# Mesa Verde Migrations

*New archaeological research and computer simulation suggest why Ancestral Puebloans deserted the northern Southwest United States*

Timothy A. Kohler, Mark D. Varien, Aaron M. Wright and Kristin A. Kuckelman

A village of vacant, sandcastle-like structures fills a shallow cave along a canyon wall. Rectangular windows adorn some houses, and a few structures rise into towers. These famous cliff-dwellings of the Ancestral Pueblo people (Anasazi to the Navajo Diné)—built from blocks of sandstone and timbers using adobe as mortar and plaster—are the culmination in the A.D. 1200s of a series of farming settlements that appeared locally around A.D. 600. This is Mesa Verde, Spanish for "green table," and it lies in southwestern Colorado in the Four Corners region, where Arizona, Colorado, New Mexico and Utah touch. Looking at these ghost towns, visitors wonder: Why were these well-constructed settlements abandoned, and where did the occupants go?

*Timothy A. Kohler is Regent's Professor in the Department of Anthropology at Washington State University and an external professor at the Santa Fe Institute. He earned a Ph.D. in anthropology from the University of Florida, and he studies Neolithic societies around the world and the application of evolutionary logic to understanding change in human societies. Mark D. Varien is Vice President of Programs at the Crow Canyon Archaeological Center in Cortez, Colorado. He holds a Ph.D. in anthropology from Arizona State University, and he studies household community organization, patterns of sedentism and mobility and a variety of other topics. Aaron M. Wright is a doctoral student in anthropology at Washington State University and a preservation fellow at the Center for Desert Archaeology. He studies paleoclimatology, palynology and Southwest archaeology. Kristin A. Kuckelman is Senior Research Archaeologist at the Crow Canyon Archaeological Center. She earned an M.A. in anthropology from the University of Texas at Austin. She studies field methodology, spatial patterning and other topics in the Southwest. Address for Kohler: Department of Anthropology, P.O. Box 644910, Washington State University, Pullman, WA 99164-4910. Internet: tako@wsu.edu*

Early archaeologists often invoked single factors—such as climate change or conflict—as explanations for the depopulation of more than 600 cliff dwellings in Mesa Verde, as well as thousands of home sites and community centers across the Four Corners. More recently, some scholars have posited that better conditions or new types of social organization drew Pueblo people south. We propose, instead, that the emigration resulted from a combination of causes. To explore such a complex hypothesis, we employ computer modeling, using new climatic, ecological and demographic data that synthesize a century of archaeological research.

Over the past century, archaeologists have developed more-precise methods for estimating population sizes and dating the occupations of southwestern agricultural settlements. Tree-ring scientists, for example, build local reference chronologies to date individual beams of wood from archaeological sites. Many species of trees in semi-arid areas put on wider rings in years with relatively greater amounts of precipitation and narrower rings in years of lower precipitation. At an archaeological site, the outermost ring of a section of tree—most commonly left behind as a construction timber—can be dated if it can be uniquely matched with a portion of the local master sequence. As a result, scientists can determine the year when Pueblo people cut that timber for use. Moreover, data on lower-frequency climatic variation—for example, trends that are imperceptible on yearly scales but which accumulate over decades—come from analyses of pollen and an assortment of macrofossils recovered from $^{14}C$-dated sediment cores drawn from lakes and bogs.

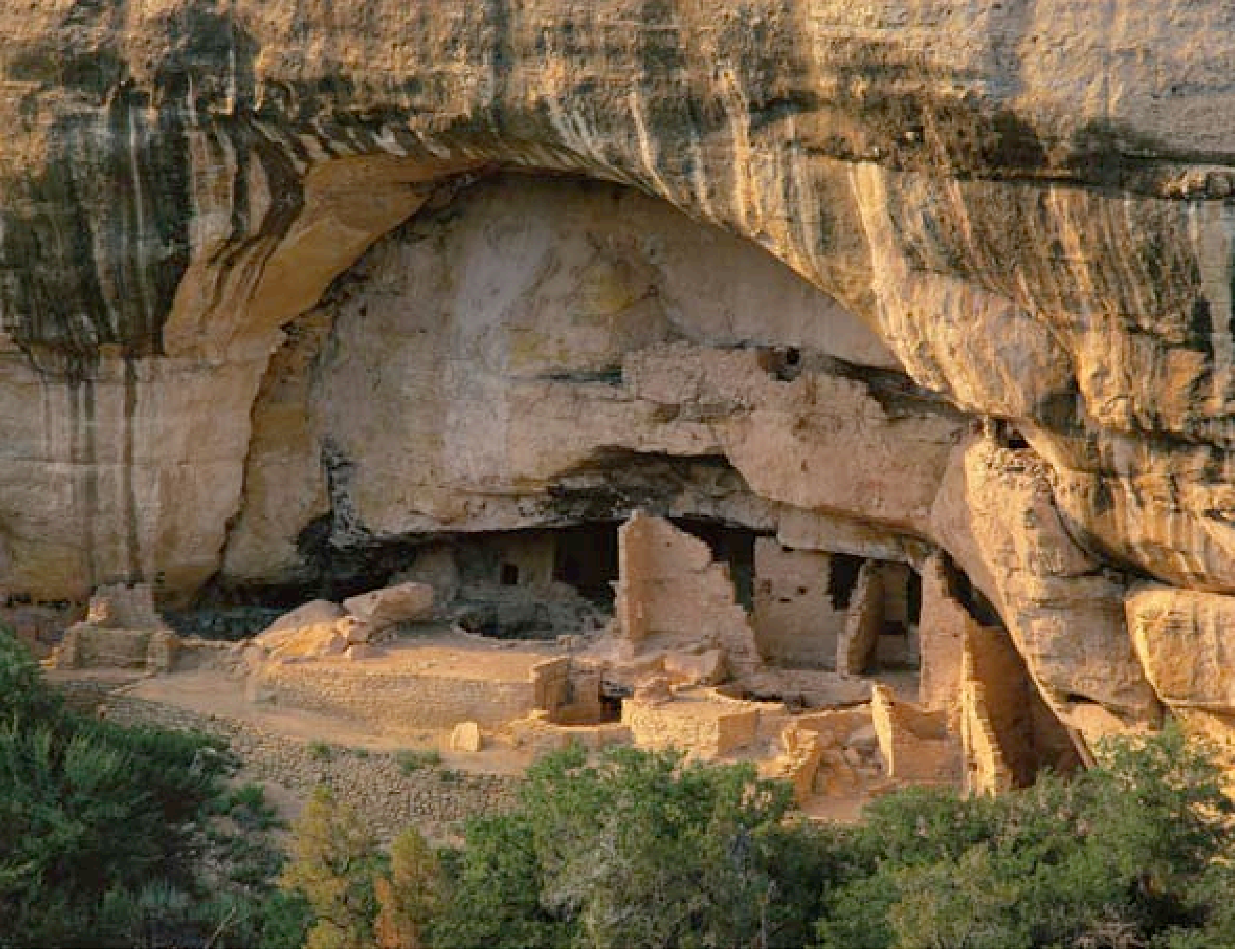
By synthesizing these data and examining them against simulation results we gain new insights into why Ancestral Pueblo people migrated from the Four Corners region. A combination of factors—including climate change, population growth, competition for resources and conflict—seem to have sparked the move.

**Building a Village**

In 2002 we began working with colleagues to start the Village Ecodynamics Project (VEP). This ongoing study explores the interactions between Ancestral Pueblo people and their environment in a portion of the northern San Juan region, which encompasses areas studied by several large archaeological projects. For example, the Dolores Archaeological Project (DAP) undertook very large-scale excavations of early Pueblo villages (A.D. 780 to 920) in this area. The VEP study area is among the most productive farming areas in the Southwest. Consequently, it supported very dense populations throughout most of the period from A.D. 600 to 1300.

Some of the DAP investigators also founded a non-profit research and educational organization in our study area called the Crow Canyon Archaeological Center (CCAC). For the past 25 years, the center has studied the 150 to 1280 period, the final episode of Pueblo occupation in the Mesa Verde area.

The VEP addresses two main puzzles and tries to solve them through a combination of collecting new data, synthesizing existing data and modeling. First is the question of aggregation: Why in some periods did most people live in hamlets—small settlements of one or a few households—whereas at other times most people



George H. H. Huey/Corbis

**Figure 1. Cliff dwellings and other Ancestral Pueblo ruins cover the Four Corners region of the United States, where Arizona, Colorado, New Mexico and Utah touch. As shown here, Oak Tree House in Mesa Verde National Park, Colorado, includes remains of sandstone-and-adobe structures nestled in a shallow cave on a canyon wall. From A.D. 600 until 1280, Pueblo people occupied this region. The question is: Why did they leave?**

aggregated in villages that ranged in size from 9 to more than 100 households? Second, what prompted the two major cycles of population growth and decline, the first between A.D. 600 and 920 and second between 920 and 1280? After the first depopulation, some people remained in the area, but Ancestral Pueblo peoples left the area entirely—as well as the rest of the northern Southwest—by the end of the second cycle.

We believe these phenomena are linked, because intensive aggregation preceded each drop in population. Here we concentrate on what we know about the second episode of depopulation, after which our study area was not repopulated by farming populations until Euroamerican settlers arrived toward the end of the 19th century.

## Producing Population Estimates

To determine if resource limitations stimulated the depopulation in the late-1200s, we needed numerical estimates of resources and people. Scott Ortman of the CCAC led our effort to develop population estimates. He started by dividing the years from 600 to 1280 into 14 periods ranging in length from 20 to 125 years. These are the shortest episodes that we can discriminate using changes in the style of pottery and buildings in our area. Some periods are longer than others because styles changed more slowly in those periods.

As a start, we needed to date sites. We can precisely date excavated sites if they yield wood amenable to tree-ring dating, but the vast majority of the more than 4,000 habitation sites in our area are known only through examination of the modern ground surface. To date such sites, we primarily rely on visible pottery types and architecture, correlating these characteristics with the pottery and architecture from excavated sites that have been precisely dated by tree rings.

Ortman developed an approach to dating sites and estimating their momentary populations that yields useful results even when applied to surveys conducted by many different researchers over more than 50 years. This technique uses the most-precise dating evidence available for each site, which usually comes from pottery counts, observations on types of surface-exposed architecture and dating estimates made by the initial surveyors and recorders. Where fewer


**Figure 2. Timbers found in Ancestral Pueblo structures—such as these protruding beams at the Balcony House cliff dwelling in Mesa Verde National Park—can often be dated to estimate a building's age. The annual precipitation determines the width of tree rings, allowing scientists to match specific sequences of ring thickness to years. If a remaining piece of wood contains enough rings, the outermost ring reveals the year in which the timber was cut.**

data were available, we relied on the fact that in our area sites of similar age tend to cluster together. We dated these data-poor sites by analyzing the pottery at other sites in a seven-kilometer neighborhood and then used this information to determine the most likely period of occupation.

To estimate the human populations of study-area sites, we drew on previous research suggesting that each household occupied a single pitstructure. A pitstructure consists of a subterranean chamber covered with a wooden and earthen superstructure. Some are masonry-lined, and some have specific characteristics that indicate they were also used for ceremonial activities; such structures are commonly called kivas.

We counted pitstructure depressions (or estimated how many were suggested by the extent of rubble and artifacts) to estimate the total number of houses built at each site. Then we determined how many of these houses Pueblo people occupied during each period.

Our team then translated these total-occupied-house estimates for each period into momentary-population estimates for the VEP area. This corrected for variable *uselives* of houses—the typical time that residences were in use before they were abandoned or rebuilt—during the occupation. Uselives were shorter for early pithouses, with their wooden roof supports, than for later masonry structures. As a final step, we extrapolated from the data for recorded sites to the entire study area using a variety of procedures, which resulted in a range of estimates *(see Figure 5).* We prefer our middle estimate, which assumes the surveyed areas are representative of the whole for small settlements and that all the large settlements are known and recorded. We consider the high and low estimates to be informal, approximate confidence

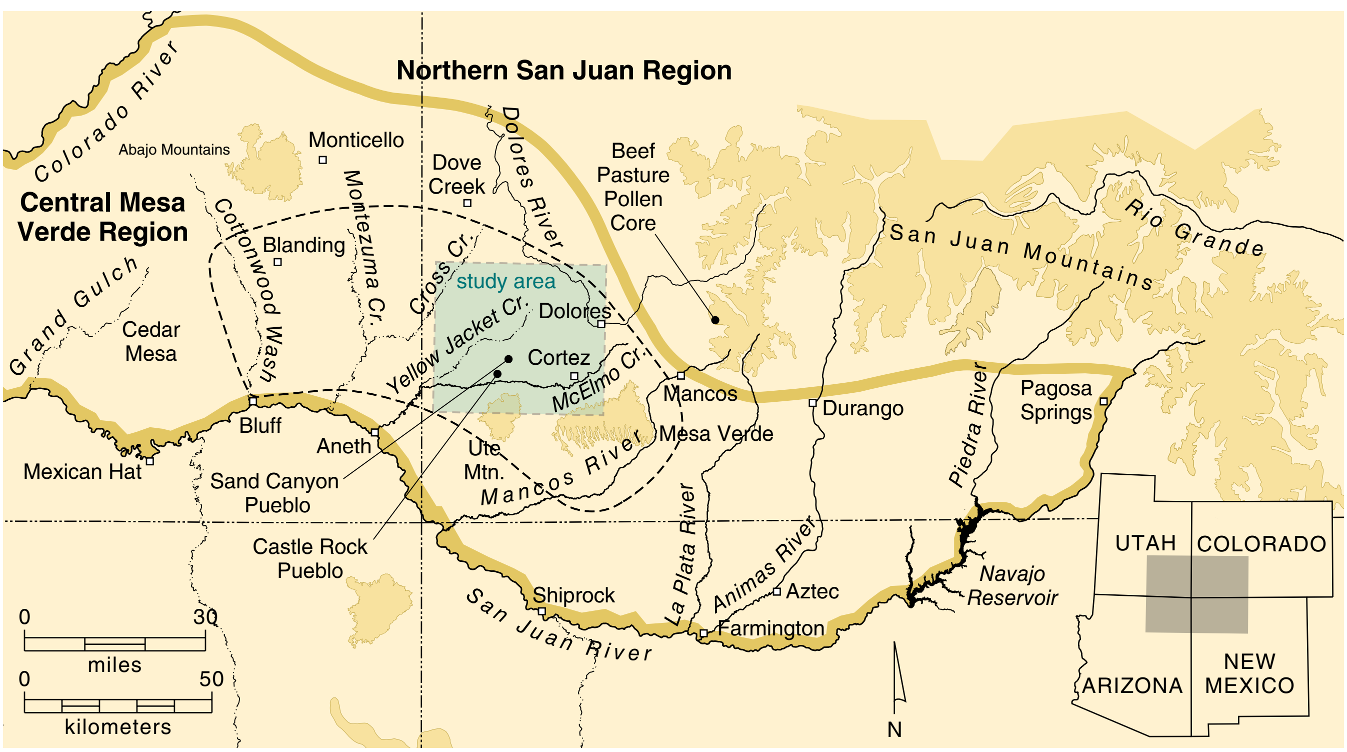



**Figure 3. The Village Ecodynamics Project—run by the authors and their colleagues—explores how Ancestral Pueblo people interacted with their environment in an 1,816-square-kilometer study area *(green)* in southwestern Colorado. This area supported dense populations for most of the A.D. 600–1280 period. Toward the end of that time, for example, Sand Canyon Pueblo grew into a large community of around 500 people.**

intervals around this best estimate. All three reconstructions, however, show the two distinct population cycles. In the VEP, the number of households peaked at about 1,000 in the mid-800s and at about 3,200 in the mid-1200s. Assuming an average of six people per household—based on studies of early historic Pueblo households—these counts suggest populations of about 6,000 and 19,200, respectively.

No other demographic reconstructions of comparable precision exist in the northern Southwest for areas this large. When such reconstructions are built, we suspect they will not look like this one. Current indications are that the VEP area received populations from some nearby regions as those began to shrink in population in response to unfavorable farming conditions in the 12th and 13th centuries. Migration, it seems, was essential to Pueblo peoples' centuries-long occupation of the arid Southwest.

**Modeling Crucial Resources**

With populations of this size in the VEP area, did any resource become limiting? Various lines of evidence on ancient diet—botanical remains, the composition of preserved human feces and ratios of isotopes in human bones—show a high dependence on maize agriculture. Moreover, many archaeologists assume that shortfalls in maize triggered the depopulation. So we modeled potential maize production, as well as other often-overlooked, crucial resources.

We incorporated changes through time and across space in these resource-availability models. Temporal control came from tree-ring data with a resolution of one year. We added spatial information by dividing our 1,816-square-kilometer study area into 200-by-200-meter cells. These techniques provide 700 years of potential availability for several resources—maize, potable water, fuel wood, cottontail rabbits and jackrabbits—at a spatial resolution of 200 meters. We also modeled deer populations, but using 1-square-kilometer cells, because of deer's larger size and home range.

For maize, as an example, our annual estimates for average potential productivity in the VEP area fluctuate widely between about 125 and 400 kilograms per hectare from A.D. 600 to 1300, depending on the climatic conditions during a specific year. As we will see, limitations in our calibration data, on which these estimates are based, make it possible that production was in fact considerably lower than these estimates in some years.

We also needed to know how Pueblo households used these resources. First, not all the potential productivity of these resources could necessarily be realized. Some areas of high productivity for firewood or maize, for example, might have been too remote from domestic water to be practical for human use. People needed all of these resources and likely preferred to live in areas where they co-occurred. More important, we needed to examine the possibility that the use of some of these resources led to their depletion during the Pueblo occupation. For example, zooarchaeologist Jonathan Driver of Simon Fraser University has shown that deer remains declined over time, probably as a result of overhunting.

**Modeling Human Populations**

To combine all this resource information and to assess possible human impact on these resources, we developed an agent-based simulation for the occupation of our study area. In this computer simulation, the agents are households that interact with one another and with their environment.

This program "sets loose" households on our reconstructed study-area landscape. In these virtual worlds, resource distributions change every year because of climate-driven factors. In our current rules for agent behavior, households make approximately optimal decisions about where to live. Taking into account the number of household members and their ages, our agents attempt to locate their resi-

**Figure 4. Pitstructures, or buildings that are partially subterranean, were usually residential in this area. A pitstructure at Duckfoot *(left)* was the central room of a single household. More-elaborate pitstructures, such as a masonry-lined kiva at Castle Rock Pueblo *(right)*, also appear to have had ceremonial uses. To estimate the number of households in the Village Ecodynamics Project study area, the authors counted each pitstructure as evidence of a household. (Photographs courtesy of the Crow Canyon Archaeological Center.)**

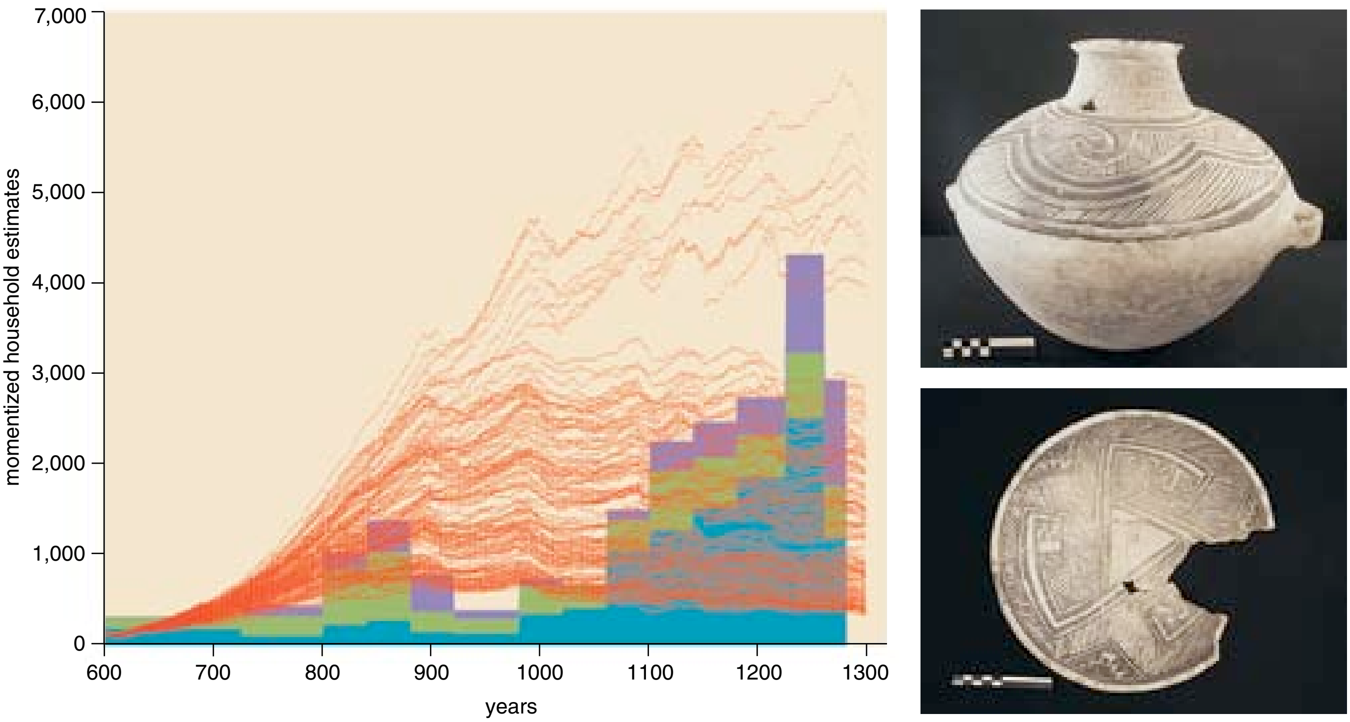



**Figure 5. Estimates of household numbers come from a combination of data-collection and statistical techniques. For example, types of pottery *(right)* and other evidence, such as tree-ring dating, provide age estimates for household sites. The authors produced three estimates *(left; column graphs)* for the number of Ancestral Pueblo households in each period. The middle estimate *(green)* represents the most likely number of households—peaking at about 3,200 in the mid-1200s—and the other estimates *(blue* and *purple)* provide approximate confidence intervals. All three estimates show two cycles of population increase and decline. In addition, the authors developed an agent-based computer simulation that generates estimates of carrying capacity *(red lines)* given specific values for various parameters, such as the amount of protein required by households. (Photographs by David M. Grimes, courtesy of the Crow Canyon Archaeological Center.)**

dences to minimize their caloric costs for obtaining adequate maize harvests, protein through hunting, domestic water and fuel wood. Working with computer scientists Robert Reynolds of Wayne State University and Ziad Kobti of the University of Windsor, we added to some simulations the effects of exchanging protein and maize between households.

So far, our simulations have produced two startling findings. One is the relative ease with which populations—even ones as small as those in the first population peak—deplete deer on this landscape. We see this effect in all of our simulations, even under a variety of assumptions about how many grams of meat protein people seek, how far from home they are willing or able to hunt, the priority they give to hunting prospects in their decisions on where to settle, and the effects of too little protein on their birth and death rates. Sixteen runs of this simulation with varied parameters all result in depletion of deer to the lowest levels allowed by the simulation, which is 1,000 deer in the study area.

Equally surprising to us is the finding that our simulations rarely generate the number of human households we see on this landscape during the population peak in the 1200s. Only in those cases where all the parameters—such as productivity of the landscape, the presence and types of exchanges, the severity of soil depletion and so on—are set to allow the largest human population sizes do we begin to generate the numbers of households that we believe actually occupied this landscape.

At first we worried that underestimates of population resulted from some error in our simulation's logic. Although we had carefully entered numbers gleaned from ethnographic reports on the amounts of time people spend on domestic tasks (such as planting and weeding fields, gathering water and fuel wood), caloric expenditures for hunting at various distances from home, basic metabolic rates and so forth, we omitted turkey domestication. Models necessarily omit details believed to be unimportant—but deciding which really are unimportant can be a matter of trial and error. In our simulations, populations became protein limited before reaching levels that we estimated from pitstructures and other evidence. We now believe that protein deficiency could have been overcome by raising turkeys.

We therefore suspect that populations as large as those seen in our study area in the 12th and 13th centuries would have been possible only with turkey domestication. This coincides with Driver's finding that turkey bones became much more prevalent as deer bones declined and virtually disappeared from many sites in the VEP area after A.D. 1150. We plan to add turkey farming to our simulations as a way for households to produce crucial protein from less-scarce resources.

Pueblo people apparently used maize to feed both themselves and their turkeys. As a result, Pueblo populations became reliant on maize for its carbohydrate calories and to feed their main protein source. Consequently, shortfalls in maize in the 1200s surely triggered serious nutritional deficiencies.

## Maize Production and Pollen

To correlate climate with potential maize production, we used production data on maize and beans from southwestern Colorado between 1930 and

1960 together with annual data on temperature and precipitation. These production data were corrected for the differences between Puebloan and modern farming technologies and the different varieties of maize in use. But there were many years from 600 to 1300 that were colder than any years during the 1930–1960 interval, and it is likely that we overestimate maize production in these years.

Moreover, we needed to put these annual weather measurements and the associated production estimates into a longer-term climatic context. To investigate the low-frequency component of climate change in our region, one of us (Wright) developed measures using pollen to estimate changes in winter precipitation and annual temperature. A core of peaty sediments from a high-elevation fen—a type of wetland—provided material dated from 100 B.C. to A.D. 2005. We can estimate low-frequency changes in winter precipitation from the relative deposition rates of pollen from sedges—grass- and rush-like plants of the family Cyperaceae—and from the weedy families Chenopodiaceae and Amaranthaceae. Sedges indicate wet and waterlogged sediments whereas Chenopodiaceae and Amaranthaceae species indicate disturbed environments, such as meadows experiencing low rates of winter precipitation. Moreover, Wright detected long-term warming conditions by documenting increased deposition rates for Ponderosa-pine pollen relative to that of Engelmann spruce. For these two ratios in the period from 500 to 1400, we calculated *z*-scores, which provide a distribution with a mean of zero and a standard deviation of 1.

We are reasonably confident that when both of these *z*-scores are strongly negative—meaning drier winter conditions as indicated by the ratio of sedges to Chenopodiaceae and Amaranthaceae, and cooler conditions suggested by the ratio of the two evergreens—our annual reconstruction overestimates production for maize. Similarly, we might underestimate productivity when both *z*-scores are strongly positive.

About A.D. 900, for example, strongly negative *z*-scores for both pollen ratios coincide with declines in our population estimates. Presumably, the most productive portions of this area became cold enough in the 900s to make maize farming risky. Dry winters compounded this problem.

In fact, droughts occurred at various times during the Pueblo habitation of the Four Corners region. Some could even be called megadroughts. These might not have been more severe than droughts of the modern period, such as the Dust Bowl years, but they lasted much longer, sometimes for sev-

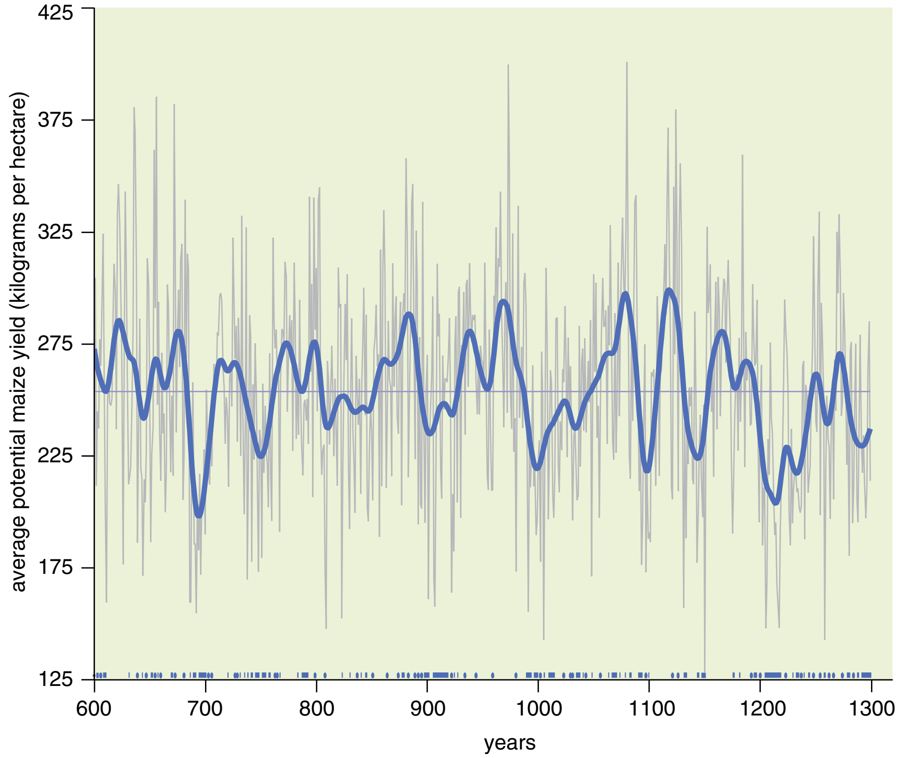



**Figure 6. Maize was central to the Puebloan diet throughout the A.D. 600–1300 period. Using tree rings to reconstruct precipitation and temperature, calibrated against production data for maize and beans in southwestern Colorado between 1930 and 1960, the authors computed how much maize the Pueblo people might have produced prehistorically. Annual estimates *(gray)* fluctuate widely. When smoothed *(blue)*, trends on the decadal scale are more clearly visible. Along the *x* axis, blue dots or bars represent cold years in which the authors possibly overestimate production. This reconstruction also does not take into account possible decreases in production due to soil nutrient depletion or erosion.**

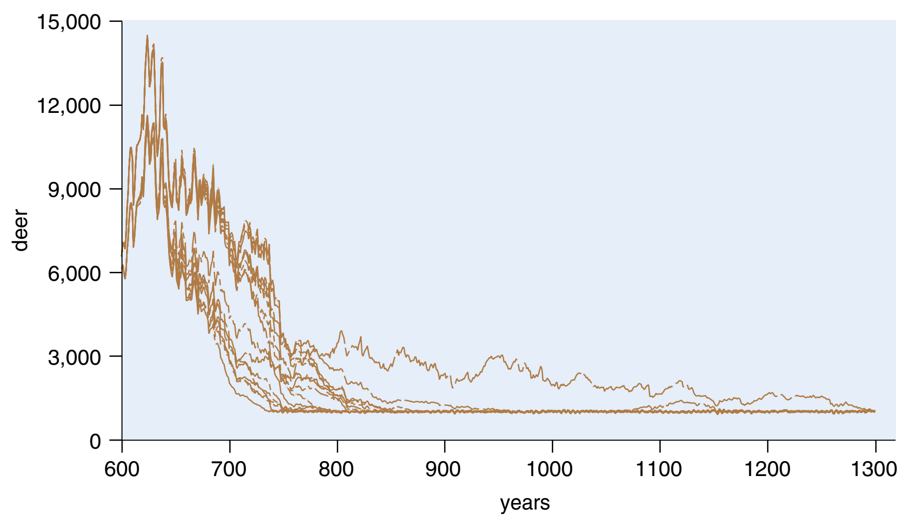



**Figure 7. Deer populations in the study area, determined with the authors' agent-based computer simulation, show that even small populations of Pueblo people likely reduced the herds to the lower limit allowed in the program, 1,000 deer. Here, 16 runs of the simulation with various assumptions show potential peak populations of more than 14,000 deer. When abundant, deer were the lowest-cost protein source available to Pueblo peoples. Their depletion appears to have made turkey domestication economically attractive.**

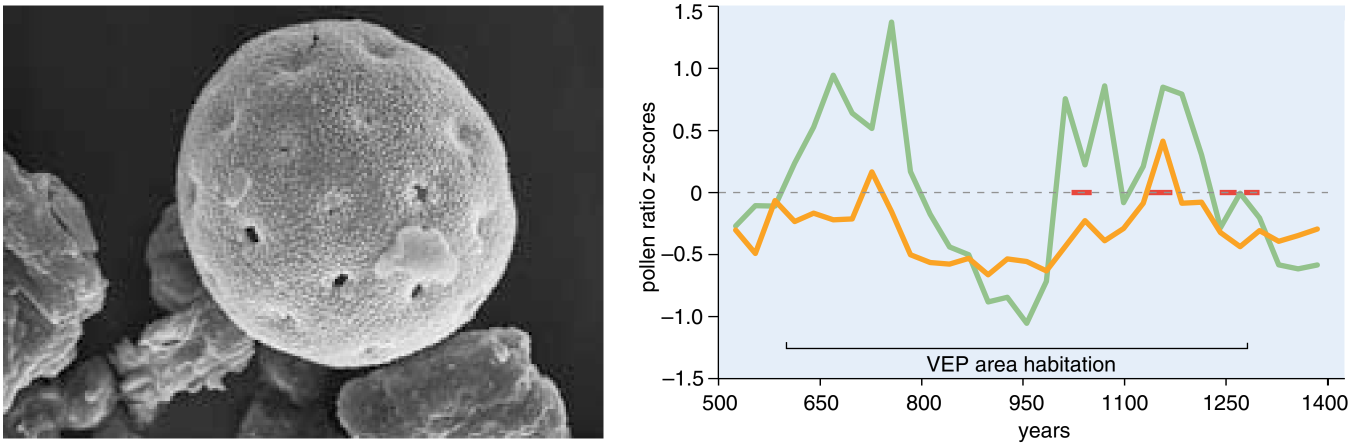



**Figure 8. Pollen was counted in a core *(see Figure 3)* to reconstruct low-frequency climate trends. Relative deposition rates of pollen *(right)* from sedges and from the weedy families Chenopodiaceae and Amaranthaceae *(orange)*—such as the Cheno-Am grain in this photomicrograph *(left)*—indicate wetter winters when *z*-scores are higher, whereas higher *z*-scores for the deposition rates of Ponderosa pine pollen relative to that of spruce *(green)* suggest warmer conditions. When both scores are positive, the authors suspect that the reconstruction in Figure 6 underestimates potential maize productivity, and it likely overestimates productivity when both scores are negative. Extremely negative *z*-scores for both ratios in the 900s—suggesting reduced maize-production potential—coincide with local declines in Pueblo populations. Bars *(red)* indicate "megadroughts"—long-term droughts reconstructed from tree rings—that afflicted large portions of the Southwest. (Photomicrograph courtesy of John G. Jones of Washington State University.)**

eral decades, and their effects were broadly felt throughout the western United States. In 1929 A. E. Douglass of the University of Arizona's Steward Observatory discovered one of these, which he called the Great Drought, which lasted from 1276 to 1299.

### Aggregating at the End

Relatively high elevation and fertile soils probably made the VEP study area more immune to drought than many surrounding areas. In fact, the VEP's population grew during or after some of the megadroughts, probably due in part to immigration.

Although immigrants continued to move into the VEP study area in the 13th century, and the area's population peaked between 1225 and 1260, this was a time of stress. Climatic deterioration and population increase were accompanied by the construction of numerous large, densely packed settlements in the northern San Juan region. Around 1250, coincident with a trough in our maize-production estimates, Pueblo people in the VEP study area constructed large villages around canyon-head springs.

For example, Sand Canyon Pueblo (SCP), one of the largest community centers in our study area, was founded about A.D. 1250. This village encircled a canyon-head spring and housed some 500 people at its peak. Like many of the centers built at this time, it was mostly enclosed by a stone wall, and several two-story towers constructed against its exterior face probably provided additional security. Between 1984 and 1993, Crow Canyon archaeologists investigated about 5 percent of this site, excavating at least part of 111 structures. Food remains indicate that residents were heavily dependent on maize, turkey and cottontail rabbits, and osteological analyses reveal that the villagers were generally well nourished and healthy during most of the village occupation.

Nonetheless, studies of refuse accumulated in this pueblo's final years suggest trouble. Among the samples of refuse analyzed for plant material, maize remains were found in 44 percent during the height of the SCP but in only 10 percent near the end. At the same time, a diverse selection of wild-plant foods—some of which appear to be starvation foods—increased in

**Figure 9. Castle Rock Pueblo, constructed around and atop an imposing butte, was one of the last Ancestral Pueblo communities in the northern Southwest. Evidence of conflict indicates that warfare played a role in the final depopulation of the area. The authors argue that a combination of dwindling resources and conflict forced Ancestral Pueblo people to migrate from the Four Corners region and to create new communities to the south. (Photograph courtesy of the Crow Canyon Archaeological Center.)**

frequency from 54 to 80 percent of the samples. Among the food bones, turkey decreased from 55 to 14 percent, compared with a marked increase in the frequency of wild-animal bones. These data suggest that, near the end of the pueblo's occupation, Sand Canyon villagers experienced substantial subsistence stress and adopted a largely hunting-and-gathering strategy to compensate for crop failure.

When the SCP community was in its final throes, probably within a few years of the latest tree-ring date of 1277, 25–75 percent of the villagers had already left, and signs of desperation are evident. Refuse was being deposited in once-important civic or ceremonial structures, such as the great kiva. Moreover, excavators found 23 complete or fairly complete human bodies, as well as scattered bones from at least 11 other individuals, indicating that at least 34 people died at or near the end of the village occupation. None of these bodies was formally buried, and at least eight exhibit direct evidence of violent death.

The skeletal trauma and abundant additional contextual and analytic data pertaining to the human remains clearly indicate that the village was attacked. Other inhabitants of the Four Corners region or Pueblo people from an adjacent region might have been the aggressors, because many local projectile points were found at the site. However, we can't rule out the possibility that the attackers were from the Fremont or Virgin areas to the west, because a few projectile points characteristic of those regions were also found. Some of the defenders were scalped, and the condition and characteristics of some disarticulated human bones suggest that there was anthropophagy.

Violent death and anthropophagy are even more evident at Castle Rock Pueblo, a smaller contemporaneous village 10 kilometers to the south. At about the same time as the attack on SCP, unknown assailants killed at least 41 of the 75–150 residents at Castle Rock, terminating its occupation. It is likely that, had we excavated more of this site, we would have discovered the remains of many more villagers who also perished in the attack. We do not know the frequency of such violent events across the northern Southwest during the chaos of regional depopulation, but it is clear that conflict contributed to it. This conflict exacerbated climatically induced subsistence stress by forcing residents into highly aggregated settlements. These large settlements provided increased security, but packing more people into fewer sites made it difficult to use the region's dwindling resources efficiently.

Thus there is no single, simple cause for this depopulation. Instead, it was a cascade of events that included climate-induced immigration from peripheral regions resulting in overpopulation of the VEP study area, in turn generating resource depletion that was exacerbated by a decline in maize productivity that affected both carbohydrate and protein intakes. These changes provoked conflict, which in turn induced more scarcity. As these societies began to lose population, they also functioned less successfully and became vulnerable to aggression. In the end, violence and famine provided potent motives for departure.

Evidence suggests that the survivors of these final events moved south, following kin who had pioneered migration streams in that direction at least a century earlier. Osteological similarities between the VEP's final populations and later Pueblo peoples—and some oral traditions among the modern Pueblos—suggest that they joined related groups to the south and east, mostly along the northern Rio Grande of New Mexico. Nevertheless, the societies that they joined and helped build there were substantially different from those they left behind. Perhaps this suggests the degree of trauma that the Pueblo people experienced toward the end in the Four Corners region, and why they never returned to farm the Mesa Verde.

## Bibliography


Benson, L. V., M. S. Berry, E. A. Jolie, J. D. Spangler, D. W. Stahle and E. M. Hattori. 2007. Possible impacts of early-11th-, middle- 12th-, and late-13th-century droughts on western Native Americans and the Mississippian Cahokians. *Quaternary Science Reviews* 26:336–350.

Cole, S. 2006. *Population Dynamics and Sociopolitical Instability in the Central Mesa Verde Region, A.D. 600-1280*. Unpublished M.A. thesis, Department of Anthropology, Washington State University, Pullman.

Cowan, J. A., T. A. Kohler, C. D. Johnson and K. D. Cooper. *In prep.* Supply, demand, return rates, and resource depression: Hunting in the village ecodynamics world. In *Archaeological Simulation: Into the 21st Century*, ed. André Costopoulos.

Herweijer, C., R. Seager, E. R. Cook and J. Emile-Geay. 2007. North American droughts of the last millennium from a gridded network of tree-ring data. *Journal of Climate* 20:1353–1376.

Johnson, C. D. 2006. Critical Natural Resources in the Mesa Verde Region, A.D. 600–1300: Distribution, Use, and Influence on Puebloan Settlement. Unpublished Ph.D. dissertation, Department of Anthropology, Washington State University, Pullman.

Kobti, Z., R. Reynolds and T. A. Kohler. 2006. The emergence of social network hierarchy using cultural algorithms. *International Journal on Artificial Intelligence Tools* 15:963–978.

Kohler, T. A., and S. van der Leeuw (eds). 2007. *The Model-Based Archaeology of Socionatural Systems*. Santa Fe: School of Advanced Research Press.

Kuckelman, K. A. *In press*. The depopulation of Sand Canyon Pueblo, a large ancestral Pueblo village in Southwestern Colorado. *American Antiquity*.

Kuckelman, K. A., R. R. Lightfoot and D. L. Martin. 2002. The bioarchaeology and taphonomy of violence at Castle Rock and Sand Canyon Pueblos, Southwestern Colorado. *American Antiquity* 67:486–513.

Lipe, W. D. 1995. The depopulation of the Northern San Juan: conditions in the turbulent 1200s. *Journal of Anthropological Archaeology* 14:143–169.

Ortman, S. G., M. D. Varien and T. L. Gripp. 2007. Empirical Bayesian methods for archaeological survey data: An application from the Mesa Verde region. *American Antiquity* 72:241–272.

Varien, M. D., and R. Wilshusen (eds). 2002. *Seeking the Center Place: Archaeology and Ancient Communities in the Mesa Verde Region*. Salt Lake City: University of Utah Press.

Varien, M. D., S. G. Ortman, T. A. Kohler, D. M. Glowacki and C. D. Johnson. 2007. Historical ecology in the Mesa Verde region: Results from the Village Ecodynamics Project. *American Antiquity* 72:273–299.

Wright, A. M. 2006. *A Low-Frequency Paleoclimatic Reconstruction from the La Plata Mountains, Colorado and Its Implications for Agricultural Productivity in the Mesa Verde Region*. Unpublished M.A. thesis, Department of Anthropology, Washington State University, Pullman.


For relevant Web links, consult this issue of *American Scientist Online:*

http://www.americanscientist.org/IssueTOC/issue/1061