Appendix 1: Insecurities Coding: Relationships, Proxies, Questions, Definitions, Uncertainties

Appendix 1 provides additional information on the coding procedures for the seven human securities categories in eight culture areas. There is no standard set of insecurity indicators in the present or archaeologically; indicators are selected based on available data, assessor judgments, and assessment objectives (Human Security Unit 2016). Indicator selection in this study was driven by the need for comparable data throughout the region and limited by the types of data and archaeological proxies available. We expect future archaeological studies will improve and rely on an expanded range of indicators.

Economic insecurity (Indicator: decreasing trade and exchange)

Plausible relationship with sustainability and depopulation: As trade and exchange networks declined, opportunities to engage social strategies for buffering risks decrease (e.g., alliances, reciprocity) and economic insecurity increased (Braun and Plog 1982). Risks (real or perceived) that cannot be buffered can lead to strategies such as migration to mitigate risks.

Proxies used to assess indicator: extent of non-local pottery and other goods in settlements

Assessment question for coding: What was the extent of interregional trade/exchange relative to previous periods? (Note that a coding of "Low" insecurity reflects a high level of trade and exchange.)

Low: Abundant evidence of non-local artifacts in quantities likely exceeding those for individual or household consumption.

Moderate: Evidence of the presence of multiple non-local artifact classes in moderate quantities likely for individual or household consumption.

High: Evidence of primarily localized production of primary artifact classes (e.g., pottery, lithics) or the presence of a limited amount of non-local artifacts from only a few artifact classes (e.g., minimal quantities of non-local sherds).

Food insecurity (Indicator: increasing resource depletion/degradation)

Plausible relationship with sustainability and depopulation: As resources relied on for food decrease, food insecurity increased. Perceptions of better conditions elsewhere can stimulate movement to lessen food insecurity (Halstead and O'Shea 1989). Population levels will decline when insufficient food decreases fertility and increases mortality.

Proxies used to assess indicator: declining diet breadth, change in previous resource procurement strategies (for example, shifting from cultivated to wild foods or vice versa),

increased reliance on smaller or more immature mammals, increasing soil degradation, bioarchaeological indicators of food stress.

Assessment question for coding: What was the extent and severity of resource depletion and degradation relative to previous periods?

Low: Little to no shift in dietary breadth or subsistence strategies and or minimal bioarchaeological evidence of nutritional stress.

Moderate: Limited evidence of shifting subsistence strategies on a local level and limited bioarchaeological evidence of nutritional stress.

High: Abundant bioarchaeological evidence of nutritional stress, evidence of shifting subsistence strategies (ex. increased reliance on wild foods, decreased prevalence of former staple crops), evidence for significant soil degradation, evidence for decreased availability local arable land.

Health insecurity (Indicator: increasing settlement aggregation and bioarchaeological evidence of disease)

Plausible relationship with sustainability and depopulation: As people lived increasingly closer together in aggregated settlements, mechanisms for disease transmission increased (Martin 1994:105; Phillips et al. 2018:266), mortality increased, health insecurity increased, and decisions to migrate increased. This plausible relationship is based on the link between aggregation/urbanization and increases in the vulnerability to infectious diseases.

Proxies used to assess indicator: spatial clustering of households into larger communities; skeletal indicators of health/disease.

Assessment question for coding: What was the extent of settlement aggregation and bioarchaeological evidence of disease relative to previous periods?

Low: Little to no change in the extent of settlement aggregation

Moderate: Evidence of settlement aggregation but settlement sizes are not substantially increasing from previous periods. Some bioarchaeological evidence may be available for increasing levels of disease or infection.

High: Evidence of increasing settlement aggregation with relatively large settlement sizes and bioarchaeological evidence for increasing diseases compared to prior periods.

Note: In addition to coding this insecurity based on published scholarly assessments of the extent of aggregation, we calculated an aggregation index for each culture area using settlement data in the Coalescent Communities Database (Hill et al. 2012). Our index is: total number of documented rooms (within settlements and used as an indicator of population levels) in a culture area divided by the total number of settlements in each area. The percent change in the index

from the 50-year interval prior to depopulation and during the initiation of depopulation informs the coding. Where settlement data are available, we present these percentage changes in the evidence to support the coding.

Environmental insecurity (Indicator: increasing relative climatic dryness)

Plausible relationship with sustainability and depopulation: As dryness increased, wild and cultivated food resources decreased, and environmental insecurity increased. Resource shortfalls (real or perceived) can stimulate movement toward more productive areas (Halstead and O'Shea 1989) and insufficient food decreases fertility and increases mortality.

Proxies used to assess indicator: Average Palmer Drought Severity Index (PDSI) during depopulation compared to average prior period PDSI. Summer (June, July, August) growing season precipitation retrodictions from tree-rings are used to identify PDSI (Cook et al. 2010, data available at: http://drought.memphis.edu/NADA/)

Assessment question for coding: What was the extent of climatic dryness coincident with the decline, relative to dryness during the period preceding decline?

Unlike other indicators, this measure assesses conditions prior to the initiation of depopulation and during the depopulation interval. Based on a previous study of the temporal correspondence between major social transformations and multi-year droughts in the SW (Kintigh and Ingram 2017), we did not expect the onset of drought to match the start of depopulation in most regions. Due to the endemic risks of food provisioning in the highly variable climate of the SW/NW, we expected that environmental insecurity would be highly variable and more influential when people were deciding to move or remain in place rather than during the ~50 to 100 years prior to these decisions. Thus, our indicator, in a broad sense, answers the question, "Were conditions during the depopulation less secure (dryer), more secure (wetter), or about the same (no change) compared to conditions prior to depopulation?"

Proxy: Method of calculation: The duration of the decline in each culture area (e.g., 1375 to 1450 = 75 years) determines the duration of the period preceding decline used to compare relative dryness (e.g., 1299 to 1374 = 75 years). Entire culture area Palmer Drought Severity Indices are calculated for both periods using the North American Drought Atlas (Cook et al. 2009) and the associated database (http://drought.memphis.edu/NADA/). Prior interval and depopulation interval and percent change between the intervals are presented for each culture area in Appendix 2. Differentiating Moderate from High environmental insecurity was based on the range and distribution of the percentage change in relative dryness among all culture areas. High insecurity was assigned to areas with an increase in relative dryness between 89% and 169% and Moderate insecurity was assigned to areas with an increase between 45% and 71%.

Low: Growing season precipitation levels were wetter (creating more secure conditions) during depopulation than during the period prior to depopulation, based on a comparison of tree-ring retrodicted average annual June/July/August PDSI in the culture area.

Moderate: Growing season precipitation levels somewhat drier during depopulation than during the period prior to depopulation, based on a comparison of tree-ring retrodicted average annual June/July/August PDSI (Palmer Drought Severity Index) in the culture area.
High: Growing season precipitation levels were substantially drier during depopulation than during the period prior to depopulation, based on a comparison of tree-ring retrodicted average annual June/July/August PDSI (Palmer Drought Severity Index) in the culture area.

Uncertainty: Moderate: Reconstructions of growing season precipitation (June, July, August) based on tree-ring retrodicted and geographically interpolated Palmer Drought Severity Indices (PDSI) in the North American Drought Atlas (Cook et al. 2010) provide a strong relative comparison of the extent of dryness in each archaeological culture area. This provides some knowledge of the *supply* of water for food resources (wild and cultivated) but does not address the *demand* for this water based on population levels, densities, and uses. When water demand exceeds supply, insecurity likely results. Projecting water supply relative to demand is beyond the scope of this study.

Personal insecurity (Indicator: increasing conflict and violence)

Plausible relationship with sustainability and depopulation: As conflict and violence increased, mortality increased, personal insecurity increased, and movement away from dangerous conditions increased (LeBlanc 1999).

Proxies used to assess indicator: skeletal trauma, unburied bodies, fortified and defensive structures/settlements

Assessment question for coding: What was the extent and trajectory of conflict and violence within the culture area relative to previous periods?

Low: Little to no evidence of skeletal trauma, unburied bodies, fortified and defensive structures/settlements

Moderate: Some evidence of skeletal trauma, unburied bodies, fortified and defensive structures/settlements

High: Extensive evidence of skeletal trauma, unburied bodies, fortified and defensive structures/settlements

Community insecurity (Indicator: increasing immigration):

Plausible relationship with sustainability and depopulation: As immigration increased within and near existing communities, insecurities increased, and new social strategies were necessary for resolving tensions (Clark et al. 2019). These tensions likely increased due to increased resource competition in marginal areas (Schwindt et al. 2016). If immigration created untenable social and environmental conditions within communities, movement away from these conditions could have lessened tensions.

Proxies used to assess indicator: rising population levels above internal population growth rates (using compound annual growth rate calculations, where possible); architectural and/or material cultural differences within settlements associated with immigrants

Note: Compound Annual Growth Rate (CAGR) formula: $CAGR = (p2/p1)^{1/n} - 1$. In this study, p2 and p1 are the number of identified rooms in, for example, the 1300 to 1349 interval and in the 1250 to 1299 interval, respectively, and *n* is the number of years in the interval. For example, if depopulation begins in 1350, we use room counts during the 1250 to 1299 and 1300 to 1349 intervals to identify the trajectory and level of growth rates prior to the start of depopulation. Growth rates greater than 0.7 percent exceed what can be expected from changes in fertility and mortality (Cowgill 1975), and thus in-migration is strongly implicated. We calculate growth rates where settlement data is available in the Coalescent Communities Database (Hill et al. 2012). Where data is not available, we rely on assessments by scholars active in those sub-regions.

Assessment question for coding: What was the extent of in-migration from people outside the culture area relative to previous periods?

Low: Compound Annual Growth rates within a range (<0.3) not associated with strong evidence of in-migration. Little to no evidence of intra-community, ethnic-based architectural and material cultural differences identified.

Moderate: Compound Annual Growth rates within a range (0.3 to 0.7) associated with changes in fertility/mortality of growing populations. Limited evidence of exogenous material culture or architectural signatures associated with groups from outside the culture area. Some evidence of intra-community, ethnic-based architectural and material cultural differences identified.

High: Compound Annual Growth rates in excess of what can be expected from changes in fertility and mortality (>0.7) with in-migration strongly implicated (Cowgill 1975). Evidence of exogenous material culture or architectural signatures associated with groups from outside the culture area were identified.

Political insecurity (Indicator: increasing social stratification)

Plausible relationship with sustainability and depopulation: As social stratification increased, some portion of a population had less access to political, ritual, and/or socioeconomic resources (Brandt 1994) and political insecurity likely increased. Movement away from these conditions can lessen the perceived inequalities.

Proxies used to assess indicator: architecture within settlements increasingly differentiated, exclusive spaces, unequal distribution of prestige goods, differential burial treatments or grave goods

Assessment question for coding: To what extent did individuals/groups have different levels of access to structural, ritual, or socioeconomic resources relative to previous periods?

Low: Little to no evidence of differentiation in domestic architecture (e.g., size/shape/access) within settlements, unequal distribution to prestige goods, or substantial differences in grave goods or burial treatments.

Moderate: Recurring evidence of differentiation in domestic architecture (e.g., size/shape/access) within settlements, unequal distribution to prestige goods, and substantial differences in grave goods or burial treatments.

High: Extensive evidence of differentiation in domestic architecture (e.g., size/shape/access) within settlements), unequal distribution to prestige goods, and substantial differences in grave goods or burial treatments.

CODING UNCERTAINTIES

We code and describe/support our uncertainty assessment for each insecurity category by culture area in Appendix 2. Conflicting interpretations by scholars and/or limited information on a security and its indicator were among the factors affecting uncertainty. This is not a problem unique to archaeology but endemic in the analysis of most complex and large-scale social phenomenon. For non-archaeologists, we clarify that archaeological data accumulates and interpretations evolve to accommodate new data. The uncertainties disclosed in this document are an inherent property of all interpretations of archaeological data. Most new research and advancements in archaeological interpretations of the past arise from acknowledged uncertainties. We did not allow uncertainties to prevent our analysis or change its spatial scale, given the urgency of local to global-scale sustainability challenges and our desire to contribute insights from the past. It will take several lifetimes before data quality improves in some areas.

Data quality is uneven throughout the region. We know most about depopulation of the Mesa Verde region (within the Ancestral Puebloan culture area) and much less about Fremont, Casas Grandes, Rio Sonora, Trincheras, and Patayan areas. Data were insufficient to document most insecurities in the Patayan region, but we retain the culture area in the main text to emphasize the analytical importance of the entire SW/NW region and interactions therein. Inclusion of the Patayan area will hopefully stimulate further research in that area.

Uncertainty Codes:

Low: There is strong supporting evidence and consensus in the literature that justifies the coding.

Moderate: There is some supporting evidence and consensus in the literature that justifies the coding.

High: There is high coding uncertainty due to minimal evidence and/or conflicting interpretations of the evidence.

LITERATURE CITED

Braun, D. P. and S. Plog. 1982. Evolution of "tribal" social networks: theory and prehistoric North American evidence. *American Antiquity* 16:301-313.

Clark, J. J., J. A. Birch, M. Hegmon, B. J. Mills, D. M. Glowacki, S. G. Ortman, J. S. Dean, R. Gauthier, P. D. Lyons and M. A. Peeples. 2019. Resolving the migrant paradox: Two pathways to coalescence in the late precontact US Southwest. *Journal of Anthropological Archaeology* 53:262-287.

Cook, E. R., R. Seager, R. R. Heim Jr., R. S. Vose, C. Herweijer and C. Woodhouse. 2010. Megadroughts in North America: Placing IPCC projections of hydroclimatic change in a long-term palaeoclimate context. *Journal of Quaternary Science* 25:48-61.

Cowgill, G. L. 1975. On causes and consequences of ancient and modern population changes. *American Anthropologist* 77:505-525.

Halstead, P. and J. O'Shea, editors. 1989. Bad year economics: cultural responses to risk and uncertainty. Cambridge, Cambridge University Press.

Hill, J. B., D. Wilcox, W. Doelle and W. Robinson. 2012. Coalescent Communities Database version 2.0. Tucson, Archaeology Southwest.

Human Security Unit. 2016. Human security handbook: an integrated approach for the realization of the sustainable development goals and the priority areas of the international community and the United Nations system. United Nations Trust Fund for Human Security, United Nations.

Kintigh, K. W. and S. E. Ingram. 2018. Was the drought really responsible? Assessing statistical relationships between climate extremes and cultural transitions. *Journal of Archaeological Science* 89:25-31.

LeBlanc, S. A. 1999. *Prehistoric warfare in the American Southwest*. Salt Lake City: University of Utah Press.

Martin, D. L. 1994. Patterns of health and disease: Stress profiles for the Prehistoric Southwest. Pages 87-108 *in* G. J. Gumerman, editor. *Themes in Southwestern prehistory*. Albuquerque, University of New Mexico Press.

Phillips Jr., D. A., H. J. Wearing and J. J. Clark. 2018. Village growth, emerging infectious disease, and the end of the Neolithic demographic transition in the southwest United States and northwest Mexico. *American Antiquity* 83(2):263-280.

Schwindt, D. M., K. Bocinsky, S. G. Ortman, D. M. Glowacki, M. D. Varien and T. A. Kohler. 2016. The social consequence of climate change in the central Mesa Verde region. *American Antiquity* 81(1):74-96.