within this radius. Moreover, Easter Islanders claimed that they regularly undertook voyages to the island of Salas-y-Gómez, to the east-northeast, a round-trip of 930 km (Flenley & Bahn 2002, p. 67). The Easter Islanders have a name for this island, and the claim is generally accepted. Salas-y-Gómez is considered Polynesia's easternmost tip. Boats could also have been made of reeds (Van Tilburg 1994, pp. 47–48). These facts challenge Diamond's (2005) claim that "Lack of timber . . . brought to an end . . . the construction of seagoing canoes" (p. 107). Still, unless the early faunal remains from Anakena are an unrepresentative sample, deep-sea catches seem to have declined in later prehistory (Steadman et al. 1994).

Even if lack of wood meant a decline in the availability of sea mammals and large fish, the entire population would not have been equally affected. As is common in Polynesia, the high-ranking Miru clan controlled fishing in deeper, offshore waters. High chiefs had the right to distribute prestigious fish. The Miru could place *tapu* (taboo) on marine resources from May through October, when only nobles could eat larger fish like tuna (Flenley and Bahn 2002, p. 100; Kirch 1984, p. 272). If deforestation did lead to a decline in the catch of larger fish and marine mammals, a large part of the population was only minimally affected.

A decline in agriculture would have been more serious than the loss of marine delicacies. Easter Island undoubtedly experienced erosion. It is a common mistake, though, to assume that erosion is always detrimental. Ancient Egypt and Mesopotamia were sustained by upstream erosion, as other places have been. No research has shown that erosion adversely affected Easter Island agriculture. Removing forest cover would have exposed soils to drying and challenged young plantings. The islanders responded by digging pits, erecting small windbreaks, and employing lithic mulch. Problems of soil fertility could have been addressed by shifting cultivation and/or by use of night soil. In late prehistory, chickens were kept in stone structures with small runs. This was reportedly to deter theft, but it would also have the consequence of making chicken manure easier to collect. The chicken houses have small entrances and passageways (McCoy 1976, pp. 23–26), but not so small that a child could not crawl inside. Chicken manure could have been used to enhance soil fertility.

Nearly the entire surface of Easter Island is arable (Kirch 2000, p. 272), yet in recent centuries only the coast and the interior of Rano Kau crater were intensively cultivated (Flenley & Bahn 2002, pp. 96, 158; McCoy 1976, pp. 78–79, 84). The factor limiting agriculture may have been water (McCoy 1976, p. 142), rather than erosion, wind, or soil fertility. If agricultural productivity declined with deforestation, this could have been compensated for by increasing the area under intensive cultivation. Diamond (2005) cites Cook's 1774 description of the Easter Islanders as "small, lean, timid, and miserable" (p. 109) to support his view that deforestation led to starvation. Yet he ignores Roggeveen's statement in 1722 that the islanders were "well proportioned, generally large in stature, very sturdy with strong muscles, and extremely strong swimmers" (Flenley & Bahn 2002, p. 90). When people face agricultural problems, a common response is to intensify production. This is what the Easter Islanders did (McCoy 1976, pp. 145–146).

Finally there is the mystery of the end of statue production. Some scholars have suggested that production ceased because there was no longer wood to move and erect statues. Others have even suggested that moving the statues caused the deforestation. Perhaps 800 to 1000 statues had been produced, or partly produced, when work ceased (Flenley & Bahn 2002, p. viii). Of these, 324 statues were ultimately erected on 245 *ahu* around the coast (Kirch 2000, p. 272). Some 397 statues remain in the quarry zone of Rano Raraku crater (Van Tilburg 1994, p. 21). About 200 statues lie unfinished within the quarry (Kirch 2000, p. 272), some of which broke during production. Ninety-two statues were abandoned in transport (Van Tilburg 1994, p. 148). From these figures it is clear that statue-making continued at an undiminished rate until production ceased. It is even possible that the rate of production was increasing. When production ceased, it did so abruptly. Had production simply tapered off, we would expect to see fewer unfinished statues and fewer statues in the quarry zone. These figures contradict the interpretation that deforestation caused the end of statue production. It is inconceiveable that new statues would be commissioned at a constant or accelerating pace if the means to transport them was visibly dwindling. Clearly the end of statue production was linked to some factor other than the end of the forest. Even without trees, statues can be dragged over ground lubricated with sweet potatoes (Flenley & Bahn 2002, p. 122). This would take a lot of sweet potatoes, but that resource is more readily replenished than are trees.

In short, Easter Island may not qualify as a case of overshoot and collapse. The Polynesian rat had much to do with the decline of the palm forest, so human use affected the rate of deforestation but not the ultimate outcome. Diamond (2005) acknowledges that Easter Island's deforestation was due in part to its latitude, low rainfall, lack of volcanic ash, lack of dust from Asia, and small size (pp. 115–18). Even without tall trees, Easter Islanders made water craft capable of long voyages and deep-sea fishing. Marine mammals and large fish did decline in the diet, but this decline primarily affected the elite segment of the population. Agriculture was probably compromised by deforestation, but Easter Islanders responded to this in time-honored fashion: They intensified production. Finally, the end of statue production seems to have occurred for reasons other than deforestation.

CONCLUSIONS

When the *ARA* Editorial Committee invited me to address the topic "Archaeology of Overshoot and Collapse," I assumed I could review only part of a voluminous literature. Although I have extensively read the collapse literature (Tainter 1988), I was surprised to realize that the literature has produced few cases that postulate overshoot of population and/or mass consumption, followed by degradation and collapse. Writers today prefer to explain collapse by the occurrence of extreme events (e.g., Binford et al. 1997). Within the small overshoot literature, many of the most ardent proponents are outside archaeology.

Some overshoot interpretations are not credible (environmental limitations), or have been proven wrong (savannah formation in the Maya Lowlands). Others are untested (Bronze Age core-periphery systems) or cannot explain collapse (deforestation in Rome and Cahokia). Other cases advanced as overshoot examples (Anasazi, Maya) prove to be overshoot in regard to extreme conditions. The collapses of the Third Dynasty of Ur and the Abbasid Caliphate seem to be cases of overshoot. Yet the proximate causes were not overpopulation nor mass consumption, but elite mismanagement and a failure of information feedback. The reasons why Mesopotamian elites acted detrimentally in regard to their long-term interests remain to be determined. This question pertains also to the Maya collapse. Easter Island, considered the paradigmatic case of overshoot and collapse, is equivocal. Easter Island may be such a case, but there is contradictory evidence. There does not presently appear to be a confirmed archaeological case of overshoot, resource degradation, and collapse brought on by overpopulation and/or mass consumption. As a personal aside, I consider myself to be conservation-minded, and I currently focus my research on sustainability (e.g., Allen et al. 2003). I realize the political and ideological implications of this conclusion and how it might be used.

With limited space, I briefly raise two questions: Why are there no cases of what Diamond (2005) calls "'pure' ecological collapse" (p. 20)? And does this mean that Spaceship Earth is reprieved? These are rich topics that cannot be explored here. A few words alone are possible, but the fundamental issues are quickly drawn.

The concept of overshoot is teleological, as if humans could set a target for population or consumption. Overshoot denies the human capacity for flexible adjustments, including intensifying production. Overshoot and depletion of megafauna, for example, occurred in many places (e.g., Barnosky et al. 2004) but seem not to have caused a single collapse. It is usually possible to coax more resource production by applying capital and technology, increasing labor, applying energy subsidies, and making production more knowledge-intensive. Irrigation, fertilization, and mechanization are all ways to increase production, as is putting in more hours or tilling more land. Wallace, Malthus, Jevons, and Ehrlich have, so far, been wrong.

As an alternative to intensifying, societies or institutions may simplify so that they are less costly, or people may otherwise reduce consumption. This was the strategy of the Byzantine Empire when it lost its wealthiest provinces in the seventh century A.D. and responded with what may be history's only example of a large, complex society systematically simplifying (Tainter 2000b).

The question for our time is whether intensification can continue indefinitely. Can we forever find some way to escape the Malthusian fate? Neoclassical economists assume that, with incentives and unfettered markets, there will always be new technologies and new resources. Humanity, in this view, need never face a crisis of overpopulation or overconsumption. The contrary view is well known: We must reduce our ecological footprint or eventually collapse. The neoclassical argument is based on faith that markets will always work and denial of diminishing returns to innovation (Rescher 1978). Should we base our future on faith and denial, or on rational planning? That is open for debate. It is a question in the wild.

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LITERATURE CITED

Adams RM. 1981. *Heartland of Cities*. Chicago: Aldine

Allen TFH, Tainter JA, Hoekstra TW. 2003. *Supply-Side Sustainability*. New York: Columbia Univ. Press

Ayres WS. 1985. Easter Island subsistence. *J. Soc. Ocean*. 80:103–24

Barnosky AD, Koch PL, Feranec RS, Wing SL, Shabel AB. 2004. Assessing the causes of late Pleistocene extinctions on the continents. *Science* 306:70–75

Binford MW, Kolata AL, Brenner M, Janusek JW, Seddon MT, et al. 1997. Climate variation and the rise and fall of an Andean civilization. *Quat. Res.* 47:235–48

Brandner JA, Taylor MS. 1998. The simple economics of Easter Island: a Ricardo-Malthus model of renewable resource use. *Am. Econ. Rev*. 88:119–38

Catton WR. 1980. *Overshoot: The Ecological Basis of Revolutionary Change*. Urbana: Univ. Ill. Press

Chew SR. 2001. *World Ecological Degradation: Accumulation, Urbanization, and Deforestation, 3000 B.C.–A.D. 2000*. Walnut Creek, CA: AltaMira

Cooke CW. 1931. Why the Mayan cities of the Peten district, Guatemala, were abandoned. *J. Wash. Acad. Sci*. 21(13):283–87

Culbert TP. 1988. The collapse of Classic Maya civilization. In *The Collapse of Ancient States and Civilizations*, ed. N Yoffee, GL Cowgill, pp. 69–101. Tucson: Univ. Ariz. Press

Dalan RA. 1997. The construction of Mississippian Cahokia. In *Cahokia: Domination and Ideology in the Mississippian World*, ed. TR Pauketat, TE Emerson, pp. 89–102. Lincoln: Univ. Neb. Press

Dalton TR, Coats RM. 2000. Could institutional reform have saved Easter Island? *J. Evol. Econ*. 10:489–505. **http://springerlink.metapress.com/link.asp?ID=2G7POXXAU7L8LA9G**

Diamond JD. 2005. *Collapse: How Societies Choose to Fail or Succeed*. New York: Viking

Ehrlich PR. 1968. *The Population Bomb*. New York: Ballantine

Erickson J, Gowdy JM. 2000. Resource use, institutions, and sustainability: a tale of two Pacific island cultures. *Land Econ*. 76:345–54

Flenley J, Bahn P. 2002. *The Enigmas of Easter Island*. Oxford: Oxford Univ. Press. 2nd ed.

Flenley JR, King SM. 1984. Late Quaternary pollen records from Easter Island. *Nature* 307:47–50

Heckenberger MJ, Kuikuro A, Kuikuro UT, Russell JC, Schmidt M, et al. 2003. Amazonia 1492: pristine forest or cultural parkland? *Science* 301:1710–14

Hodges R, Whitehouse D. 1983. *Mohammed, Charlemagne and the Origins of Europe*. Ithaca, NY: Cornell Univ. Press

Hughes JD. 1975. *Ecology in Ancient Civilizations*. Albuquerque: Univ. N.M. Press

Hughes JD, Thirgood JV. 1982. Deforestation in ancient Greece and Rome: a cause of collapse. *Ecologist* 12:196–208

Jacobsen T, Adams RM. 1958. Salt and silt in ancient Mesopotamian agriculture. *Science* 128:1251–58

Jevons WS. 1866. *The Coal Question*. London: Macmillan. 2nd ed.

Kirch PV. 1984. *The Evolution of the Polynesian Chiefdoms*. Cambridge, UK: Cambridge Univ. Press

Kirch PV. 2000. *On the Road of the Winds: An Archaeological History of the Pacific Islands*. Berkeley: Univ. Calif. Press

Lopinot N, Woods WI. 1993. Wood overexploitation and the collapse of Cahokia. In *Foraging and Farming in the Eastern Woodlands*, ed. CM Scarry, pp. 206–31. Gainesville: Univ. Press Fla.

Lowe JWG. 1985. *The Dynamics of Apocalypse: A Systems Simulation of the Classic Maya Collapse*. Albuquerque: Univ. N.M. Press

McCoy PC. 1976. Easter Island settlement patterns in the late prehistoric and protohistoric periods. *Int. Fund Monum., Easter Island Comm., Bull.* 5. New York: Int. Fund Monum

McCoy PC. 1979. Easter Island. In *The Prehistory of Polynesia*, ed. JD Jennings, pp. 135–66. Cambridge, MA: Harvard Univ. Press

McGovern TH. 1994. Management for extinction in Norse Greenland. In *Historical Ecology: Cultural Knowledge and Changing Landscapes*, ed. CL Crumley, pp. 127–54. Santa Fe, NM: Sch. Am. Res. Press

Malthus TR. 1798. *An Essay on the Principle of Population*. London: J. Johnson

Mann D, Chase J, Edwards J, Beck W, Reanier R, Mass M. 2003. Prehistoric destruction of the primeval soils and vegetation of Rapa Nui (Isla de Pascua, Easter Island). In *Easter Island: Scientific Exploration Into the World's Environmental Problems in Microcosm*, ed. J Loret, JT Tanacredi, pp. 133–53. New York: Kluwer Acad./Plenum

Meggers BJ. 1954. Environmental limitation on the development of culture. *Am. Anthropol.* 56:801–24

Milner G. 1990. The late prehistoric Cahokia cultural system of the Mississippi River Valley: foundations, florescence, and fragmentation. *J. World Prehist.* 4:1–43

Mulloy W. 1970. A speculative reconstruction of techniques of carving, transporting and erecting Easter Island statues. *Arch. Phys. Anthropol. Oceania* 5:1–23

Phillips DA. 1979. The growth and decline of states in Mesoamerica. *J. Steward Anthropol. Soc.* 10:137–59

Ponting C. 1991. *A Green History of the World*. New York: St. Martin's

Powell MA. 1985. Salt, seed, and yields in Sumerian agriculture. A critique of the theory of progressive salinization. *Zeitschrift für Assyriologie und Vorderasiatische Archaeologie* 75:7–38

Rees WE. 2004. Carrying capacity and sustainability: waking Malthus' ghost. In *Introduction to Sustainable Development*, ed. DVJ Bell. In *Encyclopedia of Life Support Systems*. Oxford, UK: EOLSS. **http://www.eolss.net**

Rescher N. 1978. *Scientific Progress: A Philosophical Essay on the Economics of Research in Natural Science*. Pittsburgh: Univ. Pitts. Press

Sanders WT. 1962. Cultural ecology of the Maya Lowlands, part I. *Estudios de Cultura Maya* 2:79–121

Sanders WT. 1963. Cultural ecology of the Maya Lowlands, part II. *Estudios de Cultura Maya* 3:203–41

Sheets PD. 1999. The effects of explosive volcanism on ancient egalitarian, ranked, and stratified societies in Middle America. In *The Angry Earth: Disaster in Anthropological Perspective*, ed. A. Oliver-Smith, SM Hoffman, pp. 36–58. New York: Routledge

Steadman DW. 1989. Extinction of birds in eastern Polynesia: a review of the record, and comparison with other Pacific island groups. *J. Archaeol. Sci.* 16:177–205

Steadman DW. 1995. Prehistoric extinction of Pacific island birds: biodiversity meets Zooarchaeology. *Science* 267:1123–31

Steadman DW, Casanova PV, Ferrando CC. 1994. Stratigraphy, chronology, and cultural context of an early faunal assemblage, Easter Island. *Asian Perspect.* 33:79–96

Tainter JA. 1988. *The Collapse of Complex Societies*. Cambridge, UK: Cambridge Univ. Press.

Tainter JA. 2000a. Global change, history, and sustainability. In *The Way the Wind Blows: Climate, History, and Human Action*, ed. RJ McIntosh, JA Tainter, SK McIntosh, pp. 331–56. New York: Columbia Univ. Press

Tainter JA. 2000b. Problem solving: complexity, history, sustainability. *Popul. Environ.* 22:3–41

Turner BL. 1974. Prehistoric intensive agriculture in the Mayan Lowlands. *Science* 185:118–24

van Andel TH, Zangger E, Demitrack A. 1990. Land use and soil erosion in prehistoric and historical Greece. *J. Field Archaeol.* 17:379–96

Van Tilburg J. 1994. *Easter Island: Archaeology, Ecology and Culture*. London: Br. Mus. Press

Wallace R. 1761. *Various Prospects of Mankind, Nature, and Providence*. London: A. Millar

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