The Nature and Timing of the Neolithic Demographic Transition in the North American Southwest

Timothy A. Kohler and Matt Glaude

Abstract Maize agriculture was practiced in the US Southwest slightly before 2000 BC, but had a negligible impact on population growth rates until it was coupled with other innovations in subsistence and social practice. These include the development or introduction of more productive landraces; the ability to successfully cultivate maize under a greater variety of conditions, with dry farming especially important; the addition of beans, squash, and eventually turkey to the diet; and what we infer to be the remapping of exchange networks and the development of efficient exchange strategies in first-millennium-AD villages. Our tabulations of the P(5–19) proportion emphasize the heartlands of the Chaco and Mesa Verde Anasazi (prehispanic Pueblo) populations. We find that this measure is somewhat affected by warfare in our region. Nevertheless, there is a strong identifiable Neolithic Demographic Transition signal in the US Southwest in the mid-first-millennium AD in most subregions, visible a few hundred years after the introduction of well-fired ceramic containers, and more or less contemporaneous with the first appearance of villages.

Keywords Maize · North American Southwest · ceramic containers · demography

Background Considerations: Early Maize in the US Southwest

Following its domestication in southern Mexico more than 6300 years ago, maize arrived in the southern portions of the US Southwest slightly before 2000 BC[1] (Diehl and Waters 2006; Huber 2005; Huckell 2006). The earliest presently known maize sites in the American Southwest (Fig. 1) do not form a strong south-to-north chronological gradient (Blake 2006; Huber 2005: Fig. 36.11; Smiley 1994), since maize appears to have reached northeastern Arizona by 1940 BC (Smiley 1994), which is almost as early as the southern Arizona dates. More lag can be seen in its subsequent east–west spread—for example, it reached the Northern Rio Grande in

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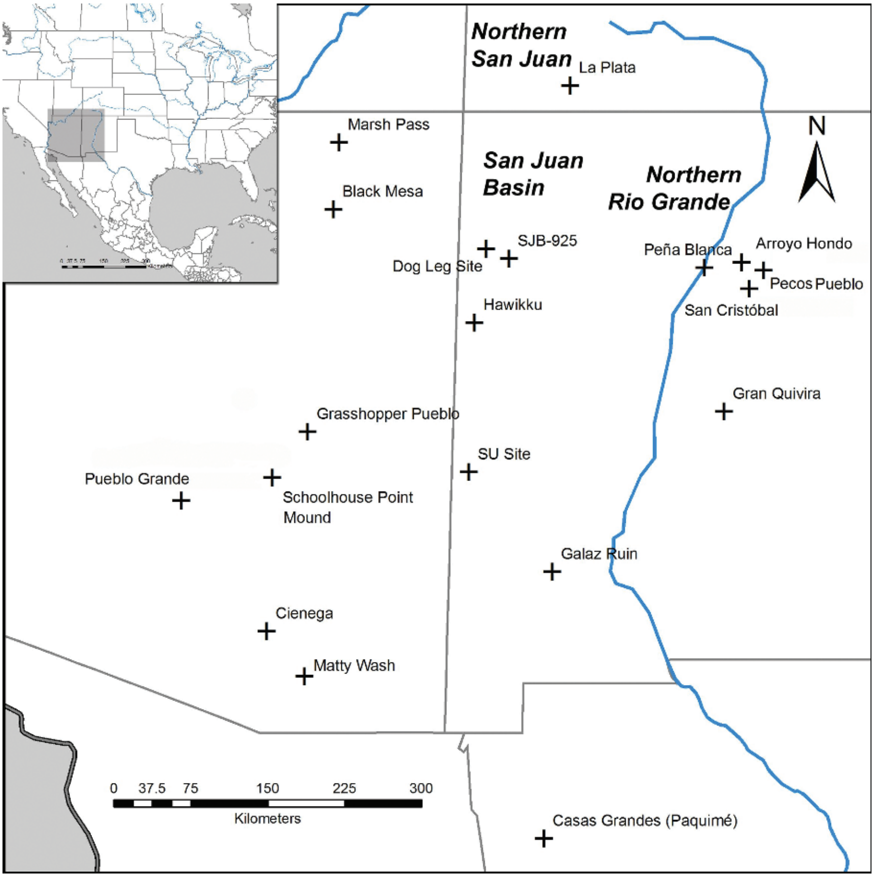

Fig. 1 Location of study area and some of the key sites used in the analysis

New Mexico by about 1200 BC (Vierra and Ford 2006:505)—and in its later spread into the northern reaches of the Colorado Plateau in Utah, around AD 600 (Barlow 2006) (Fig. 2). While the core cultigens of the Mesoamerican agricultural adaptation also included beans and squash, their entrance into the Southwest was later and less distinct. Macrobotanical evidence for these plants is much less abundant than is the evidence for maize throughout southwestern prehistory, and the first occurrences of each are generally in the first millennium BC (Smith 2001).

So familiar is the concept of the Neolithic wave-of-advance defined for Europe by Ammerman and Cavalli-Sforza (1973) that archaeologists tend to assume that the model will work elsewhere. But in Europe, a highly productive package of domesticates, including animals, and ceramic vessels for cooking and storage, was "assembled" early and was then able to spread very rapidly from east to west through zones of relatively similar climate and biota. From its probable homeland in the tropical deciduous forests or thorn forests of the Balsas depression to the US Southwest,

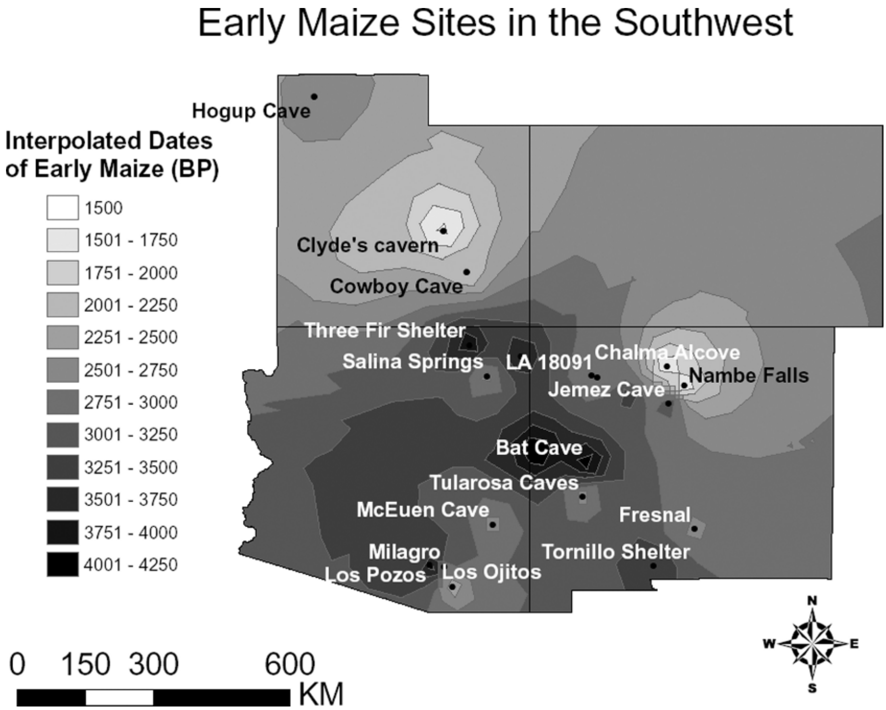

Fig. 2 Interpolated dates for earliest maize in the US Southwest

by contrast, the spread of maize was largely south to north, demanding selection for domesticates capable of thriving under novel combinations of heat units, day lengths, and precipitation regimes (Adams et al. 2006).

The spread of maize was accompanied and to some extent made possible by the development of novel cultivation strategies. Early maize husbandry apparently emphasized water-table farming and overbank flood farming. The Southwest is famous for its aridity, and in many areas, irrigation is either helpful or essential to maize production, yet the earliest irrigation in the Southwest follows the first appearance of maize by some 500–1,000 years (Doolittle and Mabry 2006). Dry farming—essential to opening up large and highly productive mesa tops in the northern Southwest—was added last of all, ca. AD 300 (Doolittle and Mabry 2006; Kohler 1993).

Except in the northern-most portions of the Southwest a considerable lag exists between the first appearance of maize and the development of well-fired ceramic vessels, which regionally varies between about AD 1 and 500. Moreover, Southwestern domesticated animals (dog and turkey) never rivaled in dietary contribution the ovicaprids, cattle, and pigs that yielded so much protein to European Neolithic diets. Turkey, which has greater dietary importance, is relatively uncommon before the AD 1100s in many portions of the Southwest.

Finally, recent research has helped to trace changes in the nutritional value of maize, which has important implications for its role in prehistoric diets (Benz 2006; Iltis 2006). Although it is not currently possible to accurately assess the yield of Early Agricultural period (roughly, the last two millennia BC) maize, it does not seem to have been particularly productive. Morphological observations underscore its very small size, with cupule size increasing very slowly through the 2000-year Early Agricultural period and then more rapidly in the first millennium AD (Diehl 2005). Adams (1994: Table 16.9; Huckell 2006) recounts the prehistory of maize landraces in the Southwest as it is currently understood, demonstrating important additions to the maize repertoire at ca. 100 BC, AD 500, and AD 1000. In short, the inhabitants of the ancient US Southwest spent some 3000 years assembling their Neolithic package; it was not given to them at the outset. Considering this history, it is highly uncertain whether a specific threshold that resembles the Neolithic Demographic Transition (NDT) identified in Europe by Bocquet-Appel (2002) can be identified in the human remains of the Southwest.

Indeed, the relative dietary and social importance of maize cultivation during the Early Agricultural period has been debated for some time. A series of recent discoveries at sites in the Tucson Basin such as Milagro (Huckell et al. 1995; ca. 1100–800 BC), Santa Cruz Bend (Mabry 1998; ca. 800–100 BC), and Las Capas (Mabry 1999; ca. 800–400 BC) showed use of irrigation canals at Las Capas and an extensive distribution of 730 features covering a total over 1.2 hectares of excavations at Santa Cruz Bend, which is thought to represent only 15 percent of the total site (Bellwood 2005:172). These Early Agricultural period sites are near streams and contain pit structures, probable storage pits, and large quantities of maize. The presence of multiseasonal residences is suggested, as is a reliance on storage for winter months.

Nevertheless, the extent to which the use of maize affected other aspects of those societies adapting it during the Early Agricultural period remains an open question. In part, this reflects a lack of consensus within the literature as to how productive early maize was, as well as how dependent early populations were on agriculture. Some researchers (e.g., Huckell 1995:127–133) argue that such usage was relatively intensive and precipitated significant increases in sedentism. A program of fluoride dating on one of the latest of these sites, Los Pozos, however, suggests that what looks like a large settlement with many contemporaneous households, from the perspective of the chronological resolution available from ^{14}C dating, is more likely a series of small settlements occupying a favored locale over several centuries (Schurr and Gregory 2002). Based on decreases in diet breadth from ca. 1200 BC to the local onset of the Early Ceramic period ca. AD 150 in southern Arizona, Diehl and Waters (2006) have argued that floodplain agriculture markedly intensified early in the first millennium AD with the appearance of high-quality ceramic containers that may have significantly reduced maize seed storage losses.

Further north, on the Rainbow Plateau in northeastern Arizona and in Grand Gulch, Utah, the earliest evidence of intensive agriculture dates from approximately 300 BC (Geib and Spurr 2002), though the use of domesticates is considered common by ca. 600 BC on neighboring Black Mesa, Arizona (Gumerman and Dean

1989:111). Both of these dates lag first appearance of maize in northeastern Arizona by well over a 1000 years. In these Pueblo areas of the Southwest, as well as adjacent portions of the Mogollon region to the south, large pithouse villages appeared only around the middle of the first millennium AD (Kohler 1993; Wills 1991, 1995), although fairly intensive use of maize seems to be indicated by stable isotope analyses of (preceramic) Basketmaker II human remains and analysis of pollen and macrofossil concentrations in rockshelter middens and coprolites in SE Utah by ca. AD 1 (Matson and Chisholm 1991), now pushed back to ca. 400 BC for adjacent portions of NE Arizona by a comprehensive program of radio- and stable-isotope analysis of Basketmaker II human remains (Coltrain et al. 2007).

In overview, although we know much more now than we did 20 years ago about the time of arrival of maize in most areas of the Southwest, much about the importance and impact of preceramic maize cultivation in the US Southwest remains contested. In this chapter, we hope to further understand the processes by which farming becomes central to lifeways in the US Southwest by answering the following questions:

- Was there an NDT in this region that can be recognized with existing data?
- If so, does it coincide with the earliest appearance of Mesoamerican domesticates, or was it triggered only by later, presumably more intensive use—and if so, when?
- If a regional NDT exists, does it differ from that suggested for Europe by Bocquet-Appel (2002)? In what ways, and why?

Investigating the NDT in the US Southwest

NDT theory predicts a relatively abrupt increase in the proportions of immature (aged 5–19) individuals for some 500–700 years following the local onset of the Neolithic. The increase is thought to reflect an increase in crude birth rate, perhaps because of decreased birth spacing accompanying sedentism (Bocquet-Appel and Naji 2006:349). This is eventually offset by an increase in mortality due, Bocquet-Appel and Naji (2006:349) suggest, to the emergence of new pathogens, especially zoonoses, with aggregation.

Data Collection and Methods

To determine whether an NDT exists in the US Southwest, we have compiled data for as many relatively large, well-dated assemblages of human remains as we could find. We began from compilations by Kramer (2002) and Bocquet-Appel and Naji (2006:349).[2] To these we added the other assemblages in Tables 1 and 2. Our sample is not comprehensive, though it is more complete for the eastern Pueblo areas (central and northern New Mexico and Southwest Colorado) than for the remainder of the Southwest. We follow Bocquet-Appel's (2002; see especially online

Table 1 Sites used in analysis of Southwestern demographic data

Area/Site	Subregion	Calibrated Dates AD					Demographic Data		Sources
		Site date	Early Maize	Effective use of Maize	dt Early Maize	dt Effective Maize	n(5+)	P(5–19)	
Hohokam Area									
Cienega[a]	Tucson Basin	−125	−2000	150	1875	−275	55	0.236	Mabry 1998: Table 16.2
Matty Wash[a]	Tucson Basin	−443	−2000	150	1557	−593	15	0.133	Huckell 1995: Table 3.5
Pueblo Grande – Early Classic	Phoenix Basin	1212.5	−2000	150	3212.5	1062.5	88.67	0.222	Sheridan, in Mitchell and Brunson-Hadley 2001
Pueblo Grande – Late Classic	Phoenix Basin	1362.5	−2000	150	3362.5	1212.5	61.33	0.217	Sheridan, in Mitchell and Brunson-Hadley 2001
Mogollon Area									
Casas Grandes	Chihuahua	1300	−2000	1	3300	1299	550.8	0.4	Bocquet-Appel & Naji 2006:243
Galaz Ruin – Late Pithouse[a]	Mimbres	775	−2000	1	2775	774	64.75	0.377	Anyon & Leblanc 1984
Galaz Ruin – Classic Mimbres[a]	Mimbres	1075	−2000	1	3075	1074	540.75	0.299	Anyon & Leblanc 1984
Grasshopper Pueblo	Cibecue	1337.5	−2000	1	3337.5	1336.5	279	0.323	Bocquet-Appel & Naji 2006:243
SU	Cibola	500	−2000	1	2500	499	27	0.111	Buron & Grauer 2002: Table 1
Pueblo Area									
Arroyo Hondo*	Northern Rio Grande	1362.5	−1250	300	2612.5	1062.5	59	0.305	Bocquet-Appel & Naji 2006:243

Black Mesa – Early Pueblo[a]	Kayenta	925	−1900	600	2825	325	35.43	0.294	Martin et al. 1991: Table 2-11
Black Mesa – Late Pueblo[a]	Kayenta	1100	−1900	600	3000	500	79	0.291	Martin et al. 1991: Table 2-11
Gran Quivira – Early Phase	Northern Rio Grande	1375.5	−1250	300	2625.5	1075.5	22	0.136	Hayes 1981
Gran Quivira – Middle Phase	Northern Rio Grande	1475	−1250	300	2725	1175	49.7	0.264	Hayes 1981
Gran Quivira – Late Phase	Northern Rio Grande	1611	−1250	300	2861	1311	62	0.166	Hayes 1981
Hawikku LA37	Zuni	1562.5	−2000	300	3562.5	1262.5	147	0.299	Bocquet-Appel & Naji 2006:243, Stodder 1994
La Plata[a]	La Plata	1100	−400	500	1500	600	41	0.268	Martin and Akins 2001
Marsh Pass[a]	Kayenta	−233	−1900	600	1667	−833	21.00	0.125	Coltrain et al. 2007: Table 1
NRG – 1150[a]	Northern Rio Grande	1150	−1250	300	2400	850	17.96	0.122	Kramer 2002: Appendix D
NRG – 1250[a]	Northern Rio Grande	1250	−1250	300	2500	950	17.02	0.142	Kramer 2002: Appendix D
NSJ – 850[a]	Northern San Juan	850	−400	300	1250	550	86.14	0.241	Kramer 2002: Appendix D

Table 1 (continued)

Area/Site	Subregion	Calibrated Dates AD					Demographic Data		Sources
		Site date	Early Maize	Effective use of Maize	dt Early Maize	dt Effective Maize	n(5+)	P(5–19)[b]	
NSJ – 950[a]	Northern San Juan	950	−400	300	1350	650	20.4	0.167	Kramer 2002: Appendix D
NSJ – 1050[a]	Northern San Juan	1050	−400	300	1450	750	31.78	0.024	Kramer 2002: Appendix D
NSJ – 1150[a]	Northern San Juan	1150	−400	300	1550	850	65.77	0.380	Kramer 2002: Appendix D
NSJ – 1250[a]	Northern San Juan	1250	−400	300	1650	950	82.3	0.313	Kramer 2002: Appendix D
Pecos Pueblo – Forked Lightning	Northern Rio Grande	1225	−1250	300	2475	925	99.33	0.195	Mobley 1980
Pecos Pueblo – Glaze B&W	Northern Rio Grande	1337.5	−1250	300	2587.5	1037.5	39.57	0.242	Mobley 1980
Pecos Pueblo – Glaze I	Northern Rio Grande	1400	−1250	300	2650	1100	118.71	0.174	Mobley 1980
Pecos Pueblo – Glaze II	Northern Rio Grande	1450	−1250	300	2700	1150	69.86	0.127	Mobley 1980
Pecos Pueblo – Glaze III	Northern Rio Grande	1512.5	−1250	300	2762.5	1212.5	122.71	0.161	Mobley 1980

San Cristóbal	Northern Rio Grande	1502.5	−1250	300	2752.5	1202.5	203	0.271	Bocquet-Appel & Naji 2006:243
SJB – 700[a]	San Juan Basin	700	−980	300	1680	400	43.94	0.217	Kramer 2002: Appendix D
SJB – 850[a]	San Juan Basin	850	−980	300	1830	550	42.76	0.222	Kramer 2002: Appendix D
SJB – 900[a]	San Juan Basin	900	−980	300	1880	600	9	0.111	Herrmann et al. 1993
SJB – 925[a]	San Juan Basin	925	−980	300	1905	625	15	0.364	Herrmann et al. 1993
SJB – 950[a]	San Juan Basin	950	−980	300	1930	650	89.85	0.409	Kramer 2002: Appendix D
SJB – 1050[a]	San Juan Basin	1050	−980	300	2030	750	139.74	0.277	Kramer 2002: Appendix D
SJB – 1150[a]	San Juan Basin	1150	−980	300	2130	850	222.63	0.411	Kramer 2002: Appendix D
SJB – 1250[a]	San Juan Basin	1250	−980	300	2230	950	26.76	0.450	Kramer 2002: Appendix D

[a] Composite samples (more than one site). See Table 2 for additional information.

Table 2 Details on composite burial assemblages

Area/Site	Number of sites	n(5+)	Sites	Largest contributing site	Comment	Sources
Hohokam						
Matty Wash	2	15	Donaldson Site, Los Ojitos	Los Ojitos (n = 10)	(none)	Huckell 1995: Table 3.5
Cienega		55	Coffee Camp (AZ AA:6:19), Wetlands (AZ AA:12:90), S. Cruz Bend (AZ AA:12:746),Stone Pipe (AZ AA:12:745), Los Pozos (AZ AA:12:91), Clearwater (AZ BB:13:6), Pantano (AZ EE:2:5)	AZ AA:12:90 (Wetlands), n = 21	Compendium of sites from South-Central Arizona	Mabry 1998: Table 16.2
Pueblo						
Black Mesa – Early Pueblo	13	35.43	7:98, 7:134, 7:135, 7:262, 7:234, 7:707, 7:2103, 11:2023, 11:2025, 11:2030, 11:2040, 11:2062, 11:2068	7:234 (n = 8)	Compendium of Black Mesa sites dating to A.D. 800 – A.D. 1050.	Martin et al. 1991: Table 2-11
Black Mesa – Late Pueblo	39	79	7:11, 7:12, 7:23, 7:27, 7:102, 7:109, 7:216, 7:716, 7:719, 7:220, 7:725, 7:2001, 7:2017, 11:3, 11:12, 11:14, 11:97, 11:260, 11:265, 11:275, 11:289, 11:290, 11:300, 11:335, 11:348, 11:352, 11:409, 11:425, 11:426, 11:500, 11:569, 11:666, 11:686, 11:687, 11:2013, 11:2048, 11:2068, 11:2108, 11:2155	11:500 (n = 7), 11:300 (n = 7)	Compendium of Black Mesa sites dating to A.D. 1050 – A.D. 1150.	Martin et al. 1991: Table 2-11

Marsh Pass	4	21.00	Sayodneechee Cave, Kinboko Cyn Cave 1, White Dog Cave, Tsegi Canyon Cave 3	Sayodneechee Cave, n = 9	Compendium of regional sites dating to Kayenta.	Coltrain et al. 2007: Table 1
NRG – 1150	4	17.96	LA000649, LA006865, LA011633, LA000654	LA000649 (Nogales Cliffhouse), n = 11	Compendium of regional sites dating to A.D. 1100 – A.D. 1199.	Kramer 2002: Appendix D
NRG – 1250	9	17.02	LA011843, LA022866, LA022867, LA022868, LA022895, LA022902, LA023043, LA011850, LA011841	Even distribution of burials	Compendium of regional sites dating to A.D. 1200 – A.D. 1300.	Kramer 2002: Appendix D
NSJ – 850	16	86.14	5MT02192, 5MT02848, 5MT02853, 5MT05107, 5MT02182, 5MT00023, 5MT04671, 5MT04725, 5MT02320, 5MT04475, 5MT05108, 5MT04480, 5MT01604, 5MT08899, 5MT08937, 5MT03868	5MT05107 (Pueblo de las Golondrinas), n = 19	Compendium of regional sites dating to A.D. 800 – A.D. 899.	Kramer 2002: Appendix D
NSJ – 950	5	20.4	5MT04477, 5MT02525, 5MT08934, 5MV01452, 5MV00875	5MV01452 (Badger House), n = 11	Compendium of regional sites dating to A.D. 900 – A.D. 999.	Kramer 2002: Appendix D
NSJ – 1050	7	31.78	5MT05501, 5MT05106, 5MT08827, 5MT02433, 5MV01452, 5MV00866, 5MV01229	5MV01452 (Badger House), n = 12	Compendium of regional sites dating to A.D. 1000 – A.D. 1099.	Kramer 2002: Appendix D

Table 2 (continued)

Area/Site	Number of sites	n(5+)	Sites	Largest Contributing Site	Comment	Sources
NSJ – 1150	10	65.77	5MT05498, 5MT02149, 5MT02235, 5MT00948, 5MT02148, 5MT02544, 5MV01595, 5MV00499, 5MT07723, 5MT10207,	5MV01595, n = 20	Compendium of regional sites dating to A.D. 1100 – A.D. 1199.	Kramer 2002: Appendix D
NSJ – 1250	7	82.3	5MT09735, 5MV00034, 5MV01452, 5MV01200, 5MV01228, 5MV01229, 5MT10206	5MV01200 Long House (n = 28)	Compendium of regional sites dating to A.D. 1200 – A.D. 1300.	Kramer 2002: Appendix D
SJB – 700	10	43.94	LA045689, LA002507, LA008939, LA016029, LA004195, LA008662, LA080407, LA083505, LA083506, LA083507	LA004195 (Sambrito Village), n = 16	Compendium of regional sites dating to A.D. 600 – A.D. 799.	Kramer 2002: Appendix D
SJB – 850	12	42.76	LA003562, LA004487, LA003646, LA004363, LA004384, LA004151, LA004131, LA004148, LA004242, LA004198, LA080934, LA083507	LA004487, n = 15	Compendium of regional sites dating to A.D. 800 – A.D. 899.	Kramer 2002: Appendix D
SJB – 925	2	15	423–129, 423-130	423-130, n = 8	Upper Puerco River burial sites	Herrmann et al. 1993

SJB – 950	16	89.85	LA050337, LA004169, LA004298, LA004380, LA004131, LA004053, LA004086, LA004088, LA002585, LA000226, LA040299, LA040626, LA040627, LA040935, LA041629, LA083506	LA004086 (Sanchez Site), n = 27	Compendium of regional sites dating to A.D. 900 – A.D. 999.	Kramer 2002: Appendix D
SJB – 1050	35	139.74	LA016660, LA 104984, LA008846, LA080440, LA059497, LA002675, LA002699, LA002701, LA002937, LA005062, LA006383, LA006387, LA016254, LA008779, LA002585, LA002592, LA080377, LA040395, LA000226, LA000838, LA000841, LA002470, LA040394, LA040396, LA040399, LA040597, LA040626, LA042385, LA083498, LA100627, LA100628, LA100629, LA083500	LA040399 (Tom Mathew's Dig), n = 19	Compendium of regional sites dating to A.D. 1000 – A.D. 1099.	Kramer 2002: Appendix D
SJB – 1150	17	222.63	LA000045, LA008846, LA005057, LA000226, LA002985, LA002987, LA002988, LA002470, LA040394, LA040396, LA002464, LA008978, LA040395, LA040397, LA040721, LA002592, LA040399	LA000226 (Pueblo Bonito), n = 62	Compendium of regional sites dating to A.D. 1100 – A.D. 1199.	Kramer 2002: Appendix D
SJB – 1250	17	26.76	LA003292, LA000045, LA008846, LA085235, LA005596, LA002714, LA004485, LA006372, LA006380, LA006400, LA035867, LA041947, LA002508, LA004050, LA040399, LA040589, LA040633	LA00004 (Aztec Ruin), n = 88	Compendium of regional sites dating to A.D. 1200 – A.D. AD1300.	Kramer 2002: Appendix D

supplemental materials) methods for quantifying the proportions of individuals aged 5–19 in these assemblages. For example, these proportions are calculated against a total that excludes individuals below the age of 5. We excluded assemblages obviously affected by massacres or extreme perimortem processing possibly indicating cannibalism. We did not enrich the reported counts for the 20 + group by 10 percent (accordingly decrementing counts for the 5–19 interval) following Bocquet-Appel's rule 5. In cases where counts of individuals had to be reapportioned from age categories that crosscut those used here, we used rules from Bocquet-Appel (2002: online supplemental materials) or followed advice from Stephan Naji (personal communication 2006).

We did depart from Bocquet-Appel's analysis routine in one important way. Because the assemblages we used ranged greatly in size, from 7 to 540 individuals, we weighted assemblages according to their sample sizes in the loess algorithm used to fit the relationship between time and the proportion of subadults. This limits the effects of the sampling errors that are unavoidable in small assemblages on the fits obtained. Practically speaking, this makes it less essential for us to aggregate small samples that are close in space and time. In producing the loess graph discussed below, we allowed our fitting routine[3] to determine the size of the window used (Bocquet-Appel's α), within a permissible range of 0.3–0.6, so as to minimize the AIC_c value (Hurvich et al. 1998). The smoothing parameter chosen by the optimization algorithm in each of the two cases reported below was ≈ 0.3, the value typically used by Bocquet-Appel.

Results

To examine the relation of this proportion to the first arrival of maize, we use the estimates for the first use of maize in each site's region or subregion, as reported in Table 1. Figure 3 graphs, on its x-axis, the difference between the midpoint date for each assemblage and the date for the introduction of maize to that subregion, against the proportion of individuals from each site aged 5–19 on the y-axis. The horizontal dashed line represents an estimate for the location of a growth rate (r) of zero, based on simulations on 45 reference life tables as explained by Bocquet-Appel (2002:639–640).

It is immediately apparent that we have no sites with enough human remains to graph that are within 1000 years of the first local introduction of maize. This seems to imply, given the density of excavation in the US Southwest, that for a millennium or more following first local appearance of maize, populations remained low and perhaps relatively mobile (see, e.g., Coltrain et al. 2007; Diehl and Waters 2006; Simmons 1986). Figure 3 suggests that population growth rates began to increase some 1200 years after the first appearance of maize, and that growth rates peaked some two millennia after the local introduction of maize, declined over the next 500 years, and then increased once more, though more slowly. Both the first increase and the decline are interpretable in terms of NDT theory, though this first increase comes

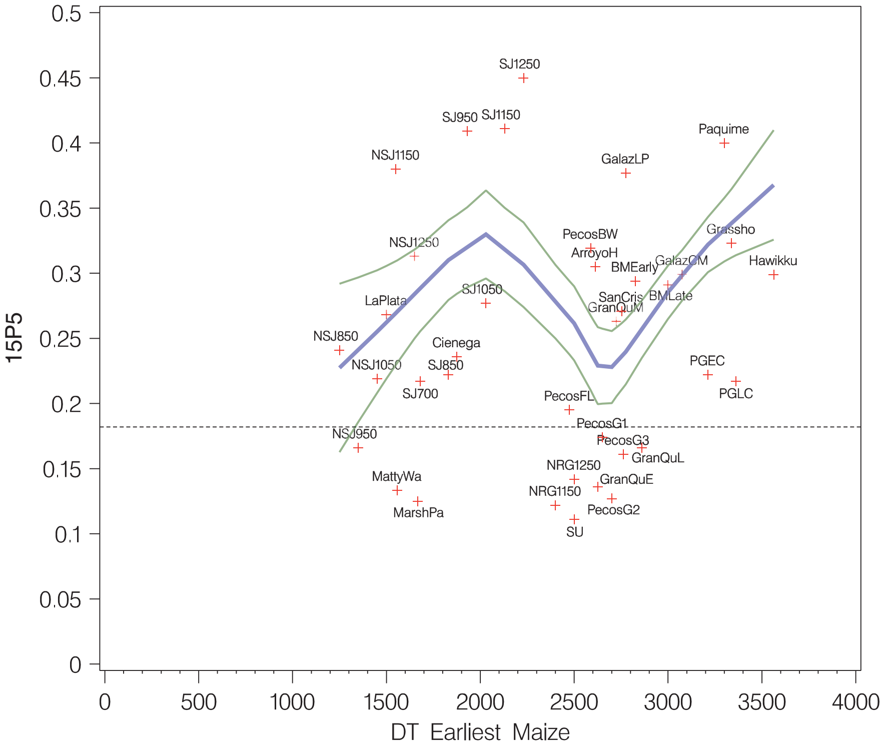

Fig. 3 Proportions of immature individuals in sites and composite samples plotted against the difference between earliest maize use in that site's subregion, and midpoint date of site occupation. Relationship fitted using loess, a nonparametric method for estimating local regression surfaces

some 1200 years later than expected. The second increase is somewhat unexpected, and we return to it below.

Perhaps we would see a better fit between the Southwestern data presented here and the NDT graphs of Bocquet-Appel (2002) for Europe and Bocquet-Appel and Naji (2006) for North America (where they include a few sites from the Southwest) if we examined the relationship between the proportion of 5- to 19-year-olds and an estimate for the earliest *intensive* use of maize. Bocquet-Appel and Naji (2006, Table 1) use AD 200 as the date for the introduction of maize throughout the Southwest except for Casas Grandes (Paquimé) where they use a date of AD 700. They do not explain the derivation of these dates, but they are much more in line with the local appearance of ceramics than they are with the first appearance of maize (Table 1). Crown and Wills (1995) and Diehl and Waters (2006) give local reasons, and theoretical arguments, to suspect that earliest well-fired ceramic containers coincide with the increasingly intensive use of cultivated plants and markedly increased sedentism, although Coltrain et al. (2007) provide much new evidence based on stable carbon isotopes that maize was a staple for Basketmaker II populations in the Four Corners area by 400 BC, some 700 years before the first local appearance of ceramic containers (see also Chisholm and Matson 1994; Matson and Chisholm 1991). Given that we do not presently have enough samples of stable-carbon isotopic data throughout the Southwest to draw exclusively on that line of very direct evidence, we will try using the local first appearance of well-fired ceramic vessels as a surrogate for the first local intensive use of maize, and see what happens.

Figure 4 shows the relationship between P(5–19) and the earliest local intensive use of maize as proxied from the appearance of ceramic containers. This graph indeed resembles that produced by Bocquet-Appel for Europe (2002:Fig. 4) more than did our Fig. 3. Six data points, all with relatively small assemblages, predate the intensive use of maize estimated in this way, and all have low P(5–19) values relatively near the estimate for $r = 0$. Unlike the European case, however, the proportions (and presumably the underlying growth rates r) appear to begin to increase markedly not around dt 0, but rather some 300–400 years after the first local use of ceramic containers. Of course, the dearth of data between about dt −200 and almost 400 weakens this suggestion. If this *is* correct, though, it would suggest that intensive maize use (as proxied by first ceramic containers) perhaps slightly

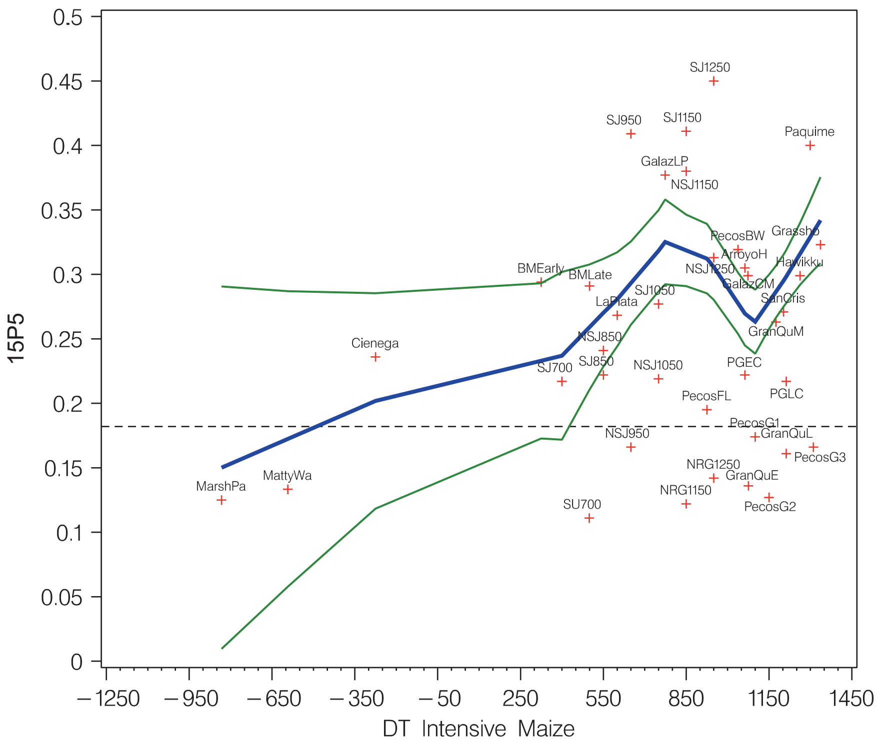

Fig. 4 Proportions of immature individuals in sites and composite samples plotted against the difference between earliest intensive maize use in that site's subregion, as proxied from appearance of ceramic containers, and midpoint date of site occupation. Relationship fitted using loess, a nonparametric method for estimating local regression surfaces

increases population growth rates, but that some other factor, generally occurring later, is even more important. The first marked increase in the P(5–19) values, beginning around dt 400, corresponds in a general way to the first pulse of aggregation in the Southwest, where it is most striking in the Northern San Juan Pueblo I villages discussed elsewhere in this volume by Wilshusen and Perry (2006), perhaps suggesting that early aggregation increased economic efficiency. This rapid increase also generally corresponds to the first appearances of Maís Blando and Harinosa de Ocho (Maís de Ocho) ca. AD 500–700 (Adams 1994), and follows shortly on the opening of a vast new agricultural niche with the development of successful dry-farming strategies. The growth rates toward the top of the peak may also be influenced by the increased use of turkey for protein ca. AD 1100 (Cowan et al. 2006).

The decline in the proportions beginning about dt 900 until about dt 1200 seems to be associated with the period of the retrenchment of population from the Northern San Juan and the San Juan Basin into the Northern Rio Grande at sites like Pecos, Gran Quivira, and into some portions of the Mogollon area, for example Point of Pines. There appears to have been great variability in P(5–19) values in sites in these destination areas, though, and some large, late assemblages with high P(5–19) values—especially San Cristobal, Hawikku, and Grasshopper—raise the fitted curve unexpectedly, on the eve of the Spanish entrance to the Southwest in 1540.

Discussion

Possible Problems with the P(5–19) Proportion

Of course, we expect the P(5–19) measure to be noisy for a variety of reasons relating to the archaeological and analytical contexts, including but not limited to possible variability through time and space in mortuary practices and preservation for children and adolescents vs. adults; differences in analytic standards for (and expertise in) determining ages for human remains; changes through time in how these decisions are made by bioarchaeologists; sampling error; and so forth. To the extent that these are random errors they will weaken but not bias the fitted relationship between the P(5–19) value and time relative to agricultural innovation.

There are as well processes in the systemic context that may tend to bias the signal, and these are of somewhat greater importance. The first of these is worthy of mention but possibly not of great concern in itself, since while it may lead to local anomalies in P(5–19), these should be balanced out in the regional data sets compiled in Table 1. This is the recent discovery by Kramer (2002) that Chacoan centers, in at least the eleventh and thirteenth centuries, seem to be importing women from outlying regions, possibly through raiding activities.

Although this effect per se might not bias our results when these are averaged over large enough spaces, the warfare that probably underlies these patterns might cause biases. Warfare differentially affects young adults and could therefore, in principle at least, raise the P(5–19) values in some of the assemblages considered here.

Kramer (2002) constructed life tables for many of the composite samples reported in Table 1 and compared the tables she constructed for each century in each region, with a composite table constructed from all the samples in that region, aggregated through time. Specifically, she compared the cumulative proportions of the numbers of individuals in each category, after smoothing as outlined by Weiss (1973), between each temporally specific subsample and the entire population from that region, including that subsample, using a Kolmogorov–Smirnov test. This approach is obviously conservative because the sample from each century also contributes to the regional distribution with which it is being compared and also, to a smaller extent, because of the smoothing before the test.

In the San Juan Basin region, only one century, the 1200s, is anomalous on this measure, with significantly more individuals in the 6- to 25-year-old age groups than in the regional sample pooled by period, and as a result, fewer individuals in the 36- to 55-year-old age categories (Kramer 2002:67). Indeed, we can see in Figs. 3 and 4 that this sample (SJ1250) has the highest P(5–19) value in our entire Southwest data set, although, since the sample size is relatively small, its effect on the fitted line is not large.

A similar, though slightly weaker, effect is seen in the contemporaneous assemblages from the Northern San Juan region to the north. In the 1200s, all age categories between 3 and 25 years are over-represented relative to the assemblage representing all *other* periods from that region (Kramer 2002:91). This effect is no longer statistically significant, though, if the assemblages from the 1200s are included in the composite assemblage with which the 1200s are being compared. It is not surprising then to see that the data point for this century (NSJ1250) is slightly above the fitted line in both Figs. 3 and 4, though it is not among the highest proportions in the data set.

Taken together, we can conclude that the P(5–19) proportions are at least somewhat affected by warfare-related processes in the Southwest, conflating as they do the high values for these proportions due to depressed denominators reflecting high mortality in young adults due to warfare, with the high values due to high numerators for the proportions that the index is designed to measure.

Other Patterns of Interest

Despite these problems—and beyond the NDT signal itself—there appear to be signals in Figs. 3 and 4 of interest to regional specialists. We note, for example, that the P(5–19) value tends to decline through time at Pecos (at the far eastern edge of the Pueblo world); and that the Gallina subregion of the Northern Rio Grande, which lies at the northeastern edge of the Pueblo world, tends to also have low growth rates. Indeed, some of the highest growth rates, as proxied by P(5–19) values, tend to be in regions that lie toward the center of the Southwest, perhaps suggesting that the reason they were at the center is that they were able to export population in various directions. Peripheral areas supported lower growth rates, contributing to their peripherality.

The second increase in the fitted line, in both Figs. 3 and 4, is not anticipated by the NDT model itself, though it has a possible analog in the second bump seen in Fig. 4 of Bocquet-Appel (2002:645) that appears to correspond, in general, to Chalcolithic sites with a megalithic aspect that are often considered to reflect a more hierarchical form of sociopolitical organization than the earlier Neolithic sites. In our sample, following the logic of the NDT model, the highly aggregated nature of late sites such as Hawikku, San Cristobal, Grasshopper, and Paquimé would lead us to anticipate low values for the P(5–19) measure, but in fact their values are high, and in conjunction with their large samples, cause the second increase in our fitted lines. We are not certain what economic or social organizational factors may contribute to the apparently high growth rates in such sites,[4] but this model throws them into relief as worthy of explanation.

Independent Corroboration for a Late Southwestern NDT

Brian Kemp (2006) recently analyzed mitochondrial DNA (mtDNA) variation in 897 individuals from 13 populations in Mesoamerica and the American Southwest—a much larger sample than those previously available for these regions. These individuals represented all the mtDNA haplogroups (A, B, C, D, and X) known for Native American populations. Kemp sampled individuals from groups speaking languages in the Uto-Aztecan family preferentially but not exclusively.

His results for haplogroup B are relevant to this chapter. This haplogroup, which was exhibited by 315 individuals, is particularly common in the US Southwest, occurring in highest frequencies in populations with a Pueblo affiliation ("Anasazi" [Carlyle et al. 2000], $n = 25$, 60 percent B; Jemez, $n = 71$, 86 percent B; Zuni, $n = 50$, 76 percent B; but by contrast, e.g., Akimel O'odham, $n = 146$, 47 percent B; Aztecs, $n = 37$, 16 percent B).

One major clade within this haplogroup exhibits a particular transition that was seen only in the Southwestern populations, and never in the Mesoamerican populations, so long as the Cora and Huichol, who exhibit this transition, are included in the "Greater Southwest" (Beals 1974). In fact, this clade was represented in every Southwestern population sampled. Kemp calculates that the expansion of this clade dates to 2,105 BP (99.5% CI $\pm$ 1, 273–3, 773 BP). This confidence interval encompasses the mid-first-millennium-AD date reported here for marked increase in growth rates accompanying the NDT in the Southwest.

Dean, Doelle, and Orcutt (1994:73–76) attempted to make pan-Southwestern population estimates by abstracting estimates from the available archaeological literature. These measures ultimately depend on site counts and sizes by phases, not by human remains, as used here. Their tabulation begins at AD 100 and ends at AD 1600. They reconstruct a rapid population increase beginning around AD 550, with population peaking around AD 1000, remaining high until AD 1200, and then declining irregularly until the end of the period they plot. The sharp mid-first millennium increase, as they point out, is not entirely credible, since it is influenced by the first availability of Hohokam-region population estimates at AD 600. If it were possible to control for that effect, they suggest, the increase would be more gradual, ramping up more slowly in the first half of the first millennium AD, but with, likely, a significant increase at that time.

Potential Issues

While this discussion focuses on changing demographic patterns subsequent to a point *dt*, these changes are understood to reflect a departure from long-term hunter-gatherer growth rates occurring prior to this transition. It should be noted, however, that this implicit contrast between population trends on both sides of the *dt* axis is based on the reconstruction of a synthetic population using individual points ordered through a relative chronology and not by linear time. Long-term hunter-gatherer population trends are unlikely to be meaningfully ordered in relation to an unknown future event, especially when the hypothesized demographic transition occurs at different times across this region. An ordered demographic process among hunter-gatherers is more likely to be affected by regional or pan-regional climactic trends occurring in linear time. This issue is unlikely to seriously affect such analyses, given the paucity of large pre-agricultural cemeteries, as well as the predominant focus on events post-dating the transition. It should serve as a cautionary note, however, especially when comparing features of the curve predating the event by which the chronology is ordered.

Conclusions

An NDT is visible in the US Southwest, but it appears much later than the earliest appearance of maize in the region (at ca. 2000 BC), providing another piece of evidence that earliest maize merely supplements a hunter-gatherer lifestyle without fundamentally altering it. Somewhat more surprisingly, the NDT also lags the earliest intensive use of maize, measured here by the appearance of ceramic containers in this region at ca. AD 300, though by a much shorter period.

The NDT, when it finally arrives, is built on the shoulders of earlier accomplishments, including the development of ceramic containers, coupled with newly arrived (or newly developed) races of maize that help make it possible to dry-farm many new areas, including some very productive mesa tops in portions of the Northern San Juan region. But before this niche can be fully developed, given the higher risk of dry farming relative to earlier forms of water-managed maize production, a way of efficiently storing and exchanging agricultural surpluses must be found. The explosive growth in places like the central Mesa Verde portions of the Northern San Juan region (Varien et al. 2007) and its accompanying Pueblo I villages (Wilshusen and Perry 2006) is the most obvious result, though less obvious population growth in other portions of the Southwest benefiting from dry farming is also probable. That these early villages appear when and where they do is logical if, as Kohler and Van West (1996) argue, such villages make possible, for the first time, durable patterns of efficient exchange among non-kin of relatively bulky goods such as maize.

Prior to the development of these villages, habitation sites, usually referred to as hamlets, appear to have been composed of a single kin group which probably practiced internally a form of generalized reciprocal exchange. Villages, on the other hand, contain several hamlet-scale roomblock units. We infer that exchange among households across roomblocks was important in the success of these villages, and that such exchanges would have been structured through balanced reciprocal exchange. This would have greatly increased the role of such exchanges in these societies, ultimately allowing much more efficient allocation of production among all households in the village. Agent-based modeling exercises on virtual landscapes resembling those used by these early villages (Kobti et al. 2006; Kohler et al. 2007) are investigating the affects of various exchange practices on population size, aggregation, and degree of settlement permanence.

Although the measure of the NDT proposed by Bocquet-Appel for Europe is not without its problems, we conclude that it gives us a new and powerful way of looking directly at the degree of reproductive success of the new Neolithic (or Formative) way of life in the US Southwest. This way of life developed slowly over 3000 years, rather than spreading dramatically at the expense of foragers or their lifestyles at its earliest appearance. Nevertheless, by midway through the first millennium AD, a threshold was reached allowing much more rapid growth. For the next 600 years or so, southwestern societies explored new sociopolitical arrangements allowing them to cope with the larger group sizes resulting from this growth. A feature of these periods, known in the Pueblo area as the Pueblo I and Pueblo II periods, is that their innovations focused more on competitive success in this new sociopolitical environment, than on innovations in food-getting. It was one of those rare periods in human history where populations found themselves, for a time at least, well below the carrying capacities of their natural environments.

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Notes

1. All dates in this chapter are either general dates, tree-ring-based dates, or calibrated ^{14}C ages.
2. We made chronological subdivisions within aggregated assemblages reported by Bocquet-Appel and Naji (2006:349) for Black Mesa and Pecos Pueblo, and we did not use their data for Mesa Verde and Pueblo Bonito, since these were included in more chronologically precise fashion in the data assembled by Kramer.

3. SAS v. 9.1.3, PROC LOESS. 80% confidence intervals are displayed around the fitted line.
4. Though we have some suspicions; Kohler et al. (2004) have pointed to the proto-market forces visible in Classic period (late fourteenth century through early sixteenth century) towns in the Northern Rio Grande and suggested that this vibrant new economic organization, which is accompanied by novel forms of ceremonial organization, contributes significantly to the success of these large aggregates.

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