

# Migration and Environmental Learning in Interstitial Areas: An Example from the Northern Rio Puerco Valley, New Mexico

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## Abstract

In this paper we illustrate the potential of interstitial areas, as distinct from both cores and peripheries, for understanding migration and environmental learning among maize farming populations. We analyze settlement data derived from pedestrian survey of a portion of the Rio Puerco (of the East) watershed in north-central New Mexico. Our exploratory analyses are suggestive of interesting patterns that speak to larger debates in the region, including the extent of the Gallina culture and migration pathways from the San Juan to Rio Grande drainage. Ceramic seriation with updated ceramic data indicates that residents of the survey area had shifting affiliations, with waves of migration from the Chaco, Mesa Verde, and Cibola regions, starting in Early Pueblo II and continuing through Late Pueblo III. Our analyses further refine the chronology and population dynamics of the region. We also provide evidence of settlement scaling, dynamic farming adaptations, and a history of burning at archaeological sites.

**Keywords:** Interstitial Settlement, Migration, Seriation

**Target Journals:** Open Archaeology

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# Introduction

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Early settlement pattern research in North America tended to focus on core areas characterized by a relatively high population density and a well-defined material culture tradition, such as the Mississippi River Valley (Phillips et al., 2003), Chaco Canyon in New Mexico (Hayes et al., 1981), or Mesa Verde in Colorado (Hayes, 1964; Rohn, 1977). However, as survey work has become increasingly associated with cultural resource management, settlement pattern data have accumulated from peripheral areas with lower population densities and “weaker” material culture patterns. We believe it is productive to subdivide these peripheries into interstitial vs. frontier regions: the former are areas that lay between multiple core areas, sometimes referred to as joint-use territories; and the latter are areas at the edge of a core region that were settled by migration from the adjacent core (Herr & Harry, 2018). Herr (2001) frames the distinction between cores and peripheries in terms of the relative demand for land and labor, with core areas having abundant labor and limited land, and peripheries having abundant land and limited labor. This leads people in peripheral areas to seek more extensive social connections (Duff, 2002), resulting in enhanced cultural diversity and enhanced raw material for social innovation (Lightfoot & Martinez, 1995).

Interpretation of settlement data from interstitial areas follows different principles than are appropriate for frontiers and core areas. For example, in core areas, one would expect population growth to reflect prosperity related to environmental conditions, social development, or both; and in frontiers one would expect population growth to follow that of the associated core as population spills out of it. Also, whereas core areas and frontiers are typically characterized by a well-defined material culture tradition whose development can be traced over long periods of time; interstitial areas are typically characterized by mixtures of material cultures associated with successive waves of migration or influence from different core areas. As a result, traces of migration are often easier to identify in interstitial areas than they are in core areas. Finally, whereas core areas are typically settled by large populations over long periods, during which knowledge of the local environment accumulates and is maintained by the social network, interstitial areas are often resettled multiple times by small groups of people who have less prior knowledge of how to make a living in the local environment. As a result, the archaeology of interstitial areas provides a record of the process by which small groups accumulate environmental knowledge, reflected in differing agricultural strategies associated with each episode of migration.

In this paper we illustrate the potential of interstitial areas for these topics by analyzing settlement data derived from pedestrian survey of a portion of the Rio Puerco (of the East) watershed in north-central New Mexico. The Rio Puerco originates in the Sierra Nacimiento and

flows southward for about 370 km to its confluence with the Rio Grande, about 80 km south of Albuquerque. The study area encompasses about 480 square kilometers (185 sq.miles) and is located about 5 miles south of present-day Cuba, New Mexico (see Figure 1). It is also roughly equidistant from Santa Fe to the east, Albuquerque to the south, and Chaco Culture National Historical Park to the west. Prominent landforms visible from within the study area include Cabezon Peak and Mesa Prieta to the south, the Sierra Nacimiento to the east, and the continental divide to the north. The study area sits in an interstitial area between several centers of ancestral Puebloan culture, including the San Juan drainage to the northwest, the Cibola region to the southwest, the Gallina region to the northeast, and the Northern Rio Grande region to the southeast. As we will show, groups affiliated with distinct cultural traditions settled the area at different times and developed different sets of environmental knowledge, reflected in differing agricultural strategies associated with each episode of migration.

The study area is also important for regional archaeology because it lies along a likely migration route taken by northern San Juan populations as they relocated to the Rio Grande drainage during the late 13th century (Varien, 2010). This specific episode led to a shifting of the demographic center of gravity of Puebloan society from the San Juan to the Rio Grande drainage, where most Puebloan peoples live today. Indeed, the study area is about 50 km north of the present-day pueblos of Zia and Jemez, and it seems likely that at least some residents of these pueblos are descendants of the people who lived in the study area. Adjacent areas have received some previous attention by archaeologists. Baker & Durand (2003) describe settlement patterns of the Guadalupe and Mesa Prieta areas south of Cabezon Peak; and Pippin (1987) reports on excavations at the southeastern-most Chaco great house at Guadalupe Ruin, also south of Cabezon Peak. Nevertheless, other than a summary paper by Roney (1995), the study area itself has received only cursory attention prior to this work.

The fieldwork reported here was conducted by Shiffler between June 2018 and October 2021 at the request of the Bureau of Land Management, which manages the study area today. Four survey areas were covered, which we will refer to as Mesa Portales, Jones Canyon, Elk Springs, and the Rio Puerco Floodplain (see Figure 1). The BLM requested a resurvey of these areas because previous researchers have offered differing interpretations of the cultural affiliations of the sites. For example, Roney (1996) considers Mesa Portales and Jones Canyon to be within the Eastern San Juan Basin, with the Gallina culture area to the north, while (Borck, 2017 [Figure 1]; see also Borck, 2018, fig. 4.1) includes these areas within an extended region containing Gallina culture sites. The survey was intended to clarify the cultural affiliations of archaeological sites in the area. In addition to the Gallina culture, the compiled evidence suggests affiliations with the San Juan, Cibola, and Northern Rio Grande traditions. Results also show that the region was settled by successive waves of people associated with these ancestral Pueblo traditions, and that in at least one case the immigrants strove to maintain their homeland material culture for generations after arrival.

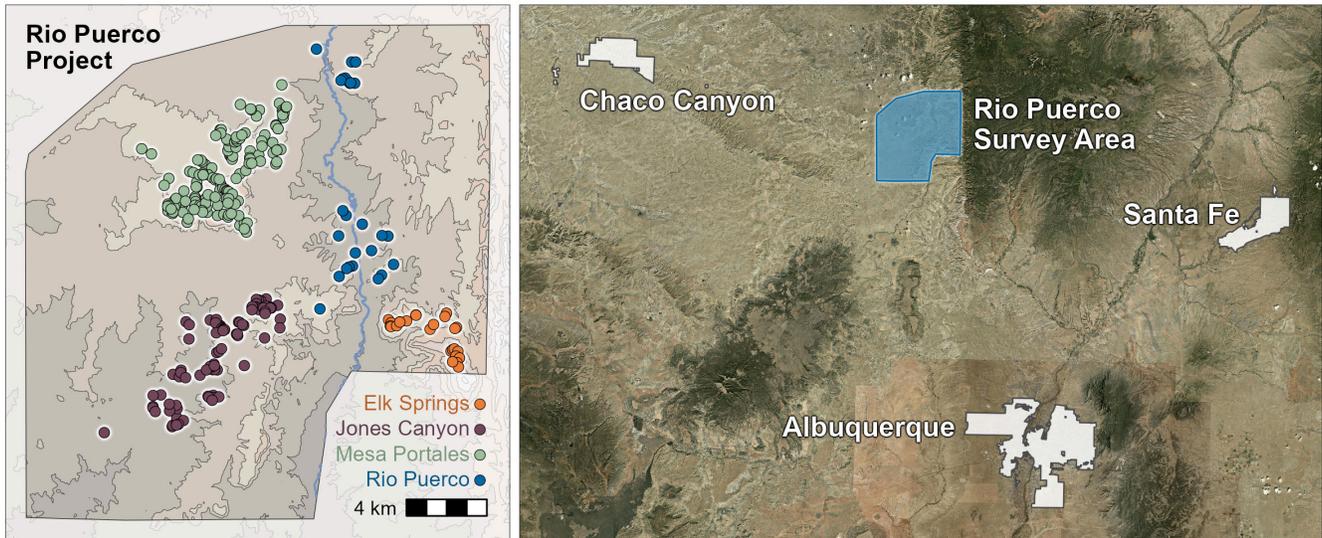


Figure 1: Overview map showing location of sites and their spatial grouping (left) and location of survey area in the wider region (right).

## Survey Methods

Between 2018 and 2021, Shiffler completed an exhaustive inventory of all residential sites in the project area using standard pedestrian survey. The research area was first accessed by vehicle, then previously recorded sites were revisited and re-recorded. From these sites, Shiffler conducted extensive surveys, typically following landforms and excluding steep slopes in excess of approximately 45 degrees. GPS mapping was conducted for each recorded site using a Garmin GPSMAP 66, which has a mean spatial error of approximately 8 feet (roughly 2.4 m). Coordinates were corroborated using a Garmin eTrex. The coordinate reference for spatial data recorded on this project was NAD83 UTM Zone 13N (EPSG: 26913). Site boundaries are based on the observed extent of the artifact scatter, with the total estimated site area measured as the product of the maximum length along each primary axis, both of which are defined by the orientation of the site. No attempt was made to systematically inventory isolated artifacts at non-residential locations.

We infer each residential site's cultural affiliation based on the dominant ceramic tradition reflected in its ceramic assemblage, with Shiffler's in-field ceramic type classifications based on three sources: Winston Hurst's system for Rio Puerco and San Juan wares as reported in (Baker & Durand, 2003), Roy Carlson's system for White Mountain Red Wares in (Carlson, 1970), and H.P. Mera's system for Northern Rio Grande wares as reported in (Mera, 1939). [Schiffler also tracked the presence vs. absence of mica in Northern Rio Grande gray wares by separating smeared-indented corrugated (no mica) from Tesuque Gray (smeared-indented corrugated with mica).] To learn these systems better, Shiffler visited sites across New Mexico and Arizona where he could observe sherds of the relevant traditions in core area sites. [Most sites recorded by the survey

contain mixtures of sherds from distinct ceramic traditions, indicating that broad and diverse social connections were the norm in this region. Nevertheless, sherds from a single tradition predominate at most sites, and we treat this as evidence of the primary cultural affiliation, or ancestral homeland, of the residents, following] Duff (1998). See Table 1 and Table 2 for summaries of ceramic types and frequencies across subregions and time periods in the survey area and Figure 2 for for summary distributions of wares across regions and time periods. For lithic identification, categories from (Baker & Durand, 2003; Bice & Sundt, 1972, 1976; Powers & Orcutt, 1999) were used.

Artifact tallies were obtained by first locating middens, then applying an arbitrary 2x2 meter square to the area with the largest observed density of surface material. Complete sampling was then performed within that square. This was done for each midden on a site to capture peak artifact density. To measure roomblock area, Shiffler used a combination of simple shapes that captured the outlines of mound areas with the least distortion. The presence of courtyards was assumed whenever enclosed intramural spaces surrounded by buildings were found. Similarly, plazas were inferred on sites with observed areas framed on two sides by buildings and on the other sides by enclosing walls. Finally, kivas were identified as circular depressions, some with masonry around the perimeter.

## Results

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The Rio Puerco survey formally recorded or re-recorded 294 sites: 26 in Elk Springs, 91 in Jones Canyon, 150 on Mesa Portales, and 27 within the Rio Puerco Floodplain. While these sites had similar layouts, patterning is discernible between the four survey areas. Pottery documented at these sites include 41 separate types grouped into 13 wares. Of those types, 13 are utilitarian gray wares and 28 are decorated types. In general, Cibola White Wares are common everywhere except Elk Springs; Gallina Gray and White Wares are overrepresented in the Rio Puerco Floodplain; Jemez White Wares and Mogollon Brown Wares are most prevalent on Mesa Portales and in Jones Canyon; Northern Rio Grande Gray Wares and White Wares are also common on Mesa Portales and in Jones Canyon, though a substantial amount of the latter ware occurs at Elk Springs, too; Rio Abajo White Wares are found most often on Mesa Portales; Rio Puerco Gray Wares occur everywhere, but the largest number were found in the Mesa Portales and Jones Canyon survey areas; and Rio Puerco White Wares occur most frequently in the Mesa Portales and Jones Canyon survey areas, as do San Juan Gray Wares and White Wares, and White Mountain Red Wares.

For the most part the pottery types observed date from the Pueblo II through Pueblo III periods, roughly 900-1300 CE. The one exception to this is the presence of Biscuit A sherds in Jones Canyon. The presence of this post-1300 type, combined with the absence of Wiyo Black-on-

white, suggests return visits by people who had relocated to the Pajarito Plateau as opposed to continued occupation or trade.

Table 1: Ceramic Assemblages for Each Survey Area

		<b>Elk Springs</b>	<b>Jones Canyon</b>	<b>Mesa Portales</b>	<b>Rio Puerco</b>
<b>Cibola White Ware</b>					
Cebolleta Black-on-white	950-1150	0	25	5	17
Chaco Black-on-white	1075-1150	0	0	8	28
Gallup Black-on-white	980-1150	0	17	12	95
Puerco Black-on-white	1000-1150	0	56	53	92
Red Mesa Black-on-white	875-1050	0	13	3	40
Reserve Black-on-white	1000-1200	2	90	406	27
Tularosa Black-on-white	1150-1300	0	84	0	0
Undiagnostic Cibola White	875-1200	0	102	57	40
<b>Gallina Gray Ware</b>					
Gallina Utility	1050-1300	0	38	6	378
<b>Gallina White Ware</b>					
Gallina Black-on-white	1050-1300	0	24	0	107
<b>Jemez White Ware</b>					
Jemez Black-on-white	1300-1700	0	45	80	5
Vallecitos Black-on-white	1250-1400	0	53	35	4
<b>Mogollon Brown Ware</b>					
Alma Plain	200-1250	0	27	390	12
Reserve Corrugated	1050-1300	0	35	268	29
Reserve Indented Corrugated	1050-1300	3	95	186	10
Reserve Indented Corrugated Smearred	1050-1300	0	53	57	4
Tularosa Fillet Rim	1050-1200	0	20	5	0
<b>Northern Rio Grande Gray Ware</b>					
Smearred Indented Corrugated	1250-1450	0	1079	725	14
Tesuque Gray	1250-1450	28	42	9	56
<b>Northern Rio Grande White Ware</b>					
Biscuit A	1350-1450	0	14	0	0
Kwahe'e Black-on-white	1050-1200	16	82	290	32
Santa Fe Black-on-white	1150-1350	276	469	372	32

		<b>Elk Springs</b>	<b>Jones Canyon</b>	<b>Mesa Portales</b>	<b>Rio Puerco</b>
<b>Rio Abajo White Ware</b>					
Socorro Black-on-white	900-1350	0	139	84	11
<b>Rio Puerco Gray Ware</b>					
Corrugated	1000-1350	20	363	620	168
Exuberant Indented Corrugated	950-1300	0	41	18	246
Indented Corrugated	950-1300	577	1688	2084	247
Plain Gray	700-1450	61	1918	2598	524
<b>Rio Puerco White Ware</b>					
Casa Salazar Black-on-white	1150-1225	0	109	161	10
Loma Fria Black-on-white	1150-1280	0	425	427	7
Loma Fria Black-on-white, ext. paint	1225-1280	0	59	60	0
<b>San Juan Gray Ware</b>					
Mummy Lake Gray	1050-1200	0	195	101	0
<b>San Juan White Ware</b>					
McElmo Black-on-white	1075-1250	0	381	1067	54
Mesa Verde Black-on-white	1150-1280	0	601	481	9
Mesa Verde Black-on-white, ext. paint	1225-1280	0	83	71	0
Undiagnostic San Juan White	1075-1280	4	385	193	19
<b>White Mountain Red Ware</b>					
North Plains Black-on-red	1050-1150	0	13	10	9
Puerco Black-on-red	1030-1150	0	17	56	21
Saint Johns Black-on-red	1150-1300	10	145	200	2
Saint Johns Polychrome	1150-1300	0	98	122	2
Wingate Black-on-red	1030-1175	2	121	132	50
Wingate Polychrome	1030-1175	0	56	26	4

Table 2: Ceramic Assemblages for Each Time Period

		<b>Pueblo II</b>		<b>Pueblo III</b>		
		<b>Early</b>	<b>Late</b>	<b>Early</b>	<b>Middle</b>	<b>Late</b>
<b>Cibola White Ware</b>						
Cebolleta Black-on-white	950-1150	0	17	5	25	0
Chaco Black-on-white	1075-1150	27	9	0	0	0
Gallup Black-on-white	980-1150	66	47	3	8	0

		Pueblo II		Pueblo III		
		Early	Late	Early	Middle	Late
Puerco Black-on-white	1000-1150	36	64	47	52	2
Red Mesa Black-on-white	875-1050	30	23	0	3	0
Reserve Black-on-white	1000-1200	0	6	419	84	16
Tularosa Black-on-white	1150-1300	0	0	0	64	20
Undiagnostic Cibola White	875-1200	14	30	58	92	5
<b>Gallina Gray Ware</b>						
Gallina Utility	1050-1300	283	123	0	16	0
<b>Gallina White Ware</b>						
Gallina Black-on-white	1050-1300	83	32	0	16	0
<b>Jemez White Ware</b>						
Jemez Black-on-white	1300-1700	0	2	0	10	118
Vallecitos Black-on-white	1250-1400	0	0	7	37	48
<b>Mogollon Brown Ware</b>						
Alma Plain	200-1250	0	6	375	40	8
Reserve Corrugated	1050-1300	0	0	292	25	15
Reserve Indented Corrugated	1050-1300	0	4	154	94	42
Reserve Indented Corrugated Smearred	1050-1300	0	3	25	29	57
Tularosa Fillet Rim	1050-1200	0	5	0	11	9
<b>Northern Rio Grande Gray Ware</b>						
Smearred Indented Corrugated	1250-1450	0	7	9	409	1393
Tesuque Gray	1250-1450	0	62	3	11	59
<b>Northern Rio Grande White Ware</b>						
Biscuit A	1350-1450	0	0	0	9	5
Kwahe'e Black-on-white	1050-1200	2	16	294	51	57
Santa Fe Black-on-white	1150-1350	0	25	53	276	795
<b>Rio Abajo White Ware</b>						
Socorro Black-on-white	900-1350	0	0	100	109	25
<b>Rio Puerco Gray Ware</b>						
Corrugated	1000-1350	90	67	566	252	196
Exuberant Indented Corrugated	950-1300	173	98	3	31	0
Indented Corrugated	950-1300	47	149	1502	1098	1800
Plain Gray	700-1450	167	213	2495	1138	1088

		Pueblo II		Pueblo III		
		Early	Late	Early	Middle	Late
<b>Rio Puerco White Ware</b>						
Casa Salazar Black-on-white	1150-1225	0	9	184	57	30
Loma Fria Black-on-white	1150-1280	0	10	0	132	717
Loma Fria Black-on-white, ext. paint	1225-1280	0	0	0	13	106
<b>San Juan Gray Ware</b>						
Mummy Lake Gray	1050-1200	0	0	6	129	161
<b>San Juan White Ware</b>						
McElmo Black-on-white	1075-1250	0	12	1017	272	201
Mesa Verde Black-on-white	1150-1280	0	3	2	258	828
Mesa Verde Black-on-white, ext. paint	1225-1280	0	0	0	12	142
Undiagnostic San Juan White	1075-1280	0	11	112	214	264
<b>White Mountain Red Ware</b>						
North Plains Black-on-red	1050-1150	0	5	10	0	17
Puerco Black-on-red	1030-1150	18	11	57	8	0
Saint Johns Black-on-red	1150-1300	0	2	0	82	273
Saint Johns Polychrome	1150-1300	0	2	0	59	161
Wingate Black-on-red	1030-1175	18	45	82	109	51
Wingate Polychrome	1030-1175	2	2	13	37	32

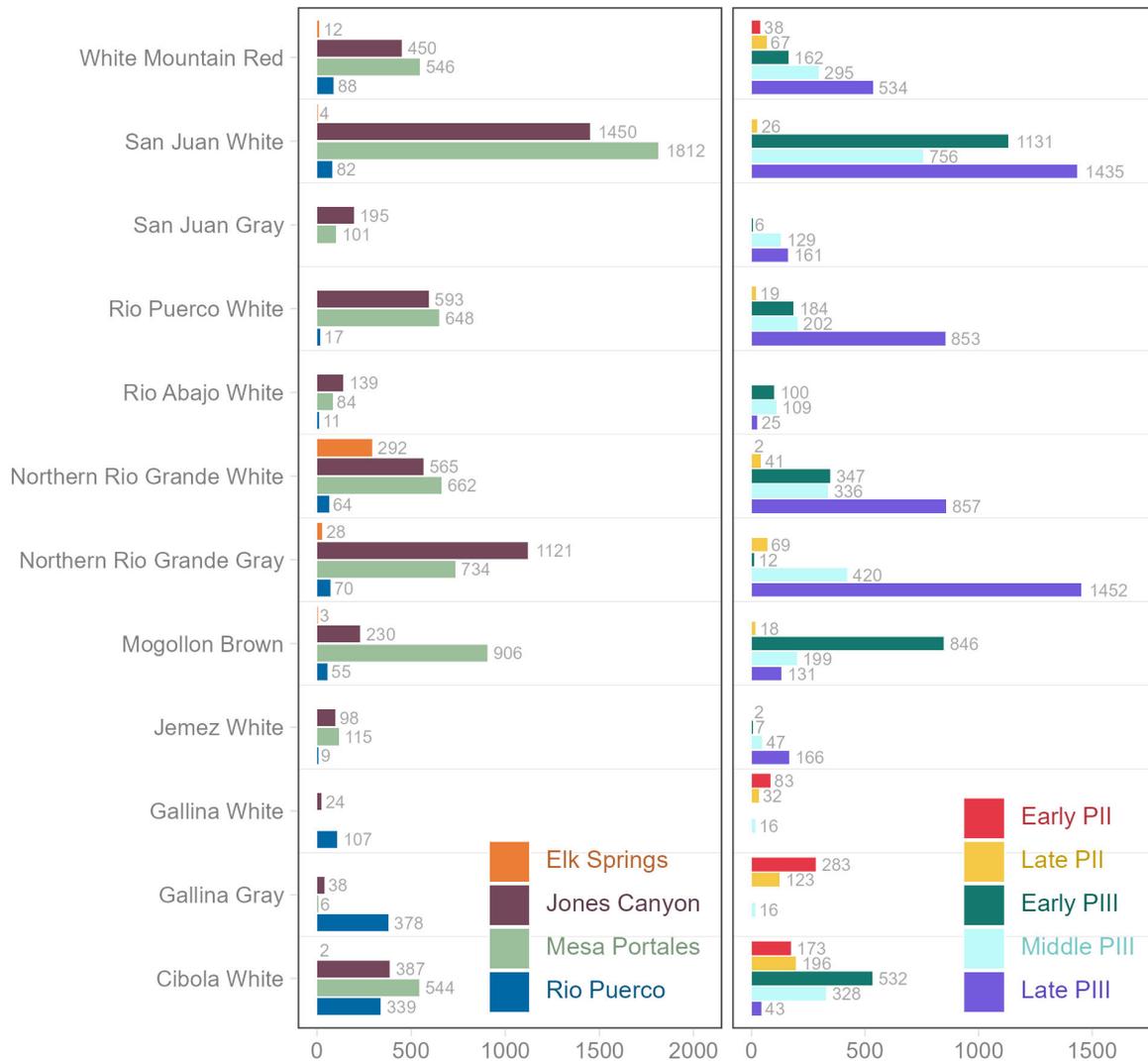


Figure 2: Figure shows spatial and temporal distribution of ceramic wares.

## Settlement Chronology

To establish a simple relative chronology for the study area, we order sites and their occupational sequences using seriation. For this we rely on a standard ordination technique known as correspondence analysis (CA), as it reduces the highly dimensional ceramic assemblages found at each site to a smaller set of principal components that we can interpret as axes of time (Baxter, 2003; Lyman et al., 1998). The dataset for the correspondence analysis includes 292 of the 294 sites and all 28 decorated ceramic types (two sites did not have any decorated ceramics). These data are stored in a count matrix with 292 rows and 28 columns. The CA is an operation on this count matrix. The results of the CA are shown in Figure 3.

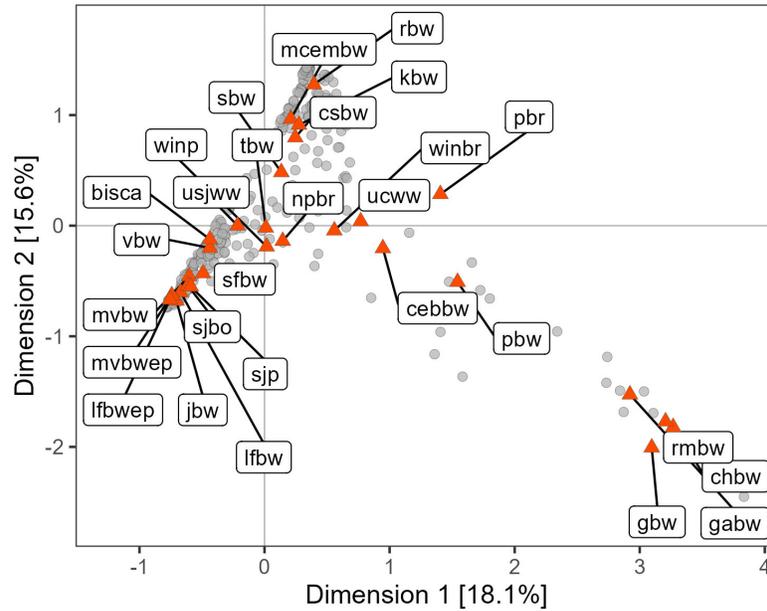


Figure 3: Results of correspondence analysis with gray points representing principal (row) coordinates for sites and orange triangles representing principal (column) coordinates for ceramic types. The type keys are as follows. Black-on-white types include Chaco (chbw), Red Mesa (rmbw), Gallup (gabw), Gallina (gbw), Cebolleta (cebbw), Puerco (pbw), Reserve (rbw), Kwahe'e (kbw), McElmo (mcembw), Casa Salazar (csbw), Socorro (sbw), Tularosa (tbw), Vallecitos (vbw), Santa Fe (sfbw), Mesa Verde (mvbw), Loma Fria (lfbw), and Jemez (jbw). Black-on-white with external panel design: Mesa Verde (mvbwep) and Loma Fria (lfbwep). Undiagnostic White Ware: Cibola (ucww) and San Juan (usjww). Black-on-red or orange: Puerco (pbr), Wingate (winbr), North Plains (npbr), and Saint Johns (sjbo). Other: Wingate Polychrome (winp), Biscuit A (bisca), and Saint Johns (sjp) Polychrome.

After conducting the CA, we then apply k-means clustering to the first two dimensions of the principal coordinates of the sites (represented by the rows in the frequency matrix). This is an efficient method that minimizes the variance within each group, here the variance in the principal coordinates within each group (Duff, 1996). We interpret the resulting clusters in terms of time, so this application of k-means can loosely be thought of as ensuring that sites within a group were likely occupied more closely in time relative to the other groups. Based on our understanding of these ceramic traditions, we choose  $k = 5$  groups for clustering. We interpret these as Early and Late Pueblo II and Early, Middle, and Late Pueblo III. The overlay of these interpretations are shown in the biplots in Figure 4.

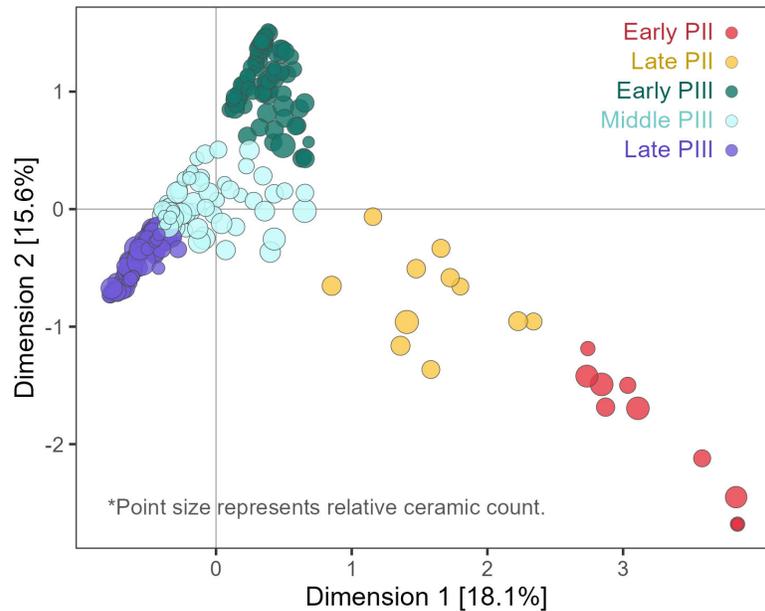


Figure 4: Results of correspondence analysis with site points color-coded by time period. Time period assignments are the result of k-means clustering applied to the results of the correspondence analysis. Point size represents the relative size of the ceramic assemblage.

Based on the placement of types within the first two axes of the CA output, Chaco, Red Mesa, Gallup, and Gallina Black-on-white are characteristic of Early Pueblo II (950-1050 CE). Cebolleta and Puerco Black-on-white and Puerco Black-on-red indicate a Late Pueblo II (1050-1150 CE) occupation. Reserve, Kwahe'e, McElmo, and Casa Salazar Black-on-white suggest an Early Pueblo III (1150-1200 CE) occupation. Middle Pueblo III (1200-1250 CE) is characterized by non-diagnostic Cibola and San Juan White Ware; Wingate and North Plains Black-on-red; Socorro, Tularosa, and Vallecitos Black-on-white; and Wingate Polychrome. A Late Pueblo III (1250-1300 CE) occupation is suggested by Santa Fe, Mesa Verde, Loma Fria, and Jemez Black-on-white; Mesa Verde and Loma Fria Black-on-white with external panel designs; Saint Johns Black-on-orange; and Saint Johns Polychrome. A few Biscuit A sherds were also found on some Middle and Late Pueblo III sites in Jones Canyon and likely reflect post-occupational return visits by descendants of residents who had relocated to the Pajarito Plateau. For additional context, Table 1 shows the combined assemblages for ceramic types for each region, and Table 2 shows the combined ceramic assemblages for each time period.

This chronology suggests that the various survey areas have distinct histories of settlement (see Figure 5). Early and Late Pueblo II sites are found almost entirely along the Rio Puerco Floodplain, with just a small fraction on Mesa Portales and in Jones Canyon. Early Pueblo III sites are more or less restricted to the northern portion of Mesa Portales, though a handful can be found along the Rio Puerco. Some Middle Pueblo III sites are found on Mesa Portales and at Elk Springs, but the vast majority occur in Jones Canyon. Finally, Late Pueblo III sites are found on

the southern side of Mesa Portales, in Jones Canyon, and at Elk Springs. We also note that no PII sites occur at Elk Springs, and only a handful of PIII sites are found in the Rio Puerco Floodplain.

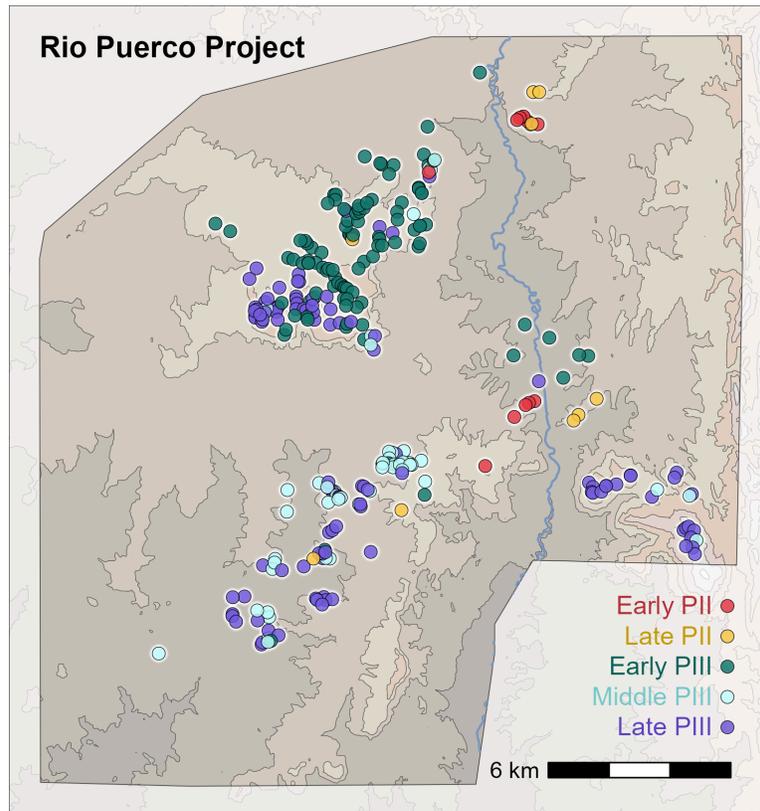


Figure 5: Settlement pattern by time period.

## Cultural Affiliation

It would seem that Pueblo II farmers along the Rio Puerco Floodplain are associated with both Chaco and Gallina traditions as they include roughly equal amounts of Gallina gray and white wares and Cibola white wares, including Chaco and Cebolleta Black-on-white. The Early Pueblo III farmers on the northern slope of Mesa Portales appear to be a mixed population, with some proportion showing affiliation with the southern Cibola region, and others showing affiliation with Mesa Verde. This is evidenced by the fact that most of the Mogollon Brown Ware is found on these Early Pueblo III sites, suggesting affiliation with the southern Cibola region (Peeples, 2018), and two-thirds of all the McElmo Black-on-white observed in the study area are also found on these sites, suggesting affiliation with Mesa Verde. Middle Pueblo III sites in Jones Canyon have extremely diverse assemblages, with ceramic types from virtually every tradition present, but they appear to be most closely aligned with the northern Cibola area, particularly given the mixture of Cibola White and White Mountain Red Wares, with the former declining from Early to Late Pueblo III, the latter increasing over that period (Peeples, 2018).

While San Juan, Rio Puerco, and Northern Rio Grande White Wares are also present on these sites, it is not clear that these represent migrations of people from those areas. For one thing, this period represents a nadir for San Juan types during Pueblo III, and while Rio Puerco and Northern Rio Grande White Wares also occur on these sites, they don't reach their maximum levels until Late Pueblo III, and then only in other survey areas.

The Late Pueblo III sites on the southern slope of Mesa Portales, in Jones Canyon, and at Elk Springs offer a more complicated picture of cultural affiliations, as these later sites include large quantities of San Juan, Rio Puerco, Northern Rio Grande, and Jemez White Wares, as well as White Mountain Red Wares. Nevertheless, in each of these survey areas, we interpret the later Pueblo III sites as being established, in one way or another, by people descended from the San Juan Tradition. For Late Pueblo III sites in Jones Canyon, we infer this affiliation from the presence of Jemez White Wares that imply some connection to nearby Jemez Pueblo, where people speak a Tanoan language that likely originated in the San Juan drainage (Ortman, 2012). For Late Pueblo III sites at Elk Springs, the fact that the vast majority of Santa Fe Black-on-white is found there suggests some affiliation with the Pajarito Tradition in the Northern Rio Grande, which is also plausibly related to the migration of Tewa-speaking people from the northern San Juan region into the Northern Rio Grande since the Pajarito Plateau is viewed as one of the destinations of migrating 13th century northern San Juan populations (Kemp et al., 2017; Ortman, 2016). In addition, Duff (1998) has argued that trade wares reflect both homeland and future destination areas of a given population, and by this principle Late Pueblo III residents of Elk Springs would have moved to the Northern Rio Grande in the late 1200s. Finally, Rio Puerco White Wares appear to be local versions of San Juan tradition types, so sites with large portions of Rio Puerco White Wares, like Late Pueblo III sites at the south end of Mesa Portales, likely had some affiliation with the San Juan Tradition as well.

It is also worth emphasizing that San Juan White Wares are very frequent during Early Pueblo III, decline in frequency in Middle Pueblo III, and increase in frequency again in Late Pueblo III. They also occur most often on sites on Mesa Portales and in Jones Canyon. Given the relative dating of those sites, this would suggest that immigrants from the San Juan drainage moved to the northern slope of Mesa Portales in Early Pueblo III and to the southern slope of Mesa Portales and Jones Canyon in Late Pueblo III, with Tewa speakers from Mesa Verde also arriving in the late 13th century and concentrating around Elk Springs.

Table 3: Lithic Distributions Across Survey Areas and Time Periods

	<b>Elk Springs</b>	<b>Jones Canyon</b>	<b>Mesa Portales</b>	<b>Rio Puerco</b>
<b>Early PII</b>				
Chinle Chert	0	0	6	0
Dacite	0	0	0	0

	<b>Elk Springs</b>	<b>Jones Canyon</b>	<b>Mesa Portales</b>	<b>Rio Puerco</b>
Gray Chert	0	0	0	0
Obsidian	0	0	3	0
Petrified Wood	0	0	0	19
Red Chert	0	0	0	27
Red/White Chert	0	0	6	17
Rhyolite	0	0	0	0
White Chert	0	0	10	222
Yellow Chert	0	0	0	4
<b>Late PII</b>				
Chinle Chert	0	0	4	7
Dacite	0	0	0	0
Gray Chert	0	8	2	31
Obsidian	0	5	0	44
Petrified Wood	0	3	0	14
Red Chert	0	9	3	39
Red/White Chert	0	0	4	27
Rhyolite	0	0	0	0
White Chert	0	22	4	92
Yellow Chert	0	3	4	11
<b>Early PIII</b>				
Chinle Chert	0	0	14	3
Dacite	0	11	19	0
Gray Chert	0	30	488	32
Obsidian	0	9	63	7
Petrified Wood	0	3	514	35
Red Chert	0	15	546	20
Red/White Chert	0	18	341	26
Rhyolite	0	3	10	7
White Chert	0	36	670	41
Yellow Chert	0	0	179	11
<b>Middle PIII</b>				
Chinle Chert	0	85	0	0
Dacite	0	58	7	0
Gray Chert	0	130	13	0

	<b>Elk Springs</b>	<b>Jones Canyon</b>	<b>Mesa Portales</b>	<b>Rio Puerco</b>
Obsidian	27	233	42	0
Petrified Wood	0	78	13	0
Red Chert	0	164	44	0
Red/White Chert	0	106	16	0
Rhyolite	0	30	0	0
White Chert	0	371	82	0
Yellow Chert	0	64	9	0
<b>Late PIII</b>				
Chinle Chert	0	21	2	0
Dacite	36	49	46	0
Gray Chert	3	82	53	0
Obsidian	250	283	284	6
Petrified Wood	0	36	8	0
Red Chert	2	139	46	3
Red/White Chert	0	77	17	4
Rhyolite	0	4	0	0
White Chert	8	339	445	9
Yellow Chert	14	48	2	0

Researchers often use site orientation (Table 4, E) and lithic assemblages (Table 3) to associate sites with specific traditions (Kantner & Mahoney, 2000). For instance, Lakatos (2007) suggests that [pit structure] orientation can be used to differentiate sites associated with the San Juan and Rio Grande traditions in the Northern Rio Grande, with San Juan sites being more south-facing, and Rio Grande sites more east-facing. While this simple model is no doubt picking up on an important pattern, our findings present a more complicated picture, especially in Late Pueblo III, when the majority of sites appear to be associated with the San Juan tradition, at least according to our interpretation of the ceramics. During the Late Pueblo III period, sites on Mesa Portales and at Elk Springs are mostly south-facing, while sites in Jones Canyon are mostly east-facing. Windes (1993) argues that orientation is less about affiliation and more an indicator of seasonal habitation, seasonal habitations typically being east-facing and year-round habitations south-facing. Presumably, site size would be correlated with the length of habitation, meaning south-facing sites would be larger on average if orientation were related to seasonality. We do not systematically test this possibility, but a cursory view of the data does not appear to support it. [It also seems to us that orientation may reflect different passive solar adaptations, with summer heat encouraging an orientation away from the afternoon summer sun, and winter cold encouraging an orientation toward the winter sun during the day. If so, one would expect the

optimal orientation to co-vary with latitude as much as with cultural tradition.] Additional research should be conducted to properly evaluate these possibilities.

Table 4: Site Characteristics by Time Period and Region

		Early PII	Late PII	Early PIII	Middle PIII	Late PIII
<b>A. N Sites</b>	Elk Springs	0	0	0	3	23
	Jones Canyon	0	2	4	44	40
	Mesa Portales	1	1	94	10	44
	Rio Puerco	10	8	7	0	1
<b>B. Area</b> [total m <sup>2</sup> ]	Elk Springs	0.00	0.00	0.00	211.12	1648.79
	Jones Canyon	0.00	284.96	448.06	4575.03	5531.77
	Mesa Portales	14.00	143.04	7296.94	669.78	5878.69
	Rio Puerco	794.46	600.09	533.43	0.00	101.24
<b>C. Area</b> [median m <sup>2</sup> ]	Elk Springs	0.00	0.00	0.00	61.26	74.47
	Jones Canyon	0.00	142.48	80.93	86.47	124.06
	Mesa Portales	14.00	143.04	65.42	74.76	99.74
	Rio Puerco	77.94	91.36	62.81	0.00	101.24
<b>D. Burned</b> [mean] (Yes, No)	Elk Springs	0.00	0.00	0.00	0.00	0.00
	Jones Canyon	0.00	0.00	0.00	0.07	0.00
	Mesa Portales	0.00	1.00	0.93	0.20	0.00
	Rio Puerco	0.50	0.25	0.86	0.00	0.00
<b>E. Orientation of Roomblock</b> [median degrees]	Elk Springs	--	--	--	180.00	185.00
	Jones Canyon	--	92.50	93.00	95.00	95.50
	Mesa Portales	90.00	180.00	175.50	92.00	180.00
	Rio Puerco	180.50	99.00	176.00	--	101.00

## Population Dynamics

Some tentative estimates of population dynamics across the four survey areas and five time periods are suggested by the ceramic chronology coupled with site counts and site sizes. Here site size is measured using the combined mound area for the roomblocks and the area of any kivas that may also occur at a site. So, we are referring specifically to the built area of each site. These measures for each site are then summed for each time period and survey area. These summaries provide coarse estimates of relative population differences through time and across the study area.

In general, we see two peaks in site counts in Early Pueblo III and Late Pueblo III, with over one hundred sites occupied in each period. A notable decline in the number of occupied sites is also visible during the Middle Pueblo III period, with approximately fifty sites occupied during this interval. The population footprint in Early and Late Pueblo II is very small when estimated using site counts, with only a dozen or so sites dating to each period. These trends in site counts

are also reflected in site sizes. The estimates are much more coarse-grained, but it should be noted that they are consistent with the reconstruction proposed by Baker & Durand (2003, see Figure 9.3, page 181).

Across the four survey areas, the population reconstruction is more variable. In Early and Late Pueblo II, the total regional population was limited and concentrated in the Rio Puerco Floodplain. The regional population expanded dramatically in Early Pueblo III, but most of that was due to population growth on Mesa Portales, notably on the northern side of the mesa. In Early Pueblo III, the total population declined, but again mostly on the northern side of Mesa Portales. During this period, the population in Jones Canyon increased substantially, even as it fell across the whole study area. Finally, in Late Pueblo III, the regional population again experienced a substantial increase, though this is largely driven by growth on the southern slope of Mesa Portales and at Elk Springs. It appears that the population of Jones Canyon remained relatively stable from Middle to Late Pueblo III. We note that in Late Pueblo III, sites appear to be rather evenly distributed between the three survey areas: Elk Springs, Jones Canyon, and Mesa Portales. However, the distribution of site area over these survey locations suggests that sites in Jones Canyon and on the south side of Mesa Portales were slightly larger than those in Elk Springs.

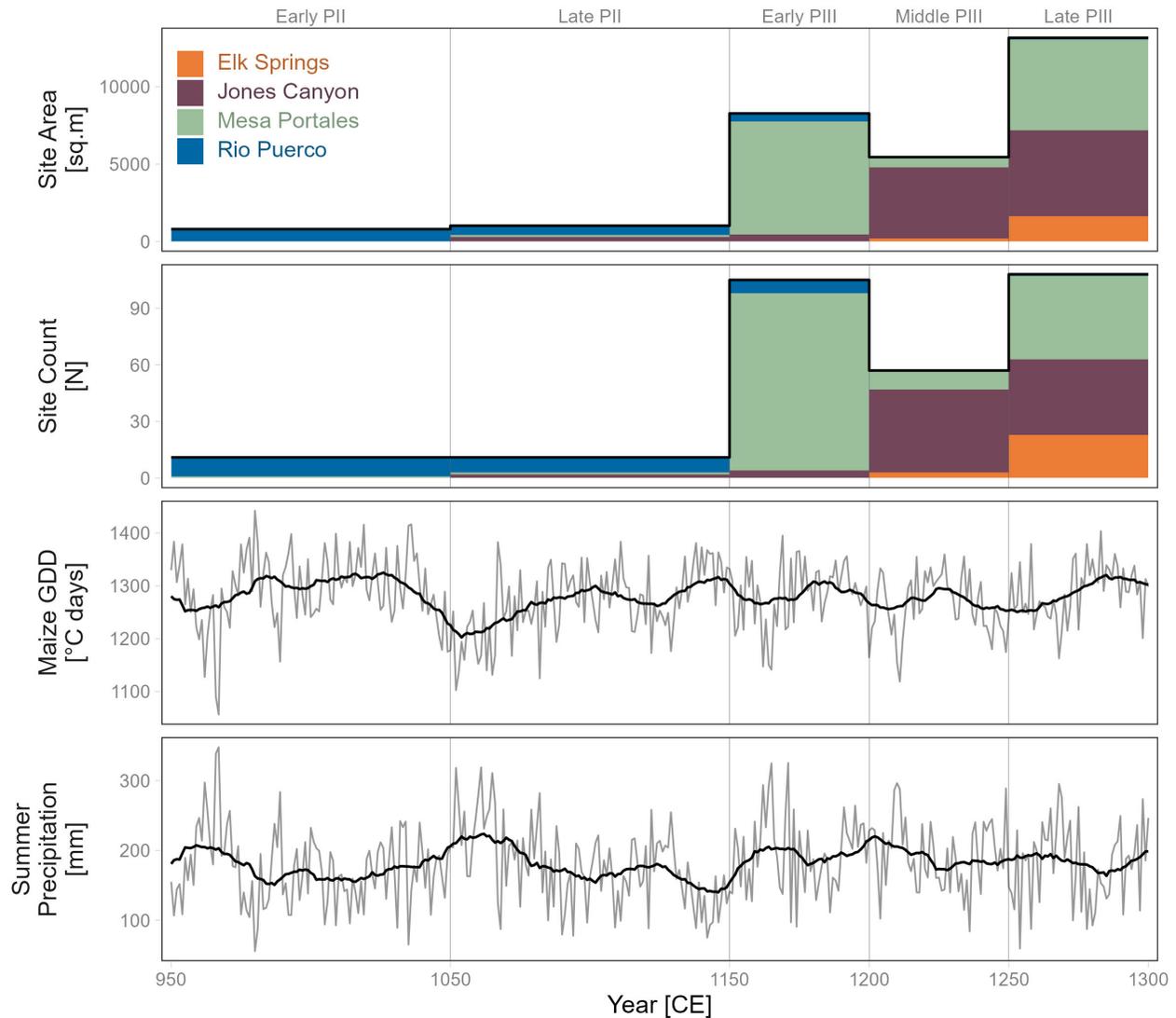


Figure 6: Time series by survey area, including two proxies for population size (total site area and site count) and two climate reconstructions related to maize productivity (summer precipitation and summer maize growing degree days). Note that the height of the bars in the population panels represent the total estimate for the project area. The filled and stacked bars are the distributions across survey areas for each time period. The light gray lines are the annual point estimates for each climate variable. The dark black line is a rolling twenty-five year mean centered on each focal year.

## Climate, Farming, and Fire

Figure 6 provides a visual representation of population dynamics in the study area, along with the local climate history derived from SKOPE (Bocinsky et al., 2023), namely summer precipitation (PPT) and maize growing degree days (GDD). While we do not conduct rigorous statistical tests to measure the correlation between these variables, the figure does suggest that population increased dramatically in Early Pueblo III during a period of decreasing maize GDD and increasing summer precipitation from approximately 1125 to 1175 CE. Total population declined during Middle Pueblo III, during a period in which maize GDD is unimodal, with temperatures

increasing up to a maximum around 1225 CE then decreasing afterwards. Over the same period, precipitation was steadily declining, also reaching a low point around 1225 CE. As population rebounded during Late Pueblo III, farmers then experienced a drop in precipitation and an increase in GDD around 1275 CE, with precipitation recovering shortly after, but GDD remaining relatively high.

Some additional patterning in the proposed chronology and population reconstruction may be inferred on the basis of variability in the local environment. In particular, the movement of populations across survey areas is suggestive of changes in farming adaptations and environmental learning as each of these areas offers unique constraints and trade-offs for maize farming.

Presumably, the floodplain of the Rio Puerco would have provided an ideal location for maize farming given access to perennial stream water. In addition, its proximity to the Sierra Nacimiento would mean its soils could also absorb runoff from winter snowpack. Sites in the Rio Puerco Floodplain would, therefore, have benefited from flood water farming. This is consistent with the climate reconstruction, which shows that the small population of Early and Late Pueblo II farmers would have experienced relatively warm and dry conditions, potentially making dry farming a less productive alternative. These populations were also affiliated with the Chaco tradition in which floodwater farming was more prevalent along the Chaco River (Benson et al., 2006). At some point, the Rio Puerco became entrenched below the level of the relic floodplain on which these Pueblo II sites occur, suggesting that at that time the Rio Puerco Floodplain was characterized by an aggrading stream.

On Mesa Portales, just west of the Rio Puerco, maize agriculture would most likely have been limited to direct precipitation or “dry” farming, as that large, elevated landform lacked access to both seasonal water run-off from the Sierra Nacimiento and perennial stream water from the Rio Puerco. It is notable that populations, possibly from the southern Cibola and northern San Juan, settled on this mesa during a period that initially favored dry farming, and that individuals from the northern San Juan, at least, would have been familiar with this style of agriculture (Bocinsky et al., 2016; Bocinsky & Kohler, 2014).

Sites in Jones Canyon and at Elk Springs probably relied on a mixed strategy, using the Rio Puerco or other floodplains for floodwater farming and run-off from the nearby mesa slopes (in the case of Jones Canyon) and the Sierra Nacimiento (for sites at Elk Springs) for run-off irrigation. In Early Pueblo III, the farmers in Jones Canyon would have been associated with the northern Cibola tradition, where conditions necessitated substantial water management strategies (Kintigh, 1985; Muenchrath et al., 2002).

When coupled with the proposed chronology and demographic reconstruction above, these spatial patterns suggest a shifting reliance on farming strategies. In general, what we see are

Gallina- and Chaco- affiliated farmers settling along the Rio Puerco during the Late Pueblo II period and practicing flood water farming during a period of relatively dry and warm conditions. Early Pueblo III farmers from the southern Cibola and northern San Juan regions then settled the northern slopes of Mesa Portales during a period of general cooling with wetter summers, where they practiced dry farming. As temperatures increased and precipitation declined during Middle Pueblo III, the population center shifted to Jones Canyon, where farmers could rely on floodwater farming and run-off irrigation. Near the end of the sequence, Late Pueblo III farmers spread out across the region, probably applying a variety of farming strategies. Curiously, farmers do not appear to have returned to the Rio Puerco Floodplain at any point after Late Pueblo II. This may be due to drought, fire, and down-cutting of the Rio Puerco itself, which would have removed the floodplain farming niche from the study area.

The spread of populations across multiple survey areas in Late Pueblo III also indicates that these populations were becoming more adept at farming regardless of the particular type of farming as they learned to cope with the unique challenges posed by these different environments. This is especially evident given the fact that there was not just an increase in the number and total area of sites from Early to Late Pueblo III (see Table 4, A and B), but total site sizes were also increasing over this period (see Table 4, C). As populations continued to infill the study area, individual settlements continued to grow as their residents adapted to local environments, becoming more efficient and able to support more complex settlements.

Another pattern worth mentioning here involves the spatial distribution of burned sites. Nearly all of these are found on Mesa Portales and are associated with Early Pueblo III occupations (see Figure 7 and Table 4, D). The fact that these sites are in close proximity to unburned sites associated with Middle and Late Pueblo III occupations suggests that a large regional fire event occurred at the end of Early Pueblo III. Future excavation of some of these burned sites could determine whether a catastrophic wildfire was the cause of abandonment, or whether it occurred after residents had moved away. It is worth noting that the period of the fire appears to be associated with a substantial reshuffling of the population across survey areas, with most farmers, as noted already, moving into Jones Canyon during Middle Pueblo III.

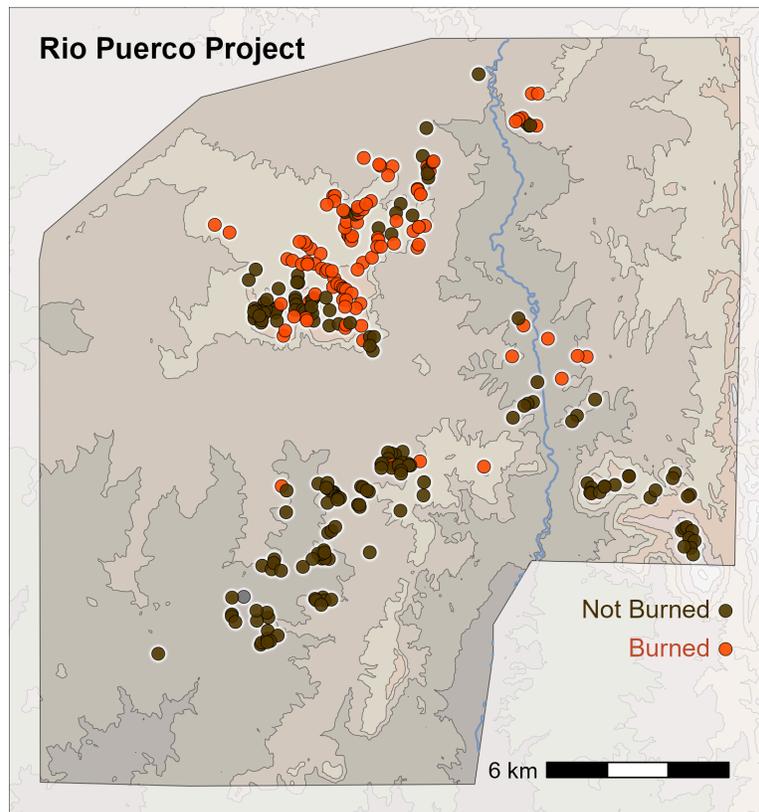


Figure 7: Geographic distribution of sites with evidence of burning.

## Agglomeration Effects

As mentioned above, there is some indication of limited agglomeration into larger, more centralized settlements. For instance, survey data suggests that the south end of Mesa Portales likely consisted of two communities of about 150-300 people, with one on the east half, the other on the west half, of the landform. Each has a clear central site with architectural features relating to the landscape. In the east community, an E-shaped building with two kivas faces east, aligning with two kivas further to the east. This site has some Northern Rio Grande tradition pottery mixed with Loma Fria Black-on-white and Mesa Verde wares. In the west community, a large site with three kivas but few Northern Rio Grande ceramics faces south.

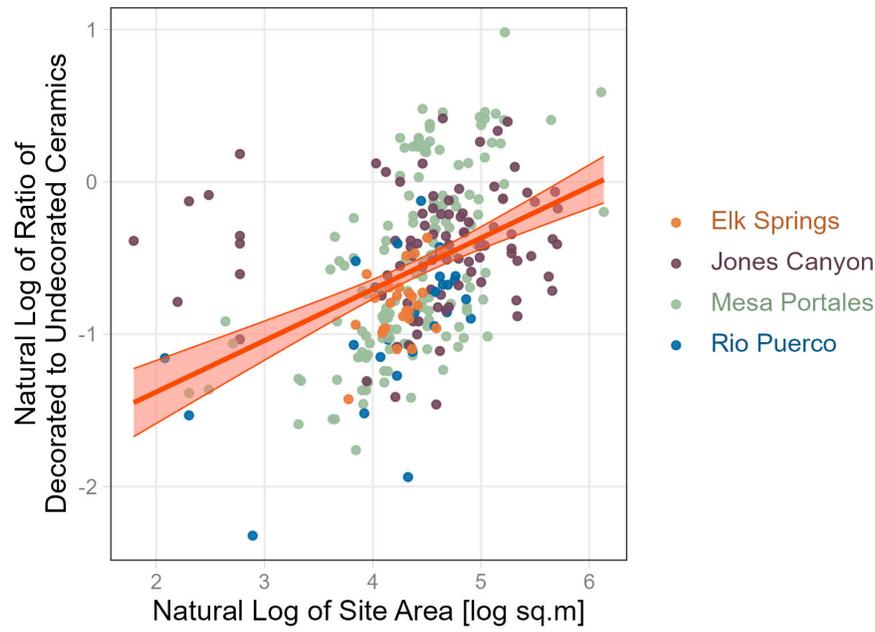


Figure 8: Response of decorated ceramics to site size. Note that the x and y axes both have log scales. Points are colored according to the survey area in which they are located.

The emergence of central places and settlement clustering may be due to network effects that incentivize individual movement to more agglomerated settlements (Ortman et al., 2015). To test for the presence of such scaling effects, we apply a method proposed by (Ortman & Lobo, 2020) that measures the relationship between painted pottery and built area at each site. Specifically, we calculate the ratio of painted to unpainted ceramics, under the assumption that increases in this ratio reflects the relative frequency of socializing with food relative to food preparation. In this case, the built area for each site serves as a proxy for total population. As these quantities are For more details about model parameters, see Table 5.

Table 5: Coefficient Estimates

Term	Estimate	Std Error	t Value	p Value
(Intercept)	-2.0534	0.1875	-10.9527	0
log(site_area)	0.3370	0.0421	8.0085	0

## Discussion

Borck & Simpson (2017, have included the study area within an extended Gallina culture area, but it is clear from our results that population dynamics were more variable than this association would suggest.) While these authors recognize that migrants to these areas came from many different places, Gallina ceramics are mostly restricted to Pueblo II sites along the Rio Puerco. In fact, our evidence suggests that populations were migrating into and out of different parts of the

study area at different times throughout the Ancestral Pueblo sequence, at least up to the Great Drought at the end of Late Pueblo III. It is likely that residents were even migrating into and out of these areas several centuries before the Gallina tradition first appears to the north, around 1100 CE.

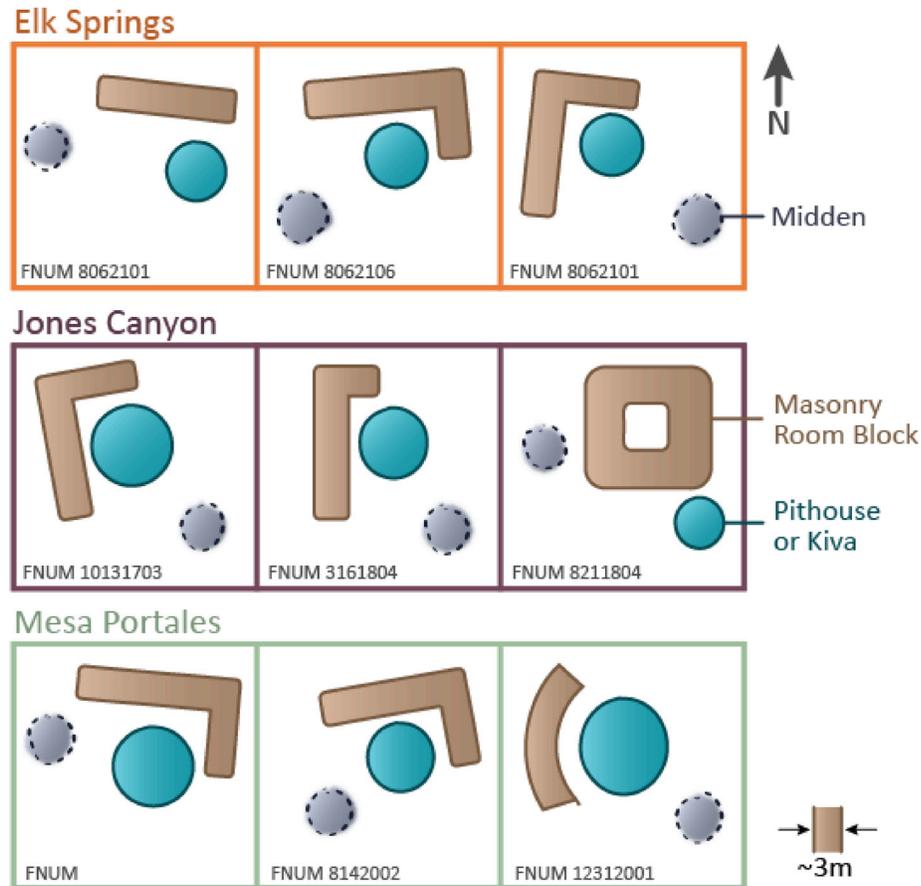


Figure 9: Representative site layouts for the different survey areas.

Other important lines of evidence include architectural and settlement patterns. Gallina specialists (Borck, 2017; Borck & Simpson, 2017) argue that residential pit structures are a key feature of Gallina material culture that persisted up to regional abandonment. At the sites recorded by Shiffler, however, there is no evidence of residential pit structures. Instead, the architectural pattern is more in keeping with wider Ancestral Puebloan developments, including above ground room blocks, small kivas, and plazas (see Figure 9). While farmsteads in this study area are generally dispersed, similar to the Gallina settlement pattern (Borck, 2017), this would not have been uncommon among non-Gallina Ancestral Puebloans during the periods in question, even at the height of the Chacoan system. Furthermore, as mentioned previously, there is some indication of at least limited agglomeration into larger settlements. And the positive, non-linear relationship between population and productivity observed elsewhere in the Southwest is replicated with this dataset (Ortman & Lobo, 2020).

Researchers have interpreted the presence of burned sites as evidence of warfare precipitated either by Gallina-affiliated peoples or by desperate migrants from the northern San Juan who were displaced by drought (Dick, 1976; Ellis, 1976). In most cases, however, the burned sites of the Gallina region also had direct evidence of violence, usually in the form of skeletal trauma. Data from this survey cannot speak to this question one way or the other, but it is worth noting that burned sites on Mesa Portales appear to be associated with Late Pueblo II farmers that occupied the area well before the disturbances of the late thirteenth century. In sum, the current evidence from Mesa Portales is most consistent with wildfires associated with a period of drought as the explanation for the burned sites.

## **Conclusion**

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The Rio Puerco study area offers important lines of evidence for this interstitial area of the Ancestral Pueblo World. Our exploratory analyses are suggestive of interesting migration patterns that speak to larger debates in the region, with Chaco migrants settling along the Rio Puerco during Pueblo II, southern Cibola migrants settling the northern part of Mesa Portales in Early Pueblo III, northern Cibola migrants settling Jones Canyon in Middle Pueblo III, and San Juan migrants, largely from the Mesa Verde region, settling Mesa Portales, Jones Canyon, and Elk Springs during Early and Late Pueblo III. The different environments of these survey areas also likely promoted different farming adaptations including flood water farming along the Rio Puerco Floodplain, dry farming on Mesa Portales, and runoff farming in Jones Canyon and at Elk Springs. When these different areas were occupied and what strategies were used at each appears to have been driven by climate fluctuations, notably long term changes in maize GDD and summer precipitation, though these relationships require further scrutiny. What is more, environmental learning likely led to increasing agglomeration and social complexity, as evidenced by the spread of populations across the diverse environments of Mesa Portales, Jones Canyon, and Elk Springs during late Pueblo III, and the increase in site size over the same period. Additional work needs to be done to more precisely date sites in the study area and to estimate changes in population through time. Larger regional comparisons would also help illuminate the core-periphery patterns of the Rio Puerco within the wider Ancestral Puebloan region.

## **Author Statements**

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## Author Contributions

Vernon conducted all analyses and wrote the manuscript. Ortman contributed to writing and analysis. Shiffler collected data and contributed to writing and analysis.

## Conflicts of Interest

The authors declare no conflicts of interest.

## Data Availability

Spatial locations of archaeological sites are protected data and cannot be shared publicly. However, the authors include all attribute data associated with this analysis (ceramic and lithic counts, site area, etc.) in a spreadsheet in the associated GitHub repository:  
<https://github.com/kbvernon/rio-puerco>.

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