A Scale Model of Seven Hundred Years of Farming Settlements in Southwestern Colorado

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“The history of life,” writes evolutionary biologist Leo Buss, “is a history of the elaboration of new self-replicating entities by the self-replicating entities contained within them. Self-replicating molecules created self-replicating complexes, such complexes created (or became incorporated into) cells, cells obtained organelles, and cellular complexes gave rise to multicellular individuals. At each transition—at each stage in the history of life in which a new self-replicating unit arose—the rules regarding the operation of natural selection changed utterly” (1987:viii).

In this chapter, we review the demographic and settlement history of a portion of the central Mesa Verde region of southwestern Colorado (USA) in the context of three models: the “Neolithic Demographic Transition” of Jean-Pierre Bocquet-Appel (2002), a model developed by ecologist Peter Turchin that links sociopolitical instability with population size, and the rank-size relationship developed by Harvard linguist George Kingsley Zipf. These are not competing models but different windows into ancient Pueblo society, and we learn a little from each about life in the early farming villages found in the central Mesa Verde region between AD 600 and 1300.

During these seven hundred years, villages emerged as novel evolutionary units from households and the kin groups in which households were embedded. Villages were facultative in the Pueblo I period but obligate by the last half of the Pueblo II period. We use the term village to denote not just a settlement of a certain size (say, some ten households or more) but, importantly, a size that is large enough that the households would not consider themselves to be closely related to all the other households. Pueblo I village life in southwestern Colorado was locally, and probably regionally, novel in both its demographic and
its social scale, since we assume that the smaller and earlier “hamlets” comprised closely related households.

Here we describe the emergence and dissolution of agricultural villages of Type 1, as Matthew Bandy uses this term in chapter 2 (this volume). Villages of this type appeared in two waves in the portion of southwestern Colorado we discuss. As in the case discussed by Nigel Goring-Morris and Anna Belfer-Cohen for the Near East (chapter 4, this volume), the earliest villages in southwestern Colorado, which appear during the late Pueblo I period between about AD 760 and 890, caused considerable local deforestation (Kohler and Matthews 1988) and were episodic in their success, usually not lasting more than a couple of generations (see also Wilshusen and Potter, chapter 9, this volume). There appears to have been competition and some violence among the communities focused on these villages, but it was relatively slight in comparison to later levels of violence in our area (Cole 2007). We have evidence that these early villages were at least partially successful in solving fundamental land-tenure problems necessary for village life (Kohler 1992). Early villages coincided with (or very shortly followed on) the first significant increases in regional population growth and degree of sedentism (Varien and Kohler 2009); in a sense, they completed the Neolithic package in the northern U.S. Southwest. They were able to grow and resist pressure for fissioning so long as they provided efficient loci for exchange among unrelated households (Kohler and Van West 1996). Their ability to do this was determined in part by climatic factors that dramatically affected the fortunes of these dry farmers.

Life appears to have been organized differently in the second wave of village expansion in our area, which lasted for about two centuries, between AD 1080 and 1280. These Pueblo II and III villages were less likely to collapse under unfavorable climatic conditions, less likely to deforest their countrysides, and more likely to remain in place for several generations (Varien 1999; Varien et al. 2007). Their ability to resist fissioning under climatic downturns that would have caused the earlier Pueblo I villages to dissolve implies that they had developed more—or more effective—institutions than were available to the Pueblo I societies. Quite likely, such institutions helped prevent fissioning by cross-cutting kin groups, as did the sodalities (e.g., medicine and hunting societies) and moieties known in historic and contemporary Pueblo societies (Kroeber 1917).
Much larger local populations were sustained during this second wave of village life in the portions of southwestern Colorado that we will be discussing, but the level of violence was also, in general, much higher (Kuckelman 2002; Kuckelman, Lightfoot, and Martin 2000; Cole 2007). Violence in this period appears to have been more regional and interregional in scale (Kohler and Turner 2006), rather than among nearby communities as we infer for the Pueblo I case. Ultimately, however, these later villages too were also susceptible to a cascade of misfortunes, including climatic deterioration, human impact on their environment abetted by significant immigration, and violence. This confluence of circumstances resulted in dramatic emigration that left the region entirely depopulated by the end of the thirteenth century (for a discussion, see Kohler, Varien et al. 2008).

The Neolithic Demographic Transition

Jean-Pierre Bocquet-Appel has argued that a demographic transition (see chapters 1 and 2, this volume) accompanied and helped make possible the spread of the Neolithic mode of production through Europe (Bocquet-Appel 2002) and North America (Bocquet-Appel and Naji 2006). Unlike the demographic transition that accompanied the Industrial Revolution, which was triggered by a decrease in mortality and ended with a decrease in fertility, the Neolithic Demographic Transition (NDT) began with increased fertility and ended with increased mortality.

In Europe, a highly productive package of domesticates and tools—including agriculture, domesticated animals, and pottery for cooking and storage—spread rapidly across the continent from east to west, through zones of relatively similar biota and climate. This shift in the mode of production was accompanied by an abrupt population increase, measured by increasing proportions of juveniles (ages five through nineteen) following the local onset of the Neolithic. This is interpreted as an increase in fertility, likely due to decreased birth spacing that accompanied increased sedentism (Bocquet-Appel 2002:646–47; Bocquet-Appel and Naji 2006:349). Fertility increases among sedentary agricultural populations were likely due to a younger age of weaning, which may have been promoted by the appearance of new baby foods, by perceived
economic advantages of more children in Neolithic economies (Hassan 1981:222–24), by the decreased costs of carrying infants in sedentary societies, and by the need to resolve scheduling conflicts with women’s labor (Crown and Wills 1995). Whatever the causes of this increase in fertility, it appears to have been eventually offset by an increase in mortality, possibly attributable to new pathogens carried by livestock and introduced into human populations as they began to live in close proximity to animals in settings that were more aggregated (Bocquet-Appel 2002:647; Bocquet-Appel and Naji 2006:349). Together these transitions in fertility and mortality are called the NDT.

An NDT has also been documented for North America (Bocquet-Appel and Naji 2006) and has recently been examined in more detail for the American Southwest (Kohler, Glaude et al. 2008). Maize began to be grown in what is today southern and central Arizona and New Mexico somewhat before 2000 BC (Matson 2003, 2005). Major clusters of Basketmaker II settlement (early agricultural, mostly prepottery) are known throughout the northern San Juan region, including our area of study for this chapter (fig. 3.1). These clusters include habitations from the Cedar

Figure 3.1. The Village Ecodynamics Project study area in the northern U.S. Southwest.
Mesa area in southeastern Utah (Matson 1991, 2003:344, 2006:159), where abundant evidence—including coprolite analysis, midden analysis, and stable carbon isotope data on human skeletal material—shows that the diet of these individuals was heavily dependent on maize by at least 400 BC (Aasen 1984; Androy 2003; Chisholm and Matson 1994; Matson 1991:90–99, 2003:344, 2006:159; Matson and Chisholm 1991). In the Durango area of southwestern Colorado, these early agricultural habitations appear by about 350 BC (Charles and Cole 2006:173–77; Lister 1997; Robinson and Cameron 1991), and in the upper San Juan River drainage in the vicinity of Navajo Reservoir, by about 400 BC as a part of what has recently been reclassified as the Archuleta phase (Charles and Cole 2006:172, 177–78; Charles, Sesler, and Hovezak 2006:231–32; Eddy 1966). To the southwest, in the Kayenta region, Basketmaker II site clusters have been identified in the Black Mesa, Glen Canyon, and Kanab areas (Charles and Cole 2006:182–86). Joan Coltrain and colleagues have recently conducted collagen stable carbon isotope analyses paired with radioisotope dating of a large sample of Basketmaker II individuals, demonstrating maize to have been an important component of the diet by about 400 BC (Coltrain, Janetski, and Carlyle 2007).

In our specific study area in southwestern Colorado, which constitutes a portion of the central Mesa Verde region of the northern San Juan, substantial populations practicing maize agriculture do not appear much before about AD 600 (Varien et al. 2007). The greater than 2,500-year lag in its spread to our relatively high, northern area was likely limited by many factors, including the possibly slow adaptation of maize to shorter growing seasons and generally higher elevations, the development of dry-farming strategies after AD 200 (Matson 1991), the relatively late arrival (sometime between AD 500 and 700) of the productive maíz de ocho that also seems to have been well suited to dry farming (Adams 1994; Doolittle and Mabry 2006), and the regular appearance of other cultigens such as beans by about AD 600. Another limiting factor may have been short growing seasons during most of the first six centuries of the first millennium AD, in conjunction with generally low summer precipitation (Wright 2006). Wright’s temperature reconstruction, based on pollen ratios from Beef Pasture in southwestern Colorado, shows cold temperatures about 100 BC, approximately as cold during the AD 900s, with generally increasing temperatures until...
about AD 600, when temperatures increase rapidly. The exception to this gradual warming trend is a brief warm period in the early AD 300s, with colder conditions returning by about AD 400.

To examine the NDT in the southwestern United States, Timothy Kohler and Matthew Glaude (2008; Kohler, Glaude et al. 2008) graphed burial data from this area using the conventions established by Bocquet-Appel (2002). We found that the first appearance of maize had relatively little effect on population growth. Only considerably later, as other changes accumulated in the mode of production, did growth rates begin to rise. As with the northern San Juan, these changes include the diversification and intensification of maize farming, the development of dry farming that was suited to local climates and soils in large portions of the Southwest, the addition of other cultigens, the development of pottery for cooking and storage, and the development of more-substantial buildings for storage. Indeed, the rapid population growth expected by Bocquet-Appel (2002; Bocquet-Appel and Naji 2006) in the early phase of the NDT did not begin until four hundred years or more after the local introduction of well-fired ceramic vessels.

We examine this pattern in greater detail in figure 3.2 by graphing data from the Pueblo area, using calendar dates rather than dates relative to the local introductions of maize or well-fired ceramic vessels. The y axis of figure 3.2 shows the $\frac{15}{5}$ proportion (the proportions of immature individuals aged five through nineteen among all individuals five years old or more). This proportion is correlated most strongly with crude birth rate but also with the coefficient of instantaneous population growth $r$ (Bocquet-Appel and Naji 2006:342), and therefore, high $\frac{15}{5}$ proportions are interpreted as evidence of increased fertility rates associated with the onset of the NDT. The two central lines in this figure represent two alternative loess smoothings that aid in the interpretation of these data. The smoother fit captures the long-term trends better; the rougher fit, however, provides some additional high-frequency detail.1

This figure shows that the $\frac{15}{5}$ proportions may be high in several of the earliest Pueblo assemblages, but the sample sizes are so small and the proportions so variable that certainty is impossible, as the wide confidence interval during this early period demonstrates. The smoother loess-fitted line shows a steep increase in these proportions beginning around AD 600, with values increasing until the mid to late 1100s. This
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is followed by a steep decline. There is a slight suggestion of another increase in the early historic period, but this is questionable given the larger confidence intervals at the same time. The rougher fit shows much the same sequence, except that it records a dip in growth rates throughout the AD 900s that may indicate a decline in fertility. This decline may have been a response to shorter growing seasons and drier winters reconstructed by Aaron Wright (2006) for this century.

In overview, it is remarkable that the first significant increases in population growth occurred only after the introduction or development

Figure 3.2. Proportions of immature individuals among all individuals five years old or older through time for the Pueblo Southwest (based on data tabulated in Kohler, Glaude et al. 2008). Loess fits with smoothing parameters of 0.31 (lighter dashed line) and 0.4 (darker dashed line), with 90 percent confidence limits around the 0.4 fit. The outer dashed lines track 90 percent confidence limits around the 0.4 smoothing. A reference line at about 0.18 on the y axis provides an estimate of the location of a growth rate of zero; on the x axis, AD 1 is marked with a vertical reference line.
of the “full Neolithic package” (pottery, bow and arrow, beans, maíz de ocho, and dry-farming strategies) and roughly coincident with, or just slightly predating, the first appearance of villages, and increasing duration of residential sedentism. Now that this coincidence has been identified, the next step is to determine the cause and effect: did villages result from high population densities, or did they promote high population densities? We suspect that the answer to both questions is yes. A distinct difference, however, can be seen between the earliest villages of the late eighth and ninth centuries and those that formed during the eleventh through thirteenth centuries. Several characteristics of the early villages—their earthen architecture, a tendency to deplete local resources, and relatively short use lives—all suggest that the early villagers had not fully worked out the terms of a sedentary aggregated lifestyle to the degree accomplished by the later villagers.

From the comparative perspective provided by the NDT, we can see that attainment of a productive and efficient Neolithic way of life represents one of those few moments in human history when a dramatic productive advance significantly raises the economic carrying capacity of the landscape. We are living in a similar moment now, though we are likely nearing the end of the cheap fossil fuel subsidies that have made it possible. These few hundred years in the Southwest, as today, were marked by unprecedented rates of culture change, fueled at least in part by the population growth resulting from increases in fertility expected in “traditional fertility” societies (those without modern contraception methods) when resources are relatively abundant (Kohler 2004b; Low 1993). Across the Pueblo area, the high proportions of juveniles began to decrease shortly after the beginning of the Pueblo III period (circa 1140–1300) amid high levels of aggregation, considerable violence, and poor high-frequency climatic conditions. Evidently, people made decisions that altered their fertility in light of greater competition for resources, though there is also some evidence for increases in mortality. In a meta-analysis of bioarchaeological studies from across the Southwest (and extending beyond the Pueblo area), Ann L. W. Stodder (2005) reports modest but continual declines in average life expectancy at birth and at age fifteen from AD 800 through the sixteenth century.
The Demographic History of Southwestern Colorado

This, then, is the larger context for our case study from the Village Ecodynamics Project (VEP) area in southwestern Colorado (Kohler et al. 2007). This project’s study area of about 1,800 square kilometers encompasses the most densely populated portion of the Mesa Verde region. The VEP has synthesized data collected by many archaeologists over nearly one hundred years and compared these data sets with agent-based models that start from virtual renditions of the southwestern Colorado landscape (e.g., Cowan et al. 2009; Johnson, Kohler, and Cowan 2005).

Scott Ortman and colleagues (Ortman, Varien, and Gripp 2007) discuss how the information from the excavated, tree-ring-dated sites in our study was used to develop a calibration data set that provided the basis for a Bayesian statistical analysis (Iversen 1984) of the unexcavated and poorly dated sites. This includes about nine thousand sites that were recorded during the many archaeological surveys that cover about 15 percent of the study area. These analyses assigned habitation sites to one or more of fourteen periods during the AD 600–1280 interval, which spans the time when farmers first arrived in significant numbers to our area to their departure from the region. An extension of these same techniques was also used to estimate how many households lived at these habitation sites in each of these periods.

Mark Varien and colleagues (2007) use these data to reconstruct population dynamics and model the historical ecology of the region, developing three methods to extrapolate from known sites and estimate population for the entire study area. All three methods show two cycles of occupation of about three hundred years, one from AD 600 to 920 and another from 920 to 1280. We prefer the results of the middle estimate in figure 3.3, but we regard the zone from the top of the highest bar to the top of the lowest bar in each period as the plausible range for the demographic reconstruction of our study area. This record yields local population growth rates (r) ranging from −.0301 to .0235. These rates do not tell us much about the underlying rates of *regional* population growth, however. In this area, as for much of the Southwest, immigration and emigration are such important processes that settlement data from any local area do not provide trustworthy estimates of underlying regional population growth rates.
Another feature of interest in figure 3.3, when it is compared with figure 3.2, is that our study area grows in population, probably in part through immigration, in the AD 1225–1260 period, even as growth rates were slowing across the larger Pueblo area. This suggests that our area served as a refugium in the northern Southwest—a place to go to when other areas were failing.

In figure 3.3, we also graph the proportion of households located in the largest sites (those with more than eight households) during each period. In the first cycle, episodes of village formation are strongly correlated with periods of high productivity (see fig. 3 in Varien et al. 2007) in the last half of the AD 700s and from about AD 850 to 890. Some positive correlation, especially in the second cycle, can be seen between this aggregation index and the number of people on the landscape. The correlation is not perfect, however, because the highest degree of

Figure 3.3. Three estimates of momentary human population size for the Village Ecodynamics Project I study area (derivation explained in Varien et al. 2007) with a spline-fitted line representing the proportion of households in each period living in settlements with at least nine other households.
aggregation in each cycle takes place just after population peaks and has
begun to decline (around AD 900 and 1270). Although aggregation is
in part a density-dependent phenomenon, these interesting departures
from this tendency need explaining.

Population Size and Warfare: The Turchin Model

In his book *Historical Dynamics: Why States Rise and Fall*, Peter Turchin
proposed a simple deterministic relationship between population size
and internal warfare, or sociopolitical instability, for agrarian states.
He has extended that work to nonstate societies with anthropologist
Andrey Korotayev (Turchin and Korotayev 2006). In summary, this
model predicts that internal warfare will increase with population size,
followed by a temporal lag, and that this will eventually cause population
to decline, after which warfare also declines, and the cycle can begin
afresh (Turchin and Korotayev 2006:fig. 4a). This proposed relationship
is reminiscent of the Lotka-Volterra predator-prey relationship, and the
equations that Turchin uses are similar in form. When this model is plot-
ted with population on the x axis and warfare on the y axis, it describes
an inwardly moving counterclockwise spiral, approaching a single-point
equilibrium (Turchin and Korotayev 2006:fig. 4b). Of course, for the
relationships to behave as expected, all this must happen in a closed sys-
tem without significant outside interference, or significant immigration
or emigration. Moreover, we must assume that technology—including
social and political organization—remains similar through time, so that
increases in population result in some increased competition over pro-
ductive resources.

To examine this model for our area, we need an index of internal
warfare. Sarah Cole (2007) developed an osteological index for total
violence—which is as close as we can come with the archaeological
record—as part of a thesis project at Washington State University. Cole
searched the published and gray literature for our study area and its
immediate surroundings and tabulated the incidence of skeletal trauma
likely attributable to violence. This includes fractures (healed or not)
to the ulna and radius, which most likely resulted from a blow to the
arm raised in defense. It also includes most perimortem and antemor-
tem cranial fractures. Finally, it includes archaeological contexts where
human remains were disarticulated and culturally modified, such as those seen at the Cowboy Wash and Aztec Wash sites (Billman, Lambert, and Leonard 2000), Mancos 5MTUMR-2346 (White 1992), and Castle Rock and Sand Canyon pueblos (Kuckelman, Lightfoot, and Martin 2002) (see fig. 3.1). Cole did not count other types of fractures to other parts of the body (the most common being rib fractures) because they may have been accidental rather than due to violence.

We assume that the proportion of individuals with warfare-related trauma is proportional to the deaths attributable to warfare. This proportion ranges from zero in some periods to almost 0.9 (that is, 90 percent) in the early Pueblo III period (AD 1140–1180). Cole (2007) and Kohler and colleagues (Kohler, Cole, and Ciupe 2009) examine Turchin’s model in detail using these data along with the middle paleodemographic estimates for the VEP area from figure 3.3. Here we simply juxtapose these two curves for population and warfare, after smoothing and standardizing both (fig. 3.4A): population increases during the first occupation cycle, and an increase in warfare lags slightly behind. This was followed by a decrease in population with a decrease in warfare after a lag—all as predicted by the Turchin model. But then around AD 1000, during the early portion of the second demographic cycle, the expected relationship falls apart, and increases in warfare precede population increases for about the next two hundred years. Around AD 1200, the predicted relationship between population and warfare re-emerges but with warfare levels lower relative to population size than in the first population cycle. The same patterns are shown in the phase plot (fig. 3.4B).

There is good agreement, then, with the Turchin model for about the first four hundred years of this seven-hundred-year sequence. During the last three hundred years, there are two anomalies, however: (1) increases in violence precede population increases from AD 1000 to 1200; and (2) after 1200, the relationships predicted by the model re-emerge but with lower levels of violence than expected.

Before discussing these two anomalies, we wish to point out that the relationship between the demographic history of this area and the record of violence helps us understand the tendency for households to remain aggregated at the end of each population cycle. If aggregates were simple density-dependent phenomena, then they would be expected to begin to disband around AD 900 and 1270 as local population levels began to
Figure 3.4. Relationship between warfare (W) and momentary population size (N) in and near the Village Ecodynamics Project I study area (after Kohler, Cole, and Ciupe 2009): A, smoothed and standardized curves for population (black line) and warfare (gray line) through time; B, smoothed and standardized values for population and warfare in their phase space. Turchin’s model predicts a counterclockwise movement through this space over time.
decline. Instead, the proportion of the population living in aggregated settlements increased during those times, probably due to the safety they offered. (Increasing aggregation could also have been caused if, as people began to leave the area, those in the small sites were the first to go.) Thus, a model that combines the effects of population size and the violence that population growth tends to entrain apparently explains much about our record of aggregation; in the first population cycle, aggregation is also strongly connected with periods of above-average local maize productivity.

The first of the anomalies thrown into relief by the Turchin model is the unexpected increase in violence in advance of population increase, beginning around AD 1000/1040. The departure from the expectations of the Turchin model suggests that the violence beginning in the early AD 1000s was different in origin than what preceded it. The greatest event in the Pueblo world at this time was the emergence of Chaco Canyon as a primate center, a process that began in the late AD 800s and culminated in the early 1000s (Lekson 2006). The Chacoan polity successfully expanded into our area from the San Juan Basin by about AD 1080, as seen from the construction in our area of “great houses” modeled on the architecture in Chaco Canyon to the south (Lipe 2006:271–76).

One reason why violence precedes population growth in our record between AD 1020 and 1080 might be that forceful but initially unsuccessful Chacoan attempts to expand into the northern San Juan region began relatively early in the eleventh century. Although there is little direct evidence for Chacoan expansion into southwestern Colorado at this time, there is evidence that violence was present in our area and that the Chacoan system was expanding elsewhere. In our study area, Cole (2007) reviews a number of stockaded sites constructed in the first half of the eleventh century (e.g., the Dobbins Stockade, 5MT8827; Kuckelman 1988). W. James Judge and Linda Cordell (2006:197–98) note that “the first half of the 1000s witnessed a new burst of construction in Chaco Canyon, new kinds of structures, alterations in the configurations of buildings, and perhaps changes in building function.” A few archaeologists (see, for example, Wilcox 1999) interpret this florescence around AD 1030 as the changes expected in a new, expansionist, tributary state.
In short, we attribute the eleventh and twelfth century failure of the local population-warfare relationships to be as predicted by the Turchin model to the decreasing sense in which our study area was a relatively closed system; instead it was brought into the Chacoan fold. In the central San Juan Basin, the Chacoan system fell apart in the mid-1100s amid poor productive conditions. In our area, this period witnessed extremely high levels of violence but a surprising degree of continuity in population size and location (Varien et al. 2007) and productive conditions in our area that were apparently somewhat more favorable than farther south. Some great houses even continued to be used and remodeled into the thirteenth century (Ryan 2008:81–82).

The second anomaly highlighted by our attempts to fit the Turchin model to our local sequence is the lower-than-expected level of violence during the early and mid-1200s, given the population-size/violence relationship in the first four hundred years of this sequence. Evidently, something important changed, both in comparison to the very violent mid–AD 1100s and in comparison with that same relationship in the first population cycle. We turn to political factors to understand this anomaly.

**Rank-Size (“Zipf”) Plots in Southwestern Colorado**

Rank-size analysis, developed by George Zipf (1949), provides a useful way of analyzing the notion of concentration by graphically displaying the relationship between the rank and size of phenomena. This analysis also generates useful numbers for comparative purposes. In settlement pattern analyses, these graphs are used to examine the relationship between the sizes of settlements and the ranks of those same settlements by plotting the logarithms of site sizes against the logarithms of their ranks (e.g., Paynter 1982:145–73).

Three classes of patterns can be expected in such plots (Johnson 1977:495–502, 1980; Tidswell 1978:193). Several centers of roughly equal size produce a “binary” or convex (upwards) pattern. This is usually interpreted as a poorly integrated settlement system characterized by competition. For example, in her examination of the emergence of complex societies in China, Liu Li (Liu 2004:164) finds that all the Early Neolithic settlement distributions along the middle Yellow River valley have distinctly convex rank-size graphs.
The opposite is the “primate” or concave pattern; this occurs when one settlement is considerably larger than any other within the area graphed. Such a primate settlement is typically interpreted as sponsoring a variety of activities that do not occur at other sites. These activities could be ceremonial, economic, or bureaucratic in nature. Robert Paynter (1982:148) suggests that concave patterns indicate “intense concentration of social surplus into a very few locations.” Gregory Johnson (1977:496) noted that primacy often occurs in systems that are in contact with external areas, with the primate center being the location through which that contact is channeled. Liu (2004:173) shows that by the Late Neolithic (Longshan) period in the middle Yellow River valley, one subregion exhibits a primate (concave) curve with a three-tiered settlement hierarchy topped by a walled center nearly three hundred hectares in size.

Finally, there is the theoretical rank-size-rule pattern, in which the rank-size distribution closely approximates a line representing a log-normal distribution. In this relationship, when settlements are ranked from largest to smallest, a settlement of rank $r$ (say, 2) has a predicted size equal to the size of the largest settlement divided by $r$ (thus, the second-ranked settlement would be $1/2$ the size of the largest settlement). When this relationship obtains, the resultant rank-size line has a slope of $-1$ when plotted on a log-log graph. This is typically interpreted as evidence of a settlement system that is “well integrated,” in which settlements of different size reflect a developed hierarchy of political or economic functions. (Although this empirical regularity has been well studied, the reasons that underlie this regularity in the rank and size of settlements [and many other things] remain controversial; various authors have argued that increasing returns, random growth processes, or locational fundamentals hold the key to generating this specific scaling pattern [see Gabaix and Ioannides 2003].)

William Lipe (2002) recently examined the changes in such graphs during the Pueblo III period for the entire central Mesa Verde region, which includes, but is larger than, our study area. Using only the largest sites, and a somewhat coarser chronology than we do here, he detected a change from a log-normal distribution during the AD 1150–1225 period to a convex distribution during the AD 1225–1290 period, suggesting multiple competing centers (Lipe 2002:218; see also Lipe and Varien 1999b:332–33).
To make the rank-size plots using data from southwestern Colorado, we performed linear regressions of the log of settlement sizes (measured by numbers of households) on the log of their ranks. We eliminated one-household dwellings prior to doing the regressions and focus here on the behavior of settlements larger than these single-family farmsteads. The empirical distributions are shown in thick continuous lines and the statistical models based on them in dotted black lines. The empirical distributions approximate the “expected” (log-normal) rank-size relationship (shown in thin continuous lines) when their associated regressions have slopes about equal to $-1$ and when all three lines are close together on the graph.

Viewed from the perspective of the rank-size model, the settlement data from southwestern Colorado show interesting patterns of change through time that echo those discerned by Lipe in periods when our samples overlap. The distributions during the four periods of the first settlement cycle in which villages were present (725–800, 800–840, 840–880, and 880–920) conform closely to the theoretical rank-size expectation, as shown in figure 3.5A, which graphs this relationship for the AD 840–880 period. Grass Mesa was the largest village throughout the first population cycle.

After the Pueblo I villages disbanded in the early 900s, the slope of the best-fit regression line is very flat (quite a bit less than the expected value of $-1$) for over a century, until aggregated villages began to form again during the late eleventh century. These results suggest a lack of political integration in our area during this time (as well as in the earliest period of occupation, AD 600–725, for which the rank-size graph looks similar).

The AD 1060–1100 period was marked by rapid growth, including immigration, accompanied by the apparent expansion of the Chacoan system into our study area. During this period, Yellow Jacket Pueblo rose to local preeminence. It remained the largest community center in our study area from the mid-late 1000s until the depopulation of the region around AD 1280. Yellow Jacket was somewhat larger than expected—that is, it falls above the regression line that is fitted to the entire distribution—from 1060 until 1140—the periods of maximum local Chacoan influence. Overall, Yellow Jacket existed in a region that was relatively “well integrated” by the metric of the rank-size rule (fig. 3.5B), though note the slight concave tendency in this plot. We consider the
(rather slight) extent to which Yellow Jacket was larger than expected to be a measure of the degree to which it drew benefits—unknown in nature—from other settlements through processes that remain to be defined but whose probable existence is signaled by these plots. These benefits ceased to flow in the mid-1100s, the same time when our index of skeletal trauma peaked and no more Chacoan-style great houses were locally constructed. Despite these dramatic changes, the shape of the settlement system shows remarkable stability in the mid-1100s, and Yellow Jacket remained on top of the hierarchy. It would be extremely interesting to know how this was achieved.

**Figure 3.5.** Rank-size relationships within the Village Ecodynamics Project I study area. The dotted line is the regression model; the thick continuous line is the empirical distribution; and the thin continuous line is the theoretical rank-size-rule pattern, the log-normal distribution of the rank-size data. Our estimate for site size is the estimate for the number of momentary households at each site.
Cole's index of skeletal trauma suggests relatively peaceful conditions during the next two periods: 1180–1225 and 1225–1260. This is surprising because of the formation (or more probably intrusion) of a number of small centers in this latter period in the western portions of our study area and also because during this period construction began at many large, walled canyon-head settlements such as Sand Canyon and Goodman Point pueblos that have a defensive character (Kuckelman 2002). Perhaps the walls and the increasing aggregation that accompanied them were effective in preventing skeletal trauma. Alternatively, our index of violence may be underestimating actual conflict in this thirteenth century. Some skeletons at Sand Canyon Pueblo, for example, show evidence of healed trauma, so individuals who received nonlethal trauma in the early or mid-1200s would have been assigned by Cole to the subsequent period. Moreover, if inferences that conflict during this period was primarily interregional are correct, then more warfare may have taken place in no-man's-lands away from habitations and perhaps outside our study area, perhaps resulting in fewer casualties preserved in sites recognized and excavated by archaeologists.

Comparing the shape of the rank-size relationships from either of the periods in the 1180–1260 interval (fig. 3.5C displays the results for the 1225–1260 period) with that during the Chacoan primacy from 1060 to 1140 (fig. 3.5B displays the results for the 1060–1100 period) suggests that the later political system may have been less dominated by Yellow Jacket. One possibility is that the political system in the study area became more cooperative in nature, operating perhaps as a confederacy of near-equals rather than a more coercive, extractive regional system fronted by Yellow Jacket and backed up by the might and glory of Chaco. Another possibility is that there were two competing polities in the 1180–1260 period, perhaps one headed by Yellow Jacket Pueblo and the other by Sand Canyon and Goodman Point communities (the second- and third-ranked communities in figures 3.5C and 3.5D). Perhaps this new system, whatever it was, was able to quench the rampant internal violence of the earlier period to a considerable degree.

In the final period of occupation, from 1260 to 1280, Sand Canyon and Goodman Point became almost as large as Yellow Jacket, which was losing its preeminent position (fig. 3.5D). Despite the presence of these large pueblos, the largest settlements in general were smaller
than expected given the characteristics in the body of the distribution; many small centers contribute to the convexity in the center of the distribution. The regression coefficients for this period exhibit steeper slopes and higher intercepts than in any other period. Together these characteristics indicate a degree of population concentration in centers never before experienced in this area—something also indicated by the simpler aggregation index illustrated in figure 3.3—even though these centers were generally rather small. Violence was also on the rise (something supported by the convexity in the rank-size plot, which suggests a pattern of competing centers), indicating the failure of the more integrated political system of the previous sixty to eighty years. Increased aggregation and conflict were part of the social context that characterized the last two decades in this region, as recounted in more detail by Kohler, Glaude, and colleagues (2008) and Glowacki (2010).

**Summary**

Some things we think we have learned here can be conveniently boiled down to a few bullet points:

- During the first six hundred years or so of the seven-hundred-year sequence reviewed here, populations in the Pueblo region were increasing rapidly, probably at rates not experienced previously in this region, with the likely exception of the post-Pleistocene peopling of this area.
- Initial aggregation in our study area was a density-dependent process, and in general the degree of aggregation tracks the local population densities. However, aggregation was prolonged at the end of each population cycle, even as local populations began to decrease, by high levels of local violence that made living in aggregates attractive for safety.
- The general tendency, predicted by Turchin and Korotayev, for warfare to follow population increases with a lag, and for population size to then decline in a lagged fashion following increases in violence, can be identified in the first four hundred years of the sequence reviewed here. Later departures from those tendencies seem to be attributable to influences by societies outside our study area, and
these departures help us to identify these influences—and the violence that accompanied them.

- Competition among communities in conjunction with population growth results in several obvious sociopolitical innovations. The first of these are the relatively ephemeral Pueblo I villages that emerged in the context of high local population densities. Balanced reciprocal exchange between households in different lineages or clans likely facilitated these high population densities in areas where dry farming was risky. The second are the more durable Pueblo II/III communities and community centers that appear to have been based on institutions that could “weather” climatic downturns so long as they were not too severe. Peter Richerson and Robert Boyd (2001) have suggested that the rate of change in social institutions tends to be slow and may come to limit the rate of population growth and subsistence intensification in sufficiently long sequences. Perhaps the situation we have documented for southwestern Colorado is an example. Certainly our local populations increase dramatically following what we suspect is the imposition of the Chacoan political pattern which, whatever its faults, permitted considerably more people to occupy the central Mesa Verde region than had ever been there before. The Chacoan system seems to have made a significant leap in sociopolitical complexity during the early AD 1000s. Such significant increases in sociopolitical complexity are, however, rare in the archaeology of the Southwest.

- Rank-size analysis identifies slight tendencies for primacy for the largest VEP community center in the Pueblo II period—Yellow Jacket Pueblo—which may identify its links to the external Chaco polity and/or signal material subsidies flowing toward it that allowed it to support more households than we would expect, given the sizes of the other settlements in the region.

- Yellow Jacket remained the largest community center in our area throughout the second population cycle, but its primacy decreased continually after AD 1140.

- Toward the end of the occupation, as the final depopulation commenced in the AD 1260 to 1280 period, our area appears to have lost its political cohesion and to have broken into smaller competing polities, in which context violence again increased after a substantial decrease around AD 1200.
Conclusions

Always in a model-based approach to science there is a sense in which we can learn something about the model from the data, as well as learning something from the model about the case we are analyzing. What in overview can we say about Neolithic Demographic Transition theory from the perspective of these data? One claim of NDT theory is that seven hundred or one thousand years after the achievement of a local Neolithic, population growth slows markedly, primarily because of disease factors in emerging compact villages where people lived in close proximity to livestock. Based on the fit between our data and the Turchin model, we suspect that variation in population growth rates in our sequence also has a lot to do with the level of violence on the landscape, not just the level of aggregation. Moreover, violence and aggregation are also connected. Although the local Pueblo I villages formed in a period of low violence (and hence do not seem to have been primarily defensive in nature), we do see a link between peoples’ desires to stay in villages at the end of each population cycle and the contemporaneous levels of violence on the landscape. By comparing our rank-size analyses with the level-of-violence data, we are also able to suggest that violence in our record is in turn connected with political processes.

Local population processes cannot be fully understood without being placed into the context of climatically induced changes in potential production (Kohler et al. 2007; Varien et al. 2007). It seems probable to us that the first phase of the NDT in the Southwest (the high-growth-rate phase) was truncated by climatic perturbations, including warm drought periods from AD 1135 to 1170 and 1276 to 1297 that were superregional in scope (Benson, Petersen, and Stein 2006), and low-frequency trends toward shorter growing seasons and lower winter precipitation during most of the thirteenth century, as documented by Aaron Wright (2006). Perhaps the declines in population growth seen in the loess-fitted lines in figure 3.2 beginning in the late AD 1100s would have been postponed if the favorable climatic conditions of the Pueblo II period (circa AD 900–1140) had continued into the late twelfth and thirteenth centuries—with results for the political history of this region on which we can only speculate. In that case, other systems on the order of Chaco’s complexity could have been expected to arise, compete, and
perhaps control even larger regions than those influenced, or dominated, by Chaco.

This sequence from southwestern Colorado between AD 600 and 1300 is probably the best-dated and most well understood example, anywhere in the world’s archaeological record, of the emergence of new hierarchical levels of social organization. In fact, we would argue for two emergences: first, in the Pueblo I period, villages emerged from a substrate of related groups of households that we can call clans for convenience; and then, in the Pueblo II period, polities composed of many villages appeared. In each case, these new organizational entities became units of action themselves, influencing the success of their constituent households and setting bounds on their possible behaviors to stabilize the higher unit.

Leo Buss (1987:171) argues that “when a transition occurs in the units of selection, synergisms between the higher and lower unit act to create new organizations which may allow the higher unit to interact effectively in the external environment.” In our setting, individuals with skills and ambitions to fill leadership positions suddenly had the possibility of leading groups that were significantly larger in scale than had previously existed, creating synergies between these incipient leaders, their households and kin groups, and their communities. We presume that the somewhat larger pithouses (protokivas) that are found in the villages of the late AD 800s are examples of the physical manifestations of these synergies. The rank-size distributions in our area provide evidence for synergies between AD 1060 and 1140 that are even larger in spatial and social scope. During that interval, communities centered on great houses and great kivas suggest the emergence of a second, inter-community level of political organization. The large aggregated villages that formed during the AD 1140–1280 period, and the new forms of public architecture found at these sites (e.g., monumental towers and biwall structures), are evidence that these new forms of organizational complexity were continuing to change during the final century of occupation. The most recently emerged unit of organization seems to be the most unstable and subject to change.

Our understanding of what happened in the VEP area is broadly compatible with John Clark and Michael Blake’s (1994) model for the emergence of institutionalized social inequality and political privilege
in lowland Mesoamerica. Population growth in the context of increasing sedentism that itself could increase the likelihood and size of intergenerational transfers of wealth (Borgerhoff Mulder et al. 2009) and density-dependent initial formation of villages during periods of high and relatively stable productivity provided the contexts within which aggrandizers could provide competitive advantages for the larger unit (see Kohler 2004a for more detail). Key advantages of these larger units probably included fielding, or threatening to field, a larger number of hunters or warriors and providing greater security to community members.

In this chapter, we have used models that are both descriptive (NDT and rank-size) and explanatory (Turchin’s). These same models can be employed elsewhere, and have been in some cases, enabling us to see specific similarities and differences in various sequences around the world using the well-specified metrics they provide. We hope this model-based approach to the archaeological record provokes by example other researchers to assess and improve these models with other data, lending our results a stronger comparative framework than they presently enjoy (see Kohler and van der Leeuw 2007 for more discussion of model-based archaeology). We think that model-based archaeology provides a novel and potentially more powerful way of doing comparative archaeology than those approaches reviewed by Peter Peregrine (2004).

We think this study also illustrates how puzzling instances of lack-of-fit between data and a specific model may become explicable when models focusing on different sets of relationships are employed. None of these models is “right” or “wrong.” They are useful if they provide assistance in identifying nonobvious aspects of the archaeological record that in turn help us to achieve the twin goals of understanding the particular historical sequences we study and placing those into the larger context of evolving biotic (including cultural) systems.

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Notes

1. The first was selected to minimize the AIC\textsubscript{c} value (Hurvich, Simonoff, and Tsai 1998) within a permissible range of 0.3–0.6; the second, to minimize the AIC\textsubscript{c} value within the range 0.4–0.6. Sample points were weighted according to the sizes of the samples.

2. In a pan-Southwestern review of bioarchaeological materials, Stodder (2005) noted that the individuals in her period 4 (AD 1151–1350) exhibited the poorest health overall; our data suggest that the Pueblo area participated in and contributed to these pan-Southwestern trends.

3. This is also when the first “pueblos” formed—that is, buildings with contiguous rooms with front rooms that protect storage rooms. This was a real change in food-storage technology, from both a physical standpoint (the rooms were more substantial and lasted longer) and a cultural standpoint (people were more able to control and monitor this stored food).

4. Some Chacoan great houses (e.g., the Porter great house) continued to be used during this period and were expanded in the following period. Some large buildings that have been labeled post-Chacoan great houses were built in the post-Chaco period, especially during the 1200s.