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Environment and Subsistence of
Chaco Canyon

Environment and Subsistence of

Chaco Canyon

New Mexico

Frances Joan Mathien

Editor

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Foreword

In 1971, a multidisciplinary National Park Service research team assembled in New Mexico to study past human adaptation to the seemingly harsh, semiarid environment of the four corners region of the American Southwest. A survey of Chacc Canyon National Monument and its environs led in 1980 to legislation that expanded its boundaries, protected 33 outlying Chacoan structures and communities, and redesignated the area as Chaco Culture National Historical Park.

To understand the conditions under which the prehistoric Chacoan Anasazi lived, more detailed knowledge was needed of both past and present environments and their changes over time in response to human influences. In what ways was it different or similar to conditions nine hundred years ago? What caused the abandonment of the area? What changes in plant and animal communities occurred? How did this affect the prehistoric subsistence activities? Was there adequate rainfall at the right time of year to grow sufficient crops? The answers to these and other questions were needed to authoritatively interpret the prehistoric Chaco culture to the park visitor.

I am pleased to introduce this volume which is the latest entry in the Chaco studies in this series. It contains a wealth of information on the past and present environments of Chaco Canyon and the San Juan Basin. Its usefulness extends to managers, interpreters, and archeologists whose efforts center on the use of this knowledge to increase our understanding of the past and our appreciation of the priceless legacy of our cultural heritage.

WILLIAM PENN MOTT, JR.
Director

Preface

The National Park Service Chaco Project encompasses a number of goals, some of which have grown more important as new knowledge is gained about the size of the settlements and how they have changed through time. Earlier estimations of population size have been questioned, as have several explanations for the abandonment of the area, particularly as it may have been precipitated by drought and arroyo cutting. Could other environmental parameters have affected the Anasazi populations, and if so, how? In order to evaluate these and other questions, numerous scholars turned their attention to many facets of the puzzle.

By the latter part of the 1970s, an extensive list of formal publications in two series, Reports of the Chaco Center and Publications in Archeology, Chaco Canyon Studies, were planned. A volume on environment and subsistence, to be edited by William B. Gillespie, was listed as Number 18E in the latter series. Bill Gillespie worked with a number of investigators who received contracts from the National Park Service to evaluate current flora and fauna in the Park and provide baseline checklists of species; to examine soils and water resources; to reexamine ideas about climatic changes in the Chaco area and their effect on the prehistoric population; and to evaluate evidence indicative of prehistoric use of available resources, especially botanical remains. Gillespie and Nancy Akins, both members of the Chaco Project staff, analyzed fauna collected from the excavated sites. Unfortunately, before all these studies were completed and presented in final form to the Chaco Center, Gillespie's term appointment ended and could not be extended. Just prior his departure, however, he was able to assemble many of the scholars at a symposium entitled "Past Environment and Subsistence at Chaco Canyon, New Mexico" which he chaired at the Annual Meeting of the Society for American Archaeology in San Diego in May 1981. Some of these presentations appeared in Recent Research on Chaco Prehistory, Report of the Chaco Center, Number 8, edited by W. James Judge and John D. Schelberg, 1984. These papers, of necessity, were brief and often summarized only partial results on particular topics of investigation or presented tentative or interim conclusions.

In addition to the expansion and renaming of the Chaco area in 1980, the responsibility for publication of results also shifted. In the fall of 1984, I was asked to assume the role of general editor of the Chaco publications, a move that was precipitated by the resignation of W. James Judge, the general editor. By this time most of the investigators were working on different projects, sometimes in other lands, and pursuing other research questions.

The following is not a complete synthesis of all the various aspects of study relative to environment and subsistence undertaken as part of the Chaco Project. It contains only seven major reports and three appendices that reflect some aspects of climate, flora and fauna, both past and present. In order to provide the reader with a more comprehensive picture of the studies carried out in Chaco, an introduction that outlines the history of these studies from the earliest work in the Canyon through the present is included. The bibliography in Appendix C lists additional sources of information on natural science studies and archeological analyses from other sites in Chaco and the San Juan Basin.

A synthesis will be written during the next few years. It will include a major section on the environment, the available flora and fauna, and changes in their availability through time. Meanwhile, it is hoped that readers will be able to develop their own viewpoints and assessments of Chaco Anasazi prehistory based on the data and references presented here.

The authors of the seven chapters have been most helpful with their comments and suggestions. To them, and to the current staff members of the Division of Cultural Research, I owe a debt of thanks. Without their generosity in assisting with the entire book as well as their chapters, this volume would not have materialized.

This endeavor was not the work of any one person. Barbara L. Daniels is the skillful editor who took the text and writing styles of numerous contributors and reworked them into a uniform presentation. Jerry Livingston drafted or re-drafted most of the illustrations to provide visual conformity as well as handled layout and design of this volume. Gloria J. Vigil typed and formatted the text into camera-ready copy; she was assisted by Dolores M. Guenzi. To all these individuals I give my thanks.

Introduction

Frances Joan Mathien

Research on various aspects of environment, albeit limited, began as soon as archeologists started working in Chaco Canyon. A brief summary of major archeological projects and their results is presented below.

The Hyde Exploring Expedition

The earliest study is that of Professor Richard E. Dodge who was in Chaco Canyon in 1889-1900 as part of the Hyde Exploring Expedition begun at Pueblo Bonito in 1896 under the scientific direction of Professor F. W. Putnam and his field director, George H. Pepper (Pepper 1920:23-25). Dodge, of Columbia University, examined the geological data with three goals in mind: first, to compare the geographical conditions at the time of occupation to those at the turn of the century; second, to determine evidence for climatic or geographical change; and third, to gather evidence that would indicate the lapse of time between abandonment of the pueblo and the present. Profile maps of the north cliff were drawn; the fault line was examined. Dodge noted an old water course near the front of the ruin at a depth of ten feet, yet there was evidence of human occupation at even greater depths--up to twenty feet below surface. He concluded the ruin was occupied for a great length of time. Based on accumulations of gravels, there were striking geographical changes after abandonment.

Studies of the arroyo walls and mapping of surface streams indicated the flow of surface water into the Chaco. Most recent deposits in the arroyo walls were formed during the present period of degradation of the arroyo plain. Pepper appreciated these contributions and applied this knowledge to problems relative to his archeological excavations at Pueblo Bonito. From local Navajos he had learned that there had been no arroyo in the center of the Chaco Wash at the time their ancestors entered the area and that the Navajos were still able to grow crops on the floodplain. Pepper quoted Simpson who suggested the soils may have been fertile when the earlier inhabitants lived in the pueblos, even though it was very arid when Simpson was there (1920:25). The first questions about the environment and subsistence of the Chaco were already formed even if emphasis on them was not as great as that placed on the architecture and material culture of the Bonitians.

During excavation, materials such as corn cobs, seeds, and nuts, as well as coprolites were collected and curated at the American Museum of Natural History. In his descriptions of the rooms excavated in Pueblo Bonito, Pepper notes the presence of vegetal materials; however, no analyses of these were ever published. It was not until recently that some of these collections were examined (e.g., coprolites; Clary [1981, 1983, 1984]).

The School of American Research

The next major excavation in Chaco Canyon began in 1920 under the direction of Dr. Edgar Lee Hewett of the School of American Research in Santa Fe. Hewett's interest in how the Anasazi produced their crops had already been aroused; he had published descriptions of irrigation ditches at several Chacoan sites, e.g., Una Vida and Kin Bineola (Kinbiniyol) (Hewett 1905).

While Hewett and his colleagues spent only the 1920-1921 season working at the site of Chetro Ketl, a report by Bradfield (1921) indicates an attempt to integrate observations on the natural environment and resources of the area with the archeological record. Discussion of the available water sources in Chaco at that time and limited rainfall, plus evidence of erosion of the Chaco Wash and the differences in species and number of trees located along the Wash, led Bradfield to conclude that changes had occurred in the environment throughout the centuries. He believed that both water and trees had been more abundant in the past, but he could not describe the rates of change or the exact conditions existing in previous years.

Bradfield also noted a discrepancy between the faunal remains recovered from Chetro Ketl and the animals observed in the canyon. Only small game (rabbits and quail) were present in the Chaco area in 1920, yet buffalo, elk, deer, mountain sheep, bear, and smaller animals were represented among the excavated bones. Corn, squash seeds, pinyon nuts, and beans, as well as a number of unidentified plants and roots, were recovered and considered part of the prehistoric diet. Samples of yucca and rabbit fur indicated the use of local resources for clothing. Pine beams used for building construction were noted on the floors of rooms in Chetro Ketl. Bradfield noted that the nearest source for this species in 1920 was 35-40 miles or more away in mountain forests (1921). Other species of pine, cedar, and cottonwood were considered more plentiful in the canyon area.

The first season at Chetro Ketl and the reports resulting from it indicate attempts to relate the local resources to the archeological record and to infer, at least minimally, the behavior of the Chaco Anasazi. Hewett did not return to Chetro Ketl until 1929, so this early attempt by School of American Research scholars was carried no further; although Hewett's colleagues did institute additional studies when they returned to the canyon in the following decade. No detailed analyses of the material from the 1920-1921 studies were reported.

The National Geographic Society

In the interim, the National Geographic Society carried out a major project at Pueblo Bonito. It was originally conceived as a five-year plan with multiple goals which Judd (1954:vii, 9) described as including a study of the physiography of Chaco Canyon and the agricultural practices of its ancient inhabitants. He was to learn everything he could about domestic water supply, sources of food and fuel, and the subsistence problems faced by the inhabitants of Chaco Canyon. A number of scholars assisted him in these studies. Annual symposia, held at Pueblo Bonito, included specialists in agronomy and botany, geology and physiology. Colleagues from the U.S. National Museum analyzed faunal and botanical remains recovered from Judd's excavations.

Judd (1954:1-68) presents data on a number of artifact and ecofact studies; he summarizes the dendrochronological research of A. E. Douglass and the work of Kirk Bryan, who examined numerous aspects of the geological record in Chaco and other washes in the Southwest. Judd's conclusions reflected the available evidence and deductions of these scholars. The Bonitians and their neighbors were farmers who depended heavily on floodwater agriculture. During the period of major florescence of the Anasazi, the climate had been slightly wetter than it was during the Great Drought of A.D. 1250. There had been several earlier droughts, but the inhabitants had been able to survive because the groundwater level was higher, allowing moisture in the soils to be replenished more easily when the infrequent and scattered showers occurred on the floodplain. Judd believed that prior to A.D. 1075, a dendrodate provided by Douglass, the Chaco Wash had not cut below the floodplain of the canyon and thus both the available water supply and the amount of gypsum may have maintained sufficient moisture levels and good soils. (Analysis of soil samples taken during excavations in the 1920s indicated poor soil along the Chaco Wash.) By about A.D. 1075, degradation of the arroyo began, and with time, it grew deeper, thus preventing replenishment of water and nutrients to the floodplain. The reversal of this slow process did not occur until around A.D. 1250, too late for the inhabitants of the canyon; they had already left as it had become more and more difficult to survive, especially in the mid-1100s.

Bryan's research was presented in part in a number of articles beginning in 1920. A list appears in the summary of his work in Chaco Canyon, which also presents his broader conclusions for the larger Anasazi area and the Southwest (1954). Bryan was aware of the work done by Dodge (1902a, 1902b, 1920) at Pueblo Bonito at the turn of the century and built on his predecessor's observations. After acquiring Dodge's notes, Bryan returned to some of the same locations in order to note differences in channel cuts. The differences, when combined with Judd's interviews of local Navajos and the results of a literature search for earlier descriptions of the area, led these scholars to postulate several aggradations and degradations.

Temperature and precipitation data were collected from various stations. Bryan noted variations in vegetation depending on location, soils, etc., and discussed the irrigation ditches recorded by Hewett in 1905 and by Judd in front of the Pueblo Bonito trash mound, trenches that had been excavated in an attempt to understand both geological events and cultural stratigraphy. The presence of springs and the effect of even slightly increased precipitation on the availability of water were evaluated. Bryan used ethnographic data on the Hopis in observing that many modern fields are often located away from sources of permanent water such as springs.

Aboriginal use of pine, unavailable in Chaco Canyon at the time of the National Geographic Society Expedition, provoked discussion among these scholars. Had there been resources closer to Pueblo Bonito at the time of its construction? Information gleaned from interviews with Navajo informants and a review of observations recorded by earlier explorers indicated the presence of other trees such as willow along the wash in the mid-1800s. Yet the pine used in Pueblo Bonito must have been cut in a mountain forest and transported many miles to the site. Judd (1954:2-3) found no evidence of transport scars on beams and Douglass indicated that his interpretation of the tree-ring patterns suggested a constant water supply and more favorable growing conditions than existed in the 1920s. These data suggested to Judd that the area had been deforested, leading to soil erosion, arroyo cutting, a lowered water table, poorer crops, and eventually abandonment.

Data on food sources were not ignored. Judd (1954:61) provided lists of vegetal remains recovered from Pueblo Bonito. In addition to the maize, pumpkins, Rocky Mountain beeplant, walnuts, grape, prickly pear, pinyon nuts, and wild potato later recovered by Judd in his excavations, Pepper had found beans and wild sunflower (1920). Judd suggested the Chacoans probably also used a number of other vegetal materials, as do modern Pueblos and Navajos.

An evaluation of the use of local mammalian species was included (Judd 1954:64). In addition to those he recovered (mule deer, pronghorn, elk, mountain sheep, jackrabbit, cottontail, grizzly bear, beaver, badger, bobcat, porcupine, gray and red fox, coyote, and Indian dog), Judd also commented on the presence of lion and bear claws that both he and Pepper found, usually in a ceremonial context. He noted bear meat was a taboo food among the modern Pueblo. Allen (1954:385-389) examined the canid remains from Pueblo Bonito (Judd 1954: Appendix B).

In summary, the National Geographic Society Expedition was concerned with two aspects of research addressed in the present volume: what were the natural environmental factors that shaped and influenced the lives of the Chaco Anasazi? How did these inhabitants utilize the resources available and react to even small changes in them? Many of the data and inferences made as a result of the Expedition's work provided a strong basis for future debate, reexamination, and additional research.

The School of American Research and University of New Mexico

Once the National Geographic Society completed work at Pueblo Bonito, the School of American Research (in cooperation with the University of New Mexico) returned to the canyon and initiated excavations at Chetro Ketl in 1929. Since Judd's report (1954) had not been published and only some of Bryan's (1925, 1926, 1928, 1929) and Douglass' (1924) work had appeared in professional journals, the students were unable to use the data of these scholars. The initial investigations by Bryan and Douglass were not ignored, however; Florence Hawley, for example, continued to work with Douglass. As a result of her work and the recent reanalysis of tree-rings by Dean and Warren, the greathouse of Chetro Ketl is the best tree-ring dated site (Dean and Warren 1983; Hawley 1933, 1934, 1938). While the cores collected were utilized initially for ordering the chronology, these cores were very useful in a reevaluation of the Chaco Anasazis' use of their resources and estimations of climate in the area (Bannister et al. 1970; Rose 1979; Rose et al. 1982).

Other students of Hewett addressed different topics. Fisher (1934) gathered data on rainfall and information on temperature from various substations in the area to calculate the number of frost-free days, correlated runoff in the Chaco, estimated the population that could be supported based on the amount of water available, and analysed information from tree rings. He relied on Bryan's evaluation of channel filling and degradation and was in agreement with the interpretation published later by Bryan (1954) and Judd (1954). Water for floodwater farming, or lack thereof, led to the downfall of Chaco, even though Fisher believed that the fields were still fertile.

Other research done includes survey of invertebrate fossils (Vann 1931). Thirty were described, as were sharks' teeth and algae. Dr. John Keur studied Threatening Rock during the summer of 1933; it fell in 1941 (Keur 1933; Keur and Keur 1935). William Chauvenet (1935) was concerned with soil erosion and protection of Kin Kletso (Yellow House). Photographs indicate the condition of the arroyo at several places (Chauvenet 1935). He noted ruins along the edge of the arroyo bank and recorded portions that collapsed during the period of his work in the area. His thesis documents the condition of the arroyo at one particular period and its changes, both natural and through stabilization. Another subject was undertaken by Francis Elmore who examined the available plants in connection with a study of Navajo ethnobotany for the University of Southern California (Brand et al. 1937:26-27; Elmore 1943).

In 1936, new directions in research were begun by the University of New Mexico field schools. Small sites located near the Great Kiva, Casa Rinconada, were excavated with the purpose of learning more about sites other than large pueblos in the Canyon. Interdisciplinary approaches were used. Guest lecturers spoke on a variety of topics, e.g., Antevs on North American paleoclimatology, Brand on anthropo-geography (Brand et al. 1937: 12).

While some reports were published by individual students, information on additional topics was presented in Brand et al. (1937). The relevant sections of this report are listed below (the author's name following):

Introduction (Brand)

The Natural Landscape (Brand): information on geology, climate, water resources, flora, and fauna.

Mammals and Bird Remains (Hibben)

Vegetal Remains (Hibben)

Subsistence (Brand)

Appendix I. Floor Deposition and Erosion in Chaco Canyon (Donovan Senter): see also Senter (1937).

Discussion of the Anasazi within the natural setting and lists of various species of plants and animals were presented in these sections.

Continued work on small sites in the Casa Rinconada area resulted in the volume on Bc 50-51 by Kluckhohn and Reiter (1939). In a section on subsistence remains, Kluckhohn admonished archeologists for their cavalier methods of documenting bird and mammal remains and indicated the need to include exact numbers in reports in order to better understand the physical environment of the time.

Post-World War II

World War II interrupted the University of New Mexico field school program in Chaco. While some work was carried out by the University in the 1940s, many of the earlier field school students and researchers never continued their studies or completed the reports on previous work. Gordon Vivian, one of Hewett's students, followed an archeological career; he was in charge of a ruins stabilization unit with a preservation mission, not just in Chaco but in other parks and monuments throughout the Southwest. He was also responsible for several archeological projects at Chaco Canyon National Monument.

In 1950 Vivian and Thomas W. Mathews resumed work at Kin Kletso where Edwin N. Ferdon had undertaken some preliminary investigations in 1934. As part of the report on Kin Kletso, Vivian and Mathews (1965:1-32) updated descriptions of the natural landscape and its relation to the inhabitants of Chaco. Their summary of the work done before 1965 encompasses all areas: arroyo cutting, prehistoric forests, factors pertaining to climate and agriculture (tree-ring data, pollen analyses, flora and faunal collections, temperature records), the effects of periodicity and amount of rainfall on agricultural practices, crop yields, etc., as well as ethnographic analogies to Navajo practices in Chaco Canyon. Lyndon L. Hargrave examined bird bones from many sites in the canyon, even ones previously excavated though not always reported.

Another topic of importance to Vivian was prehistoric water control; he initiated some research and collected notes over time (Vivian n.d.) His son, Gwinn, spent much time in Chaco and followed in his father's intellectual footsteps. While researching irrigation in Chaco, Gwinn Vivian traced the large canal system that captured runoff from the cliff tops during storms and channelled water through miles of canals located along the base of the cliffs to prehistoric fields (Vivian n.d., 1970, 1972, 1974). He continues to study the Chaco subsistence problems and to incorporate new data into his interpretations of Chacoan behavior (Vivian 1981). While his work is not included in this volume, the reader is encouraged to read his publications when evaluating prehistoric adaptations to the natural environment.

The Chaco Project

In the early 1960s, archeologists in general adopted an ecological/environmental approach to explain prehistoric behavior. In the late 1960s, John Corbett of the National Park Service, was instrumental in establishing a cooperative program with the University of New Mexico to undertake major reevaluation of the Chaco Anasazi. Numerous experts in various fields of study were invited to lend their expertise. During the tenure of its first director, Dr. Thomas R. Lyons, many departments at the University were encouraged to participate in the Chaco Project. His successors, Dr. Robert H. Lister and Dr. W. James Judge, pursued these contacts. As a result, geographers, geologists, botanists, biologists, and other specialists contributed to a number of studies that could not be included in this volume. Many new questions were addressed, though other topics needed to be reexamined, e.g., changes in temperature and rainfall regimes, soil conditions, amount of arable land available, irrigation techniques, crops actually grown versus those gathered, number and quality of faunal resources utilized, nutritional requirements that could be met based on the population estimates, etc. The work of these scholars generated a number of reports. The results of these investigations, plus any other publications not included in the reference lists in the following chapters and appendices A and B, are included in Appendix C.

References Cited

Allen, Glover M.
1954 Canid Remains from Pueblo Bonito and Pueblo del Arroyo. Appendix B in The Material Culture of Pueblo Bonito by Neil M. Judd, pp. 385-389. Smithsonian Miscellaneous Collections, vol. 124. Washington.

Bannister, Bryant, William J. Robinson, and Richard L. Warren
1970 Tree-ring Dates from New Mexico A, G-H, Shiprock-Zuni-Mt. Taylor Area. Laboratory of Tree-Ring Research, University of Arizona, Tucson.

Bradfield, Wesley
1921 Economic Resources of Chaco Canyon. Art and Archaeology 11: 36-38.

Brand, Donald D., Florence M. Hawley, and Frank C. Hibben
1937 Tseh So, A Small House Ruin, Chaco Canyon, New Mexico. Preliminary Report. University of New Mexico, Bulletin Anthropological Series vol. 2, no. 2. Albuquerque.

Bryan, Kirk
1925 Date of Channel Trenching (Arroyo Cutting) in the Arid Southwest. Science 62:338-344.

1926 Recent Deposits of Chaco Canyon, New Mexico. Journal of the Washington Academy of Science 16(3):75-76.

1928 Niches and Other Cavities in Sandstone at Chaco Canyon, New Mexico Zeitschrift fur Geomorphologie 3:125-140.

1929 Flood-water Farming. Geographical Review 19:444-456.

1954 The Geology of Chaco Canyon, New Mexico. Smithsonian Miscellaneous Collections, vol. 122, no. 7, pp. 1-65. Washington.

Chauvenet, William
1935 Erosion Control in Chaco Canyon, New Mexico, for the Preservation of Archaeological Sites. Unpublished Master's thesis, University of New Mexico, Albuquerque.

Clary, Karen H.
1981 Pollen Analysis of Coprolites from Chaco Canyon, New Mexico. Castetter Laboratory for Ethnobotanical Studies Technical Series Report no. 52. University of New Mexico, Albuquerque.

1983 Prehistoric Coprolite Remains from Chaco Canyon, New Mexico: Inferences for Anasazi Diet and Subsistence. Unpublished Master's thesis, Department of Anthropology, University of New Mexico, Albuquerque.

1984 Anasazi Diet and Subsistence as Revealed by Coprolites from Chaco Canyon. In Recent Research on Chaco Prehistory, edited by W. James Judge and John D. Schelberg, pp. 265-279. Reports of the Chaco Center no. 8. Division of Cultural Research, National Park Service, Albuquerque.

Douglass, A.M.
1924 Some Aspects of the Use of the Annual Rings of Trees in Climatic Study. Smithsonian Annual Reports for 1922, p. 238, Washington.

Dean, Jeffrey S., and Richard L. Warren
1983 Dendrochronology. Chapter V, in The Architecture and Dendrochronology of Chetro Ketl, Chaco Canyon, New Mexico, edited by Stephen H. Lekson, pp. 105-240. Reports of the Chaco Center no. 6. Division of Cultural Research, National Park Service, Albuquerque.

Dodge, Richard E.
1902a An Interesting Landslide in the Chaco Canyon, New Mexico. Science NS. 15:746.

1902b Arroyo Formations. Science NS. 15:746.

1920 Report of Field Studies. In Pueblo Bonito, by G.H. Pepper, pp. 23-25. American Museum of Natural History Anthropology Papers no. 27. Washington.

Elmore, Francis H.
1943 Ethnobotany of the Navajo. University of New Mexico Bulletin 392, Mongraph Series, vol. 1, no. 7. Albuquerque.

Fisher, Reginald G.
1934 Some Geographic Factors that Influenced the Ancient Populations of the Chaco Canyon, New Mexico. A Preliminary Report. University of New Mexico Bulletin 244, Archaeology Series, vol. 3, no. 1. Albuquerque.

Hawley, Florence M.
1933 Tree Ring Chronology in Chaco Canyon. El Palacio 34:204-205

1934 The Significance of Dated Prehistory of Chetro Ketl, Chaco Canyon, New Mexico. University of New Mexico Bulletin 246. Albuquerque.

1938 The Family Tree of Chaco Canyon Masonry. American Antiquity 3: 247-255.

Hewett, Edgar L.
1905 Prehistoric Irrigation in the Navajo Desert. Records of the Past 4:323-329.

Judd, Neil M.
1954 The Material Culture of Pueblo Bonito. Smithsonian Miscellaneous Collection vol. 124. Washington.

Keür, Dorothy, and John Keur
1935 Threatening Rock. Southwestern Monuments, July, pp. 16-17; November, pp. 389-390.

Keur, John Y.
1933 Threatening Rock. Southwestern Monuments, October, pp. A-K.

Kluckhohn, Clyde
1939 Subsistence Remains. In Preliminary Report on the 1937 Excavations, Bc 50-51, edited by Clyde Kluckhohn, and Paul Reiter, pp. 147-150. University of New Mexico Bulletin 345, Anthropology Series, vol. 3, no. 2. Albuquerque.

Kluckhohn, Clyde, and Paul Reiter (editors)
1939 Preliminary Report on the 1937 Excavations, Bc 50-51. University of New Mexico Bulletin 345, Anthropology Series, vol. 3, no. 2. Albuquerque.

Pepper, George H.
1920 Pueblo Bonito. Anthropological Papers of the American Museum of Natural History vol. 27. Washington.

Rose, Martin R.
1979 Annual and Seasonal Dendroclimatic Reconstructions for Areas in and around Chaco Canyon. Laboratory of Tree-Ring Research, University of Arizona, Tucson.

Rose, Martin., William J. Robinson, and Jeffrey S. Dean
1982 Dendroclimatic Reconstruction for the Southwestern Colorado Plateau, 2 vol. Laboratory of Tree-Ring Research, University of Arizona, Tucson.

Senter, Donovan
1937 Tree-rings, Valley Floor Deposition, and Erosion in Chaco Canyon, New Mexico. American Antiquity 3:68-75.

Simpson, James H.
1850 Journal of a Military Reconnaissance from Santa Fe, New Mexico, to the Navajo Country, Made with the Troops under the Command of Brevet Lieutenant Colonel John M. Washington, Chief of the Ninth Military Department, and Governor of New Mexico, in 1849. In Reports of the Secretary of War, Thirty-first Congress, First Session, Senate Ex. Doc. No. 64, pp. 80-81, Washington.

Vann, Richard P.
1931 Paleontology of the Upper Cretaceous of Chaco Canyon, New Mexico. Unpublished Master's thesis, University of New Mexico, Albuquerque.

Vivian, R. Gordon

n.d. Unpublished Notes on Prehistoric Water-control Systems in Chaco Canyon. Notes on file, Division of Cultural Research, National Park Service, Albuquerque.

Vivian, R. Gordon, and Thomas W. Mathews

1965 *Kin Kletso: A Pueblo III Community in Chaco Canyon, New Mexico*. Southwestern Monuments Association Technical Series, vol. 6, part 1.

Vivian, R. Gwinn

n.d. Unpublished Survey and Excavation Records, 1969-71, National Science Foundation Chaco Water Control Project. Notes on file, Arizona State Museum, Tucson, and Division of Cultural Research, National Park Service, Albuquerque.

1970 An Inquiry into Prehistoric Social Organization in Chaco Canyon, New Mexico. In *Recontructing Prehistoric Pueblo Societies*, edited by William Longacre, pp. 59-83. University of New Mexico Press, Albuquerque.

1972 Prehistoric Water Conservation in Chaco Canyon. Final Technical Letter Report for National Science Foundation Grant No. GS-3100. Report on file, Division of Cultural Research, National Park Service, Albuquerque.

1974 Conservation and Diversion. Water-Control Systems in the Anasazi Southwest. Ch. 9 in *Irrigation's Impact on Society*, edited by T.E. Downing and M.C. Gibson, pp. 95-112. Anthropological Paper No. 25, University of Arizona, Tucson.

1981 Agricultural and Social Adjustments to Changing Enviroments in the Chaco Basin. Paper presented at the 46th Annual Meeting of the Society for American Archaeology, San Diego.

Chapter One

Holocene Climate and Environment of Chaco Canyon

by
William B. Gillespie

Introduction

Chaco Canyon, in the semiarid San Juan Basin of northwestern New Mexico, is well known for its concentration of Anasazi ruins and evidence of relatively sophisticated socio-economic development. Numerous attempts have been made (and continue to be made) to explain the prehistoric cultural development there. Virtually all of these attempts have appealed to various aspects of the past climate or physical environment in trying to understand past human adaptation. Frequently, a perceived change in one or another characteristic of the past environment has been accorded primary causal significance in accounting for major cultural changes. It is not surprising then, that throughout the history of research in the canyon, there has been a profitable association of archeological and paleoecological investigations.

This paper is conceived as a summary and review of recent paleoenvironmental research in Chaco. While the orientation is toward reviewing information of potential significance in modelling past human adaptations, discussion of archeological evidence of past adaptions is minimal. The focus is on characterizing the general climatic and environmental framework, which confronted human populations at different times in the past, and on suggesting revisions of previous interpretations where warranted. This is not a comprehensive review of the paleoenvironmental data that have been generated in recent years from Chaco or elsewhere on the Colorado Plateau.

The time frame adopted spans the entire 10,000 year range of human use of the Chaco area and not just the Anasazi period; however, more consideration is given to the preceding millenia. This is in part because much of the paleoecological information that has recently become available has been from pre-Anasazi times and, in part, because different aspects of the Anasazi environment have been recently reviewed and documented in comprehensive detail (e.g., Love 1980; Rose et al. 1982).

This paper is divided into four sections. The initial discussion is of the present climatic characteristics with emphasis on the atmospheric circulation systems, which combines with geography and topography of the area to produce those characteristics. Three sections follow summarizing recent data from the late Pleistocene-early Holocene, the middle Holocene, and the late Holocene.

Present Climatic Parameters

The climate of the San Juan Basin can be described as cool and semiarid with high diurnal and yearly temperature variation, low humidity, occasionally strong winds, and generally low and variable precipitation. Rainfall is seasonal in distribution with a marked summertime peak in late July, August, and September, and a much lower peak in the winter and early spring. Drought periods occur nearly every year in June and November. Some particular precipitation and temperature values for Chaco will be discussed below.

General Atmospheric Circulation

The values and seasonal distribution of precipitation in the San Juan Basin are functions of its latitude, elevation, and geographical location in relation to atmospheric circulation features and surrounding orographic barriers. Precipitation in different seasons tends to be brought into the area from various sources by different circulation features (see e.g., Hastings and Turner 1965; Rose et al. 1982; Sellers 1960; Sellers and Hill 1974).

Winter precipitation is derived from moisture originating in the northern Pacific and brought to the area by the prevailing mid-latitude westerlies that have shifted northward with seasonal cooling. Precipitation occurs from cyclonic storms that break off from the Aleutian Low and move across the western United States with the westerlies. Most of these storm tracks enter the continent in the state of Washington and pass north of the Four Corners. Periodically during the winter, the westerly flow dips into the Southwest. It has been suggested that generally cooler temperatures result in more frequent southward displacement of the moisture-bearing westerlies, and consequently, greater cool season precipitation in the Four Corners (Van Devender and Spaulding 1979).

Cool season moisture is also brought to the Southwest from the tropical Pacific when low pressure systems move eastward and occasionally enter the Southwest. These storms can bring very high precipitation to the area and account for the wettest winters on record in southern Arizona (Sellers and Hill 1974); however, they are fairly rare in frequency and not often effective in the San Juan Basin, in part because of the blocking effects of the Mogollon Highlands. Sellers (1960) notes that high September precipitation in the Southwest is usually a result of these Pacific storms; consequently, September precipitation is often poorly correlated with July and August rainfall and better correlated with winter precipitation. This seems to be because such September storms make their incursions into the Southwest when the summer monsoonal circulation is weak and has retreated early. This also appears to be the case in Chaco, where in recent decades very high September rainfall values are frequently paired with very low July-August rainfall totals, and vice versa.

There is positive correlation in the Colorado Plateau between latitude and winter precipitation as a result of more westerly storms to the north, i.e., weather stations in eastern Utah and western Colorado consistently have higher winter precipitation values than stations in northwestern New Mexico and northeastern Arizona at comparable elevations. This trend is evident over surprisingly short distances; for example, winter precipitation has averaged higher in the San Juan Valley than in Chaco Canyon, despite the fact that Chaco is higher in elevation (by about 200 m). This occurrence runs counter to the regional trend of increasing precipitation with increasing elevation, a situation which pertains in every month of the year (Rose et al. 1982). Part of the reason for this reversal may also be the rain shadow effect of the Chuska Mountains west of Chaco.

The important rainfall peak in July, August, and early September is a result of the incursion of the summer monsoonal circulation pattern into the area, i.e., when the Bermuda High shifts northward and westward as the hemisphere warms up and the westerlies and sub-polar lows move northward (see Hastings and Turner 1965). Air flows northwestward (clockwise) along the west side of the Bermuda High and brings with it moisture from the Gulf of Mexico and tropical Pacific adjacent to Central America (Hales 1974). This moist western edge of the anticyclone is converging, rising, and unstable as it flows into the Southwest; it nearly always produces rainfall while crossing the heated lands of the area and is orographically lifted by the highlands.

The monsoon effect does not reach the Colorado Plateau until around the middle of July, but for the next two months rainfall is characteristically abundant and relatively reliable. The extent of the moist monsoonal circulation is presently delimited by a rough line from southeastern Utah through northwestern Colorado to the Great Plains (Mitchell 1976). The San Juan Basin receives less monsoonal moisture than areas to the south and east, due in part to the greater distance from the sources of moisture and resultant later date of establishment and earlier retreat of the monsoon, as well as to the interception of moisture by intervening highlands and the rainshadow effect (Tuan et al. 1973). Controlling for elevation, stations in the Mogollon-Zuni-Jemez highlands or to the southeast of them, characteristically receive 1-3 in (2.54-7.62 cm) more summer rain than do locations in the Four Corners area. A period of above thermal temperatures can be expected to increase summer rainfall by lengthening the time that the monsoonal circulation is in effect and strengthening the circulation pattern (Petersen 1981).

Combining the winter and summer precipitation, it can be seen that there is a distinct gradient in the percentage of rainfall occurring in the summer. This can be illustrated by considering a north-south transect through western New Mexico and Colorado. Using 1931-1960 normals (NOAA climatological data), the percentage of annual precipitation falling in July and August in selected areas is 38-40% (Deming-Mogollon-Quemado), 32% (Zuni), 28% (Chaco), 26% (Bloomfield), and 20% (Mesa Verde north to northwestern Colorado). Thus there is a sharp transition from nearly 40% to about 20% over the rather short distance between about 34° and 37°

latitude, or across the San Juan Basin. Rose et al. (1982) document an east-west component to the transition through northwestern New Mexico showing higher summer precipitation to the east.

This implies that the San Juan Basin occupies a sensitive transitional location between a relatively winter-dominant pattern to the north and a summer-dominant pattern to the south. Shifts in global temperature characteristics and circulation systems may be manifest more distinctly here than in other areas of the western United States.

Several climatologists (e.g., Bryson and Baerreis 1968; Bryson and Murray 1977; Lamb 1977; Winstanley 1973) have explored the possibilities of relating local changes in meteorological parameters to global changes in temperature and characteristics of circulation. Winstanley (1973), for example, uses data from the Old World to argue that fluctuations in monsoonal rainfall correlate strongly with fluctuations in the strength of mid-latitude zonal circulation (i.e., the prevailing westerlies and jet stream). With strong zonal circulation, the prevailing westerlies tend to be contracted poleward and show relatively little north-south (meridional) flow. The general lack of troughs extending into lower latitudes in the San Juan Basin implies that winter precipitation would be reduced. At the same time, summer monsoonal circulation should be stronger, indicating an increase in summer rainfall. Winstanley (1973) and Lamb (1977) suggest that such conditions existed in the centuries before A.D. 1200, or about the time of the Anasazi development in the San Juan Basin. As discussed later in this paper, paleoecological data from the Colorado Plateau tend to support this scenario (see Petersen 1981).

With weak zonal circulation, the circumpolar vortex tends to expand, that is, the prevailing westerlies shift southward (Winstanley 1973). There is more meridional flow; weather systems, often blocked by persistent high pressure systems, move more slowly. Monsoonal rains do not extend as far north and temperatures are generally cooler. These circumstances should result in drier summers in the southeastern Colorado Plateau. Lamb (1977) and Bryson (e.g., Bryson and Murray 1977) present models that differ in some details from Winstanley's scheme, but are similar in basic concepts.

Present Trends in Temperature and Precipitation

Bryson and Baerreis (1968:7) present an illustration showing that in recent decades some localities in northwestern New Mexico have experienced a marked (over 25%) reduction in July rainfall in years when westerlies have been slightly expanded. Bryson's argument is that responses such as this to recent, recorded yearly fluctuation in circulation are reasonable models for past responses to longer term changes; thus it can be suggested that periods of warmer temperatures and strong, contracted westerly flow should be characterized by relatively high summer moisture in the San Juan Basin.

There are differences between recent meteorologic trends in the San Juan Basin and what might be expected given historic trends in global temperature and circulation. While world-wide surface temperatures increased through the first half of the twentieth century to about 1945 and have since cooled (Lamb 1977; Miles 1978), temperatures in the San Juan Basin and much of the western United States continued to rise after 1945 (Bradley 1980).

The records for the San Juan Basin indicate that summer temperatures rose until the late 1960s but have since declined (NOAA climatological data). Combined July and August rainfall has followed much the same trend with a maximum in the late 1960s. Bradley (1980) presents similar results for the Rocky Mountains where he found evidence of a trend toward warmer and wetter summers over the past 70 years. Correlations between summer temperatures and precipitation at individual stations in the San Juan Basin are weak. It appears that there is a positive association between summer rainfall and summer temperatures, but the recent increase in both has occurred in the context of cooling global temperatures and generally weak westerly circulation (Lamb 1977).

It is also worth noting that over the past 40 years there has been no apparent negative correlation between amounts of summer and winter precipitation; they both peaked in the late 1960s. This suggests that the notion of summer or winter dominance alone does not adequately account for different precipitation patterns (Euler et al. 1979; Rose et al. 1982).

Summer Precipitation Characteristics

Annual precipitation has averaged about 8.5 in (220 mm) in Chaco Canyon over the past few decades. However, year-to-year variation is great. For example, from 1950 to 1980, annual totals have ranged from only 3.35 in (85 mm) to 13.75 in (350 mm). As is often the case in semiarid locations, the median is lower than the mean for all months, and for the annual. In other words, more than half of all years will have less than the mean amount of precipitation.

Throughout the San Juan Basin there is a positive correlation between precipitation amounts and elevation. Annual values for stations in the basin range from around 7 in (180 mm) at Shiprock at an elevation of under 5,000 ft (ca. 1,500 m) to 10.3 in (260 mm) at Crownpoint, just under 7,000 ft (ca. 2,130 m). In surrounding highlands precipitation may exceed 20 in (500 mm). Annual precipitation shows a lapse rate of about 0.18 in/100 ft (15 mm/100 m) for the lower parts of the San Juan Basin.

The summer maximum in precipitation is of critical importance to maize farmers in this semiarid environment. Even though overall amounts are limited, at least the wettest time of the year occurs when it is most needed; when moisture stress is greatest as crops are silking, tasseling, and coming to fruition. A few notes on characteristics of summer precipitation at Chaco Canyon are given here (figures based on the 25-year period ending in 1975).

August is characteristically the wettest month at Chaco ($\overline{x}$ = 1.37

in/35 mm), with July, September, and October all slightly less (means slightly over 1 in/25 mm). June, on the other hand, is the driest month of the year ($\bar{x}$ = 0.38 in/10 mm, median = 0.24 in/6 mm), when an average of 3.0 rainy days (i.e., with any measurable precipitation) can be expected and two-thirds of the years have no rain greater than 0.1 in. Fewer than 20% of years have any precipitation events greater than 0.4 in (10 mm).

In July, the mean number of rainy days more than doubles to 7.9 (range 4-13). Rains greater than 0.1 in occur in all years ($\bar{x}$ = 3.5 days, range 1-9) and larger events of over 10 mm (0.4 in) occur in 60% of the years sampled. In August, the mean number of rainy days is 7.6, with the events over 0.1 in occurring every year ($\bar{x}$ = 4.2, range 1-9). Heavier rains (greater than 0.4 in), however, only occur in about half of the years. September precipitation is more variable than in either July or August with a few very wet years among much drier ones (perhaps a result of non-monsoonal incursions of major storms from the tropical Pacific). The median amount (0.85 in/22 mm) is only 75% of the mean value (1.15 in/29 mm). One year no rain fell, although the average number of rainy days is 5.2. Days with less than 0.1 in rainfall occur in 80% of the years ($\bar{x}$ = 3.0 days). Precipitation events exceeding 0.4 in occur in slightly fewer than half of the years.

Temperature and Frost-free Season

The continental, high basin location of Chaco Canyon makes for substantial diurnal and seasonal variation in temperatures. Diurnal temperature range is accentuated by the location of the weather instruments in the valley bottom (at the present Visitor Center). Average annual temperatures (1941-1970 normals) is 49.8° F (9.9° C). Highest monthly temperatures are in July ($\bar{x}$ = 73.2° F--22.9° C) and lowest in January ($\bar{x}$ = 29.0° F--1.7° C).

A function of temperature of some interest to farmers (and apparently to Southwestern archeologists) is the length of the frost-free season. Recent records for Chaco Canyon are noteworthy in that they are surprisingly short. Since 1960, frost-free periods have averaged only slightly over 100 days, with over half the years in this period fewer than 100 days. By the widely accepted standards which suggest ca. 110-130 days as a minimum requirement for maize (cf. Adams 1979 for recent summary), Chaco should be considered a high risk area (by Adams' criteria, it is hard to believe anyone would ever try to farm there).

The very low recent periods from Chaco contrast noticeable with most published figures. For example, Hayes (1981) noted frost-free seasons at Chaco as being about 150 days, and Cordell (1979) shows maps indicating a growing season of over 160 days. One reason for this discrepancy is the fact that both Hayes and Cordell made use of references that were based on data no more recent than 1939. Only a few years of observation were available for Chaco at that time (Gillespie and Powers 1983). Other reasons for this apparent discrepancy include (1) the affect of a station move within the canyon; (2) a regional climatic trend toward shorter frost-free periods; and (3) a change from recognizing the length of growing season to measuring the frost-free season. The Chaco Canyon weather station was moved from Pueblo Bonito to the present Visitor Center at Una Vida in 1960, about the time measured values show a noticeable drop. Application of a test for homogeneity by plotting cumulative differences in minimum July temperatures for Chaco and nearby Bloomfield shows that the Chaco station move did indeed have a noticeable affect. Bloomfield and some other stations in the San Juan Basin show a slight trend toward shorter frost-free periods since about 1950, despite the increase in summer temperatures through the 1960s.

In the 1940s the Weather Bureau completed a transition from recording "growing seasons" as defined by "killing frosts" to only recording time spans between 32° F (0° C) minima. The definition of killing frost was not always consistent, but generally approximated 30° F (-1.1° C) temperatures rather than 32° F (0° C). In order to assess the net effect of this difference, a comparison of about 250 records (New Mexico 1921-1936) showing both daily minima and killing frost-free days was made. The comparison indicates that 85% of 31° F (-0.5° C) temperatures were ignored in defining killing frosts, 53% of 30° (-1.1° C) minima, and only 6% of 29° (-1.6° C) minima. The use of broader standards resulted in an average difference of 13 days between growing season records and frost-free season.

There is definite merit in favoring killing frost observations rather than freezing temperatures. Maize is usually not damaged until temperatures dip below 30° F (-1.1° C), although growth stage and moisture content cause variations (Chang 1968). This factor is in part countered by the positon of recording instruments more than 1 m above the ground where night temperatures are often several degrees warmer than at ground level.

Even considering these mitigating factors, it seems likely that Chaco presently has a potential for freeze damage, and may well have in the past. It is unclear how critical frost-free period length is in assessing prehistoric agricultural potential. The possibilities that fast-maturing strains of corn were used and that recent frost-free periods are not indicative of effective growing season suggest that periods less than 110-130 days are not necessarily prohibitive. These low figures would perhaps be better considered as a potential limitation rather than a barrier to maize agriculture. Nonetheless, areas such as Chaco were probably subject to occasional reduced yields, especially during periods of reduced temperatures.

Late Pleistocene and Early Holocene

The transition from the most recent glacial period (Late Pleistocene) to the present interglacial (Holocene) is usually placed around 11,000 or 12,000 B.P; however, it should be realized that dates such as these are little more than a convenient reference point during a longer period of global warming that marked the end of the Pleistocene. Major environmental changes associated with this period of warming were occurring for several thousand years both before and after 12,000 B.P. For example, Carrara et al. (1984) present good evidence indicating that much of the extensive San Juan Mountains, north of the San Juan Basin, was deglaciated by 15,000 B.P., well before the nominal end of the Wisconsin glacial. Vegetational changes accompanied this period of warming and deglaciation with several regional studies showing that perhaps the most dynamic changes occurred at around 9,000-8,000 B.P., by which time temperatures evidently met or exceeded present levels and vegetation distributions more closely approximated modern patterns (e.g., Betancourt 1984a; Carrara et al. 1984; Van Devender and Spaulding 1979; Wells 1983a). Evidence of environmental conditions during this late glacial and early post-glacial period (from 16,000-8,000 B.P.) is reviewed here, with particular reference to environmental data from the Chaco Canyon area.

The primary cause and mechanisms of this global event of warming and deglaciation are not fully understood, but there is growing acceptance of a linkage to anomalies in received solar radiation resulting from variations in the earth's orbit (e.g., Hays et al. 1976; Imbrie and Imbrie 1980; Kutzbach 1981). Orbital variations include long-term cycles in the obliquity of the earth's axis, the precession of the equinox, and eccentricity of the orbit. There is evidence that near the end of Pleistocene these factors combined to produce a maximum in summer radiation and a minimum of winter radiation in the mid-latitudes of the Northern Hemisphere at around 9,000-10,000 B.P. (Kutzbach 1981). Even though average annual global amounts of incoming solar radiation may have remained nearly constant, the change in latitudinal and seasonal distribution in insolation may have sparked major climatic changes (Kutzbach 1983). Ruddiman and McIntyre (1981) suggest than an increase in summer insolation in the Northern Hemisphere would have begun diminishing the continental ice volume and started the process of deglaciation. With the maximum in summer insolation at 9,000-10,000 years ago, Kutzbach (1981, 1983) argues that mid-latitude monsoonal circulation and precipitation would have increased at this time as well (also Markgraf and Scott 1981; Spaulding et al. 1983).

Prior to the past few years, suggestions of vegetation cover in the San Juan Basin during the late Pleistocene and early Holocene were based on extrapolation from records in surrounding areas. Suggestions of communities of desert scrub (Leopold 1951), pinyon-juniper (Wright et al. 1973), ponderosa (Martin and Mehringer 1965), and spruce-fir forest (Harris 1965) can all be found in the literature. Only in the past few years has direct evidence from the basin interior placed interpretations on firmer ground. Still, although the data have improved, varying interpretations persist and questions have yet to be resolved.

Macrobotanical Remains

Indisputable evidence of the past presence of montane conifers in Chaco Canyon was provided by the macrofossils in early Holocene packrat middens in Atlatl Cave, ca. 11,000-9,500 B.P. (Betancourt and Van Devender 1980, 1981; Betancourt et al. 1983). Included are needles of limber pine (Pinus flexilis), Douglas fir (Pseudotsuga menziesii), Rocky Mountain juniper (Juniperus scopulorum), and a single needle of spruce (Picea sp.). Betancourt and Van Devender (1981) interpret these as relicts from more widespread Pleistocene mixed conifer woodlands and note the absence of the more xeric pinyon (P. edulis) and ponderosa (P. ponderosa). Subsequently, Donaldson (1984) has found additional montane conifer macrofossils in loose sediments from Sheep Camp Shelter, where some undated late Pleistocene assemblages were dominated by limber pine and spruce. Douglas fir, Rocky Mountain juniper, and ponderosa are present in smaller numbers and are, in some instances, possibly later contaminants of the spruce-limber pine assemblage (mixing in the loose sediments was widespread).

None of the montane conifers identified at Atlatl Cave and Sheep Camp Shelter now grows in Chaco Canyon; all are found in more mesic woodland habitats at higher elevations in the area. Douglas fir and Rocky Mountain juniper are scattered through montane plant association in highlands surrounding the San Juan Basin, while spruce (P. pungens, the species probably represented at Chaco, and P. engelmanii) is largely restricted to more mesic mixed conifer communities in these highlands. Limber pine is now limited in distribution to the large mountain masses to the north and east, the San Juan and Jemez mountains, where it occurs mainly in mixed conifer communities (Osborn 1966; Peterson 1981). It is absent from the smaller Chuska and Mt. Taylor ranges, although on the basis of pollen evidence Wright et al. (1973) inferred its presence in the Chuskas in the late Pleistocene.

Palynological Evidence

In summarizing pollen studies from the Southwest, Martin and Mehringer (1965) produced a paleovegetation map for the late Pleistocene suggesting that the San Juan Basin was covered by ponderosa pine woodland, a suggestion based on evidence from several studies of elevational lowering of tree line and vegetation communities in highland areas. In studying pollen sequences from the Chuska Mountains, Wright et al. (1973) modified this interpretation somewhat by suggesting a telescoping of vegetation zones so that lower communities were elevationally displaced less than tree line and subalpine zones. By this method, Wright et al. (1973) project pinyon-juniper woodland cover for much of the basin in the Four Corners area, in part to account for the abundance of pinyon pollen in the Chuska Mountain sequences. Hall (1977), whose alluvial pollen sequences from Chaco Canyon postdate the early Holocene, could make no judgment on the relative merits of the reconstruction of Martin and Mehringer and Wright et al.

Betancourt and Van Devender's (1981) discovery of more montane conifers in the early Holocene packrat middens at Atlatl Cave was thus something of a surprise in its contradiction of vegetation reconstructions based on pollen studies. Neither ponderosa nor pinyon appears to have been present in the early Holocene assemblages. Hall (1981) studied pollen from these packrat middens and found them dominated by juniper and secondarily by Pinus and the shrubs Artemisia and Chenopodium. Hall suggests that the montane conifers may have been only rare relicts, with the dominant vegetation cover being shrub grassland, probably with more sagebrush (Artemisia sp.) than now.

Fredlund (1984) has recently analyzed pollen samples from sediments in Sheep Camp Shelter containing undated late Pleistocene faunal remains. These samples are dominated by Pinus and Picea, which together in some cases comprised over 90% of the pollen total. In contrast to Hall's early Holocene packrat midden pollen samples, juniper and non-arboreal pollen are rare. Fredlund interprets the predominance or spruce and pine pollen as indicating total forestation of the San Juan Basin and, moreover, suggests that not only spruce and limber pine were common in the basin, so also were ponderosa, pinyon, lodgepole pine, and Douglas fir, (based largely on presence of pollen morphotypes of the different Pinus species). In sediment samples interpreted by Fredlund as early Holocene, there is no indication of the increase in steppe flora suggested by Hall.

Faunal Remains

A rather large assemblage of vertebrates evidently from the late Pleistocene was recovered from the unconsolidated deposits in Sheep Camp Shelter (Gillespie 1984a, 1984b). Including more recent materials, about 60 taxa are present, the majority of which are small mammals. The presence of extinct horse (Equus sp.) and peccary (cf. Platygonus compressus) indicates a late Pleistocene deposition, although it is unclear whether materials are of the late glacial or full glacial.

The faunal assemblage includes several taxa no longer found in the interior San Juan Basin. Nearly all non-local taxa occur in more mesic situations, either cooler, wetter, or both. Most prevalent are species now found in the Great Basin, especially in the extensive sagebrush communities there: sagebrush vole (Lagurus curtatus), pygmy rabbit (Brachylagus idahoensis), and sagebrush grouse (Centrocercus urophasianus). Other species whose present ranges do not include northwestern New Mexico include the yellow-bellied marmot (Marmota flaviventris), white-tailed jackrabbit (Lepus townsendii), Richardson's ground squirrel (Spermophilus cf. richardsoni), and Heather vole (Phenacomys intermedius). The latter species in particular is now largely restricted to boreal forest habitats, lending support to the evidence of more extensive forestation in the past. Another group of non-local taxa at Sheep Camp Shelter includes species which now occur in the open habitats of the Great Basin and also in higher, more montane areas in the mountains surrounding the San Juan Basin: Merriam's shrew (Sorex merriami), least chipmunk (Eutamia cf. minimus), golden-mantled ground squirrel (Spermophilus lateralis), northern pocket gopher (Thomomys talpoides), and long-tailed vole (Microtus longicaudus).

While the presence of some species such as the heather vole suggest mixed conifer habitat, perhaps more significant are the abundant remains of taxa characteristic of cold desert scrub environments, e.g., sagebrush vole, sage grouse, and pygmy rabbit.

Only a few diagnostic vertebrates are present in the early Holocene packrat middens from Atlatl Cave (Gillespie 1982). Included are specimens of Sagebrush vole and Nuttall's cottontail (Sylvilagus nuttallii), a species now found in the Southwestern mountains and in open habitats in the Great Basin. The majority of faunal remains from Atlatl Cave are from the subsequent middle and late Holocene periods.

Discussion: Late Pleistocene and Early Holocene Vegetation

From this summary of recent studies of macrobotanical, microbotanical, and vertebrate materials from Chaco, it is evident that the new data require revision of accepted vegetation reconstructions. The suggestions of Martin and Mehringer (1965) and Wright et al. (1973) based on downward displacement of modern plant communities now seem inadequate. Perhaps most striking is the occurrence of spruce and limber pine rather than the ponderosa and pinyon cover suggested by these previous studies. Problems still in need of resolution include the extent of any mixed conifer woodland indicated by the macrofossil evidence, and of open steppe habitats, and the composition of woodlands in the area. These topics are considered here in addition to a brief discussion of the Chaco data in relation to other paleoenvironmental records in the region.

Other recent analyses of packrat midden macrofossils document similar occurrences of mixed conifers at elevations below their present distributions. For example, it now seems apparent that there was a successful late Pleistocene adaptation by limber pine throughout the West in latitudes north of Chaco Canyon (36°). Evidence of widespread occurrence of limber pine at elevations around 2,000 m or less has been reported for the southern and eastern Great Basin (Spaulding et al. 1983; Thompson and Mead 1982; Wells 1983a) for elsewhere on the Colorado Plateau (Betancourt 1984; Betancourt and Davis 1984; Spaulding and Petersen 1980), and from the east side of the Front Range of the Rockies (Wells 1983b). Presently in these areas limber pine is found mainly on rocky outcrops in upper mixed conifer or subalpine associations, if it is present at all.

There is disagreement about the extent of the cover by limber pine and other montane conifers in areas outside of the San Juan Basin. Some authors (e.g., Wells 1983b) have suggested that a predominance of limber pine in late Pleistocene deposits is indicative of a subalpine sitation not far below timberline. While limber pine is found in subalpine settings in the southern Rockies now, further north it occurs in a variety of elevations and settings, in most cases occupying relatively xeric, exposed rocky outcrops; it also occupies situations where pinyon is common, such as in southern Montana (Pfister et al. 1977). Accordingly, it seems more probable that the past presence of limber pine with spruce, Douglas fir, and Rocky Mountain juniper is more indicative of a mixed conifer or montane community, than of a subalpine one.

In the Great Basin, Wells (1983a), relying almost exclusively on packrat midden macrofossil data, argues for extensive woodlands in lowland areas and in an essential absence of desert scrub communities. In contrast, Thompson and Mead (1982), synthesizing macrofossil, pollen, and faunal data present a case for the co-occurrence of montane or subalpine conifers on rocky outcrops with sagebrush-dominated desert scrub associations on deeper alluvial substrates. Spaulding et al. (1983) and Mead et al. (1982) also interpret their data as indicating a co-occurrence of montane conifers and desert scrub communities in the southern Great Basin, as do Betancourt and Davis (1984) for the Canyon de Chelly area.

The situation described above seems most probable for the Chaco area, not only for the early Holocene as suggested by Hall (1982) but also for the late Pleistocene. The reconstruction favored here entails mixed conifer woodlands occurring on rocky outcrops and thin rocky soils such as characterize much of Chaco Canyon, and largely unforested desert scrub and shrub grassland communities in deeper sediments on the aolian-mantled mesa tops and valley floors. Woodland cover was no doubt greater than now, but not as pervasive as most earlier suggestions indicated. It is possible that open desert scrub associations were as common or more common in the San Juan Basin and Great Basin than in today's warm desert areas (Mohave, Sonoran, Chihuahuan deserts) where pinyon and juniper woodlands were apparently widespread during the late Pleistocene (Spaulding et al. 1983; Van Devender 1977; Van Devender and Spaulding 1979).

Such a reconstructed vegetation pattern for Chaco is without a local modern analogy. The best present analogy is probably the northern Great Basin or northern Rockies (northern Nevada to southern Montana) where mixed conifer forests, including locally abundant limber pine, occur just above desert scrub and grassland associations. The pinyon-juniper and ponderosa zones so characteristic of the present Southwest seem to have been missing, leaving a juxtaposition of more montane mixed conifer and open steppe habitats.

A logical question, then, is where were the pinyon and ponderosa communities in the late Pleistocene? Evidence from packrat middens throughout the West suggests that both ponderosa and Colorado pinyon (*P. edulis*) were rare, if present at all, in latitudes north of Chaco, and were not very common in southern areas (Spaulding et al. 1983). Pollen analysts such as Wright et al. (1973), Petersen (1981), and Fredlund (1984) have interpreted a local presence for pinyon woodlands on the basis of relatively abundant *P. edulis*-type pollen. Betancourt and Davis (1984) suggest that this occurrence is a result of long distance transport of pinyon pollen to the Four Corners region from areas to the south, and that pinyon was not locally represented. The same may pertain to ponderosa, which is also common in pollen records where analysts have attempted specific identifications of *Pinus* pollen. On the other hand, it is possible that scattered ponderosa were present in favorable locations, though not as widespread as at present.

Climatic Implications

Climatic conditions in the western United States in the late Pleistocene and early Holocene are not well established and still open to debate. Recent reviews by Spaulding et al. (1983), Van Devender and Spaulding (1979), Wells (1979), Galloway (1983), Brakenridge (1978), and Barry (1983) reveal acute disagreements focusing primarily on the seasonality of precipitation and temperature, and the relative contribution of each in allowing the major shifts in floral and faunal distributions.

There is no question that conditions before 8,000 B.P. were more mesic in the sense of greater net soil moisture. What is unclear is how much of this net effect is a result of lowered temperatures and how much from greater precipitation. Most reconstructions have proposed a combination of the two with reduction of a few degrees Celsius in annual temperature and an increase of 50% or more in precipitation (see summary in Spaulding et al. 1983). Brakenridge (1978) and, in particular, Galloway (1970, 1983) present arguments for greater reduction of temperature (as much as 10° C lower according to Galloway) with little or no increase in precipitation.

In assessing these different proposals it is important to consider variation in temporal, spatial, and seasonal dimensions. Galloway's (1983) suggestion of cold, arid conditions is made specifically for the full glacial of around 18,000 B.P., while most of the paleoenvironmental data available from the western United States are from the late glacial, after warming and deglaciation had begun. It is probable that there was a real increase in precipitation in the late glacial as the melting glaciers and rising sea levels put more moisture into the atmospheric circulation system.

Spaulding et al. (1983) summarize data suggesting that in the West there was a general trend in the late Pleistocene toward greater aridity with increasing latitude. They suggest that precipitation in the Northwest and northern Great Basin was only slightly, or not at all, greater than at present. In contrast, past biotic communities in the present warm desert areas are thought to be indicative of overall greater precipitation. The Colorado Plateau, in an intermediate position between the Great Basin and the Southwestern deserts, appears to have been less arid than the Great Basin. Betancourt (1984a) has suggested a temperature reduction of 3-4° C for the latest Pleistocene and 35-60% increase in annual precipitation.

Finally, changes in the seasonal distribution of both precipitaion and temperature have been suggested as being of crucial importance in understanding past environmental conditions and biogeography. Although Galloway (1983) has asserted that there was no change in the seasonal distribution of precipitation, several authors have presented convincing arguments for changes in the seasonal distribution of moisture at least at some latitudes (e.g., Betancourt 1984a; Kutzbach 1981; Spaulding et al. 1983; Van Devender and Spaulding 1984).

There is good reason to believe that with colder temperatures and southward depression of westerly storm tracks, there would be a lessening effect of the monsoonal circulation that now brings most of the summer moisture to the Southwest. At the same time this pattern resulted in greater winter precipitation in the Southwest and Great Basin. Even if annual precipitation was not much greater than now at some location and at some times, there is reason to believe that the seasonal distribution was affected in most areas and that summer precipitation was less than at present. This effect may have been greatest in areas such as the San Juan Basin that are near the present northern limit of the monsoon effect (Mitchell 1976). There is evidence that summer rainfall remained most effective in the late Pleistocene only in the southeastern portions of the Southwest (Wells 1979).

In regard to seasonal differences in temperature ranges, several authors, particularly vertebrate paleontologists, have argued that late Pleistocene climates throughout the United States were more "equable," that is, with less seasonal difference than now (e.g., Graham 1976; Lundelis et al. 1983; Martin and Neuner 1978). This inference of cool summers and mild winters is based primarily on the co-occurrence of northern boreal animals with cold-sensitive southern life forms. Similar apparently anomalous plant (as well as animal) associations are common in the Southwest and a pattern of mild wet winters and cool dry summers has been inferred (Spaulding et al. 1983; Van Devender and Spaulding 1979).

Archeological Implications

The paleoenvironmental data considered here pertain to conditions that would have confronted Paleoindian hunters and gatherers. Perhaps the most striking attribute of Paleoindian archeology in the San Juan Basin (and elsewhere in the Four Corners region) is its sparsity. Especially in comparison with later occupations, Paleoindian remains can be characterized as rare. Judge (1982) notes only 14 recorded Paleoindian sites in the San Juan Basin, despite the impressive amount of archeological survey conducted there.

Suggested reasons for this apparent paucity of sites include post-depositional factors that have reduced site visibility and the lack of familiarity and recognition by archeological surveyors in the San Juan Basin (Judge 1982; Stuart and Gauthier 1981). While these may be contributing factors, they do not seem adequate to account for the difference between the San Juan and the Middle Rio Grande Valley for example, where Judge has documented relatively abundant evidence of Paleoindian settlement systems (1973; Judge and Dawson 1972). Although comparison with other areas is difficult, it seems most probable that there was a real difference in the intensity of Paleoindian occupation in different portions of New Mexico.

The recent paleoecological information discussed here suggests a basis for such a difference. Specifically, the suggested environment of mixed conifer woodland and open steppe habitat dominated by sagebrush was probably relatively unproductive compared to areas further south and east. Available evidence indicates that greater precipitation and milder temperatures supported greater biotic diversity in southern Arizona and southern and eastern New Mexico than in the Great Basin and the Four Corners area. The more abundant evidence of Paleoindian occupation from southeastern Arizona to the southern Great Plains could be a direct function of greater abundance, diversity, and density of faunal (both megafauna and smaller game animals) and floral resources in these areas. The more arid Four Corners area may have supported smaller and more variable populations of important large game animals and a paucity of usable floral resources.

Summary

Synthesizing recently studied macrobotanical, pollen, and vertebrate materials from Chaco Canyon and other research in the western United

States gives a firmer basis for inferring paleoenvironmental conditions than was previously possible. Thin rocky sediments at Chaco apparently supported mixed conifer woodlands which persisted into the early Holocene. Surrounding mesa tops may have supported open desert scrub communities similar to the present northern Great Basin. Pinyon and ponderosa may have been absent until warmer temperatures and increased summer rainfall allowed expansion of their ranges. Increased effective moisture in the late Pleistocene-early Holocene was probably a result of both lowered temperatures, especially in summer, and increased winter precipitation. Summer rainfall was proportionally (and most likely absolutely) less than at present. While more mesic than now, the San Juan Basin was probably colder and more arid than areas further south and east where evidence of successful Paleoindian adaptations is more abundant.

Middle Holocene Climate and Environment

Abundant evidence from throughout the Northern Hemisphere shows that temperatures were generally higher between 8,000-4,000 B.P. than either before or since. Kutzbach (1981, 1983) has outlined a probable physical cause for this thermal maximum by showing that variations in the earth's orbit resulted in a peak in summer solar radiation in the mid-latitudes of the Northern Hemisphere near the beginning of this period. Kutzbach (1983) placed the "maximum interglacial" at about 6,000 B.P. In this section, the time period under consideration is extended to around 2,000 B.P. to better coincide with the Archaic and because various paleoecological records suggest an important change at that time.

Numerous terms have been applied to this warm interval, including the "Hypsithermal," "Xerothermic," "Atlantic," "Climatic Optimum," and, most widely recognized by archeologists, the "Altithermal." For the last few decades there has been considerable discussion and debate regarding the fundamental character of this warm period in the western United States. Antevs (1955) described the Altithermal as a hot, dry period that must have had an overall negative effect on Archaic hunter-gatherer populations. In contrast, Martin (1963) presented evidence from southern Arizona indicating that this time interval was characterized by relatively mesic conditions, apparently as a result of enhanced summer rainfall. More recently, additional data from southern Arizona, New Mexico, and west Texas have been found to support Martin's inference of moist Altithermal summers (e.g., Van Devender and Wiseman 1977; Van Devender and Spaulding 1979). However, other researchers have found support for a hot, dry Altithermal in the desert Southwest (Solomon and Blasing 1982).

Recent pertinent paleoenvironmental data from Chaco Canyon and the Four Corners area are summarized here and discussed in terms of these different proposals.

Macrobotanical Evidence

Betancourt and Van Devender (1980, 1981; Betancourt 1984b; Betancourt et al., 1983) have located, analyzed, and dated a small number of packrat middens from the middle Holocene, including samples from Atlatl Cave and

Sheep Camp Shelter. These collections evidently document the arrival of pinyon (*P. edulis*) and juniper (*J. monosperma*) woodlands in the canyon (and a replacement of the earlier, more mesic mixed conifers) at near the beginning of the middle Holocene (earliest sample containing pinyon-juniper dates at 8,290 ± 150 B.P.). Ponderosa and Douglas fir are present in the earliest pinyon-juniper sample and later at Atlatl Cave around 5,600 B.P. At Sheep Camp Shelter, three samples from around 6,600 B.P., and later at about 3,000 and 2,800 B.P., all contained sparse ponderosa in addition to abundant pinyon and juniper (Betancourt 1984b). Other late Holocene samples lack ponderosa, but are characterized by abundant pinyon and juniper. This general association of ponderosa (and, at Atlatl Cave, Douglas fir) with middle Holocene dates is suggestive of more mesic Altithermal conditions, at least before 5,000 B.P.; however, Betancourt (1984b) notes that these occurrences of relatively few specimens from mainly sheltered locations do not allow unambiguous inferences of general moisture conditions in the Altithermal.

Based on macrofossil data from Chaco and elsewhere in the Colorado Plateau, Betancourt (e.g., 1984a) has made a convincing case for a middle Holocene northward expansion of pinyon, ponderosa, and one-seed juniper. Such an expansion is presumed to result from the extended and heightened effect of the summer monsoonal circulation system that occurred with higher temperatures. These records suggest that conditions in the Four Corners region were more mesic the first half of the middle Holocene and drier in later times.

Palynological Evidence

Hall's (1977) study of alluvial pollen sequences in Chaco Canyon found the highest percentages of pine pollen in sediments dated to the first part of the middle Holocene. A period of reduced pine pollen occurs from around 5,500-2,999 B.P., thought to indicate less regional woodland coverage than at present. Love (1980) has pointed out that much of this decline may be a result of a shift in sedimentary facies from alluvial sediments to locally-derived colluvial deposits at Hall's sample localities for most of this period. Taking this consideration into account, Hall (1982) still believes there to be a distinct low in arboreal pollen during this time span.

Hall (1981) has also analyzed pollen samples from some of the packrat middens studied by Betancourt and Van Devender (1981). From about 5,000-2,000 B.P. middens show low percentages of pine pollen. Hall, interpreting these results as substantiating the alluvial pollen evidence of reduced regional woodland cover at this time, argues that Betancourt and Van Devender (1981) over-estimated the extent of local pinyon-juniper cover. Pollen frequencies of some taxa, notably juniper, fluctuate greatly, and some questions remain regarding the reliability of interpreting pollen frequencies from midden samples as indicative of regional vegetation. It remains to be shown that pollen assemblages accumulated in the richly organic midden deposits are not influenced by the collected materials to the extent that trends in regional pollen rain are obscured.

Fredlund (1984) has analyzed a column sample from sediments in Ashislepah Shelter near the lower end of Chaco Canyon. Although dating control is limited to dates (ca. 1,400 B.P. and 2,200 B.P.) on archeological materials from the upper part of the sequence, there is a definite similarity to Hall's alluvial and packrat midden pollen sequences (1981). In each case, pine pollen frequencies are low prior to about 2,000 B.P. At Ashislepah Shelter, this period of minimum pine pollen frequencies is preceded by very high pine frequencies, measuring over 60% in the lower levels. Based on the similarity with Hall's series, this minimum may be the equivalent of the middle Holocene pine pollen peak noted by Hall. As with Hall's alluvial and midden results, Pinus pollen identified as ponderosa is at a maximum (relative to pinyon) in the early high pine pollen zone.

In common with Hall's alluvial sequence, the pre-2,000 B.P. low pine period at Ashislepah Shelter is closely correlated with a facies change in the sediments (Fredlund 1984). The low pine frequencies are found in laminated sandy sediments deposited by the small water flowing in front of the shelter (comparable to Hall's "colluvial unit"), while overlaying and underlying deposits are aeolian and decomposed roof fall accumulations. Fredlund believes this facies difference has a coincidental relationship to the lowered pine pollen frequencies, rather than a causal one (cf. Hall 1981).

Fredlund's decision to term this zone a "mid-Holocene arid period" may cause some confusion in that the available dates indicate that most of it is probably from the late Holocene as used here (after ca. 4,000 B.P.) and by most researchers. Fredlund does note, however, that this period is later in time than Antev's Altithermal and avoids equating it with that concept.

Pollen analyses from high mountain sites in Southwestern Colorado indicate generally elevated temperatures, as inferred from evidence of higher treelines, from about 8,000 or 10,000 B.P. to 3,000 or 4,000 B.P. (Andrews et al. 1975; Carrara et al. 1984; Markgraf and Scott 1981; Petersen 1981; Petersen and Mehringer 1976). Baker (1983), in summarizing these and other studies from the mountains of Colorado and Utah, interprets a warm interval from 7,000 to 4,000 B.P. Petersen (1981) and Markgraf and Scott (1981) both present arguments in support of increased summer rainfall during this time to account for expanded pinyon and ponderosa woodlands inferred from high pine pollen frequencies. Both see maximum expansion of pinyon in the Southwest Colorado mountains as occurring near the end of the middle Holocene (ca. 4,000 B.P.). After 4,000 B.P. (or ca. 3,000 B.P. according to Carrara et al. [1984] and Petersen [1981]) cooling led to a lowering of treeline, initiation of Neoglacial conditions, and a reduction of the summer monsoon effect.

Both Petersen (1981) and Pippin (1979) challenge aspects of Hall's interpretation of the Chaco data and present alternatives. For example, Pippin (1979) suggests that the extended period of low pine pollen frequencies reflects greater pollen production by local non-arboral plants and is indicative of more mesic conditions rather than greater aridity.

Petersen reinterprets Hall's data to find support for his interpretation of increased pinyon woodland at around 4,000-3,000 B.P.

Faunal Remains

One of the few middle Holocene vertebrate faunal assemblages known from the Southwest is from the loose sediments in Atlatl Cave (Gillespie 1981, 1982, 1984b). On the basis of a single associated radiocarbon date, the bulk of the assemblage is thought to date from around 5,000 B.P. The assemblage is quite similar to modern fauna, but several non-local, small vertebrates are present as well. Except for a single sagebrush vole dentary which is thought to be derived from earlier (early Holocene) midden deposits in the shelter, the extra-limital taxa are species found geographically to the south and east where grasslands are now better developed than in the San Juan Basin. Species include the Hispid cottonrat (Sigmodon hispidis), Prairie vole (Microtus ochrogaster), hognose snake (Heterodon nasicus), and Couch's spadefoot toad (Scaphiopus couchi).

The Prairie vole now occurs only in the prairie grassland of the northern and central Great Plains, barely extending into New Mexico. The other species are now found in desert grasslands of eastern and southern New Mexico but not on the Colorado Plateau. Both cottonrat and Couch's spadefoot toad appear restricted to geographical areas with warmer temperatures than now. As discussed by Gillespie (1981), there is evidence that present-day Chaco Canyon is too cold in the winter for the cottonrat and too cool in the summer for Couch's spadefoot toad.

All of these species are characteristic grassland dwellers and their past presence at Chaco suggests better developed grasslands. It is argued that such grassland developed in response to increased summer rainfall during the middle Holocene. In southern New Mexico, Van Devender and Wiseman 1977) summarize faunal and floral evidence and suggest that the better developed grassland existed before ca. 4,000 B.P. as a result of higher effective moisture from increased summer rainfall.

Geological Evidence

Numerous geologists have studied middle Holocene aeolian and alluvial deposits from throughout the West and presented a number of interpretations. Most studies have inferred more arid conditions at some time during the middle Holocene. Wells et al. (1983) have dated a period of increased aeolian activity in the San Juan Basin to ca. 6,000-2,800 B.P., interpreting this as a relatively arid period.

In earlier regional synthesis of geologic sequences, Haynes (1968) suggested that the middle Holocene could be split into two phases: an initial arid period from about 7,500 to 6,000 B.P., and a subsequent wetter time to around 5,500 B.P. The proposed early arid period is based on evidence of widespread stream erosion prior to 7,000 B.P. Knox (1983) has recently argued that this period of erosion might better be interpreted as a response to replacement of woodland areas by grasslands and, perhaps more important, as a result of increased summer rainfall at the beginning of the middle Holcene, which would have increased stream competence and erosive capability. Subsequent alluviation could thus be a result of increased aridity.

Discussion: Middle Holocene Vegetation and Climate

Betancourt and Van Devender's (1981) packrat midden macrofossil data demonstrate that pinyon-juniper tree cover, supplemented by occasional ponderosa and Douglas fir, persisted on the rocky outcrops of Chaco Canyon throughout the Altithermal and into the late Holocene. Pinyon is well represented even in the lower part of the canyon where it is now absent. Hall (1982) believes Betancourt and Van Devender have over-estimated the importance of any pinyon-juniper woodland development and suggests instead that only scattered trees were present; however, Betancourt and Van Devender's characterization of the woodland cover as somewhat greater than at present and largely limited to this rocky sediment seems more probable in the light of the available data.

There is no doubt that large areas of open steppe existed on deep soils. On the basis of vertebrate remains, Gillespie (1981) has suggested that open vegetation was more of a desert grassland than the present desert scrub. Thus, in broad terms, the transition from the early to the middle Holocene is thought to have entailed a shift from more montane mixed conifers to pinyon and juniper on these soils and from cold desert scrub to desert grassland in open habitats. This transition fits well with other recent paleoecological data from the Southwest (Spaulding et al. 1983; Van Devender and Spaulding 1979).

The climatological basis for these vegetation changes appears to lie in a major shift in the seasonality of precipitation with a major increase in summer precipitation resulting from strongly developed monsoonal circulation during the thermal maximum. As discussed by Betancourt (1984a) and Betancourt and Van Devender (1981), pinyon and ponderosa were dependent on adequate summer moisture for successful germination. They replaced species better adapted to winter-dominant precipitation characteristic of the late Pleistocene-early Holocene. Several authors (e.g., Betancourt 1984a; Spaulding et al. 1983) have recently presented arguments for a maximum expansion of the ranges of pinyon and ponderosa during the middle Holocene.

Although several unresolved discrepancies exist in the paleoenvironmental records from the San Juan Basin, the majority of the available data run counter to Antevs' much-discussed hot arid Altithermal (1955). At least, this appears to be the case for <u>most</u> of the middle Holocene. Much of the botanical and geologic evidence suggests a change to more xeric conditions in the latter part of the middle Holocene, some time around 5,500 B.P. Prior to this time, relevant data point to relatively mesic environmental conditions, probably with greater net effective moisture than now. The various pollen records and geological studies in the Chaco area together suggest that conditions were more arid from around 5,500 B.P. to nearly 2,000 B.P. (Fredlund 1984; Hall 1977, 1982; Wells et al. 1983). In terms of overall moisture conditions this may have been the most arid time in the entire post-glacial period; however, it should be noted that other interpretations of this period have been made that do not infer such arid conditions (e.g., Petersen 1981; Pippin 1979).

It should be noted that in the northern Great Basin, where Antevs based his concept of an arid Altithermal, there is general support for his model (e.g., La Marche 1973). In general, the northern latitudes of the United States do appear to have been relatively arid in the middle Holocene (Baker 1983). The evidence from Chaco Canyon and the Four Corners area runs counter to this trend, a fact that can be explained as a function of geographical location. The Colorado Plateau is situated in a critical position near the present northwestern limit of the effective moisture-bearing summer monsoonal circulation (Bryson and Wendland 1967; Mitchell 1976). The shift to higher temperatures in the middle Holocene effectively brought this area under the influence of the monsoonal circulation and greatly increased summer precipitation. A similar effect was not evident in more northern latitudes, resulting in greater aridity. The logical probability that a large-scale episode of climatic change such as the middle Holocene thermal maximim will produce variable precipitation and biotic responses over a large geographical area has frequently not been given adequate consideration; therefore, it should not be surprising that evidence of more mesic conditions in the Four Corners area can coincide with evidence of greater aridity in the northern Great Basin and Great Plains.

Archeological Implications

Archeologists throughout the West have frequently reviewed the arguments for and against Antevs' suggested hot, dry Altithermal, and most often chosen in favor of the model (in the San Juan Basin, for example, cf. Moore and Winter 1980). The interpretation of moist summer conditions through the first part of the middle Holocene suggests generally favorable conditions for early Archaic (Jay-Bajada periods) hunter-gatherers. Enhanced summer rainfall would yield greater availablity of exploitable plant and animal resources because of increased forage production and higher densities and reproductive success of terrestrial vertebrate populations (e.g., Sims et al. 1978). Pinyon nuts would have been abundant for the first time and use of the area by bison may have been at peak (bison remains are present in probable middle-early late Holocene contexts in Atlatl Cave, Sheep Camp Shelter, and Ashislepah Shelter). As with Paleoindian remains, Archaic sites in the San Juan Basin appear distinctly sparser and more sporadic than in presumably more favorable areas to the southeast, such as those of the Arroyo Cuervo area (Irwin-Williams 1973).

In the late Archaic (San Jose and Armijo periods), conditions appear to have been less mesic, but cooler than in preceding times, and exploitable resources less abundant. It is interesting that evidence of a peak in late Archaic occupation in the Chaco area around 3,000 B.P. (and evidence of use of cultivars) may have occurred during a more xeric time. Implications of this situation are unclear. Temporal trends in the size and activities of the generally small populations were probably more responsive to social, demographic, and other non-environmental factors than to these long-term environmental changes.

The Anasazi Occupation

Recently studied paleoecological information from Chaco for the past 2,000 years is summarized in the following section. The focus is on the later Anasazi periods, preceded by a few comments on the environmental conditions prior to A.D. 900.

About 2,200 B.P. local pollen sequences (Fredlund 1984; Hall 1977, 1981) show a marked increase in pine pollen, interpreted by Hall as a return to more mesic conditions following almost 3,000 years of drought. A comparable date was proposed by Berry (1982) for an initial Basketmaker II expansion on the Colorado Plateau. This agreement implies that successful early Basketmaker occupation took place in a context of improving physical conditions, which may be significant even if, contrary to Berry's assertion, some experimentation and limited use of cultivars was made in the preceding millenium, as recent evidence from the Chaco area indicates (Betancourt 1984a; Donaldson 1984; Simmons 1984).

There is some evidence that the next major archeological transition in the region, to large Basketmaker III pithouse villages about A.D. 500-600, also occurred in the context of favorable climatic conditions (Euler et al. 1979; Schoenwetter and Dittert 1968). Well-dated paleoecological information for the Basketmaker III period, however, is sporadic and difficult to assess.

Macrobotanical Evidence

Betancourt and Van Devender (1981) demonstrated that local pinyon-juniper communities persisted in Chaco Canyon through the late Holocene at least until the intense Anasazi occupation of the canyon. Betancourt and Van Devender (and Samuels and Betancourt 1982) argue that Anasazi fuel and building demands essentially eradicated local woodland growth. While Hall (1982) and Love (1980) have criticized Betancourt and Van Devender's argument as premature, more recently collected macrofossil data continue to fit the hypothesis of Anasazi overexploitation (Betancourt et al. 1983).

The packrat midden record is also important in indicating that ponderosa and other more montane conifers were rare at best in Chaco in the centuries prior to the Anasazi occupation (an interpretation also favored by other recent paleoecological studies, e.g., Hall 1977). For many decades a widespread assumption among archeologists (e.g., Judd 1954; Vivian and Mathews 1965) implied that ponderosa was more abundant and provided construction materials for the local pueblos. The abundance of ponderosa and other mixed conifers among the building beams used in the large pueblos indicates long distance importation rather than local procurement. Betancourt et al. (1984) have recently used electron microscopy to establish the presence of both spruce (*Picea* sp.) and subalpine fir (*Abies lasiocarpa*) among the construction timber for Chetro Ketl. These species are now common only in high altitudes (over 2,900 m, lower in protected canyons) in the mountains around the San Juan Basin. Presence of spruce, fir, and Douglas fir, as well as the more common ponderosa, indicates to

Betancourt et al. (1984) that importation of construction timber from distances greater than 75 km was common.

Palynological Evidence

Hall (1977) interpreted conditions during most of the Anasazi period to have been more arid than now, based mainly on relatively low pine pollen frequencies until near the end of the Anasazi occupation when there is an apparent increase (dated by Hall at ca. A.D. 1100). Euler et al. (1979) and Petersen (1981) disagree with Hall's interpretation of late Holocene events and have offered alternative explanations. Petersen (1981) notes evidence in Hall (1977) that the apparent increase in pine pollen may have been during the Anasazi occupation rather than after it, a situation that fits better with Petersen's data from the La Plata Mountains.

Euler et al. (1979) and Petersen (1981) discuss pollen data from the Four Corners area that indicate generally mesic conditions from about A.D. 950-1150, very close to the main period of Anasazi development in Chaco Canyon. These authors have characterized the period as having somewhat warmer temperatures and increased summer precipitation, again as a result of enhanced summer monsoonal circulation (see Petersen 1981; Gillespie and Powers 1983). In the San Juan Basin, such conditions are thought to have been highly favorable to Anasazi populations in the following ways: (1) increasing average amounts of growing season rainfall (and runoff), and reducing the frequency of destructive droughts; (2) increasing the number and area of microenvironments regularly receiving enough moisture for agricultural production; (3) reducing the probability of crop damage from late spring or early fall freezes; and (4) increasing average annual productivity and average abundances of exploitable wild plant resources and terrestrial vertebrates (Gillespie and Powers 1983; Powers et al. 1983).

Tree-ring Evidence

Rose et al. (1982) have recently produced a detailed attempt to reconstruct yearly and seasonal variations in precipitation and temperature values for northwestern New Mexico and an in-depth discussion of the methodological procedures involved. Their results provide the best information on small-scale climatic fluctation during the Anasazi period. Maxima and minima in summer and annual precipitation are summarized and illustrated in Powers et al. (1983). There is some evidence, albeit inconclusive, of a partial correlation in tree-ring dated building episodes at the Chacoan large sites and above-average summer precipitation periods.

Probably the most significant event recorded included in the dendroclimatic reconstruction of Rose et al. (1982) is an extended period in the midtwelfth century (A.D. 1130-1180) of summer drought. Reconstructed Palmer Drought Severity Indicies and summer rainfall values both show that most years during this period had subnormal summer precipitation. The period correlates closely with the major drop-off of building activity at Chaco Canyon and an apparent end to Chaco's position as the major socioeconomic center of the San Juan Basin (Powers et al. 1983). The implication is that this period of summer drought had a significant adverse effect on the subsistence economy of the Anasazi, especially affecting small-scale agricultural systems dependent on summer rainfall and runoff.

Less affected were communities along the San Juan, Animas, and La Plata rivers where perennial stream flow provided abundant water, favorable runoff locations around the margins of the San Juan Basin, and highland areas (over 2,000 m) where precipitation amounts were higher (Gillespie and Powers 1983). The major depopulation of the Four Corners region at ca. A.D. 1300 may be related to the onset of the extended cool, arid summer period which persisted until the late 1800s (Petersen 1981).

Geological Evidence

Bryan's (1954) reconstruction of the alluvial history of Chaco Wash during Anasazi times has been widely accepted. Bryan believed the wash was a small surface stream until near the end of the Anasazi occupation when drought conditions caused the formation of an arroyo. The resulting incision of the stream made agricultural production in the canyon much more difficult and was thought to have been a causal factor in the abandonment of the canyon.

Hall (1977) accepted Bryan's timing for arroyo formation at around A.D. 1100, but offered a different cause for incision. Rather than drought, the pollen evidence led Hall to propose increased precipitation and greater erosive capability as the cause of arroyo cutting. Love (1980, 1983), while agreeing with Hall's mechanism of arroyo formation (contrary to Euler et al. [1979]), questions the dating of this event. On the basis of detailed examination of the alluvial deposits, Love suggested that there were more buried channels than Bryan described and that channel incision was a more common event than previously thought. Love (1983) suggests that entrenched channels may have existed prior to A.D. 700 and during much of the Anasazi occupation, thus casting doubt on proposals of disastrous consequences of arroyo formation. Agricultural strategies in the canyon which evidently focused on the use of runoff from the sides of the canyon (Vivian 1974) appear to have been successfully adapted to the presence of an arroyo.

Discussion

Regional pollen sequences (Euler et al. 1979; Petersen 1981) suggest that from about A.D. 950 to mid-1100s relatively warm temperatures with generally high summer precipitation characterized the southeastern Colorado Plateau. Anasazi cultural development at Chaco Canyon flourished during this period, in part because of favorable conditions for agricultural production. The decline of Chaco Anasazi is well correlated with a period of low summer rainfall in the middle of the twelfth century. This period of drought may have been a major destabilizing factor in the apparent decline in the Chaco-based regional economic system.

Summary

The paleoecological information summarized here indicates important changes in the biotic environment and climate in the Chaco area over the past 12,000 years. Prior to ca. 8,000 B.P., mixed conifers including spruce and limber pine were present on thin sediments along the canyon sides while areas of cold desert steppe probably existed on mesa tops. These plant associations, which are similar to some now found in the northern Great Basin and northern Rockies, imply a colder climate than anytime since, and probably a moderately wetter one.

A global warming, which had been under way for several millenia, reached or exceeded modern levels about 8,000-9,000 B.P. About this time pinyon and juniper apparently migrated into the area and replaced the more mesic mixed conifers. A switch from sagebrush-dominated cold desert steppe to a warm desert grassland may have taken place as well. The primary cause of this biotic turnover is thought to be the initiation of warm, wet summers as the Bermuda High monsoonal circulation system became established on the Colorado Plateau and winter precipitation lessened as westerly storm tracks retreated poleward.

From late in the middle Holocene (ca. 5,500 B.P.) there is evidence of increased aridity that persisted to around 2,200 B.P. While this xeric period could be considered a manifestation of an arid Altithermal episode, there are compelling reasons not to do so. Specifically, regional data indicate that this period of aridity occurred mainly in the context of cooling temperatures, rather than high temperatures. The warmest times were earlier and appear to have been more mesic.

Essentially modern conditions have existed since ca. 2,200 B.P., although short-time fluctuations probably have been important throughout this span. Most important for the local Anasazi development was a period of above average summer rainfall and temperatures from ca. A.D. 950-1130 during which the Chaco Anasazi flourished. The demise of Chaco as a regional center may be related to a period of prolonged summer drought from A.D. 1130-1180.

Throughout this paper reference has been made to a basic climatic model which relates the geographical position of the San Juan Basin (with respect to atmospheric circulation features) to expected responses to climatic changes and fluctuations. It is argued that the San Juan Basin occupies a climatically sensitive position near the northwestern edge of the summer monsoonal circulation system. Periods of warmer temperatures and strong restricted westerly flow should result in above average summer rain. General support for this concept is found at different scales, both on a large scale with major differences in early Holocene and middle Holocene biotic communities, and on a smaller scale, with the fluctuations evident during the Anasazi occupation.

References Cited

Adams, E.C.
1979 Cold Air Drainage and Length of Growing Season in the Hopi Mesas Area. The Kiva 44:285-296

Andrews, J.T., P.E. Carrara, F.B. King, and R. Stuckenrath
1975 Holocene Environmental Changes in the Alpine Zone, Northern San Juan Mountains, Colorado: Evidence from Bog Stratigraphy and Palynology. Quaternary Research 5:173-198.

Antevs, E.
1955 Geologic Climatic Dating in the West. American Antiquity 20:317-335.

Baker, R.G.
1983 Holocene Vegetational History of the Western United States. In Late Quaternary Environments of the United States, vol. 2, edited by H.E. Wright, Jr., pp. 109-127. University of Minnesota Press, Minneapolis.

Barry, R.G.
1983 Late Pleistocene Climatology. In The Late Pleistocene, edited by S.C. Porter, pp. 390-407. Late Quaternary Environments of the United States, vol. 1. University of Minnesota Press, Minneapolis.

Berry, M.S.
1982 Time, Space, and Transition in Anasazi Prehistory. University of Utah Press, Salt Lake City.

Betancourt, J.L.
1984a Late Quaternary Plant Zonation and Climate in Southeastern Utah. The Great Basin Naturalist 44(1):1-35.

1984b Fossil Packrat Middens from Sheep Camp Shelter (29SJ 178). In Archaic Prehistory and Paleoenvironments in the San Juan Basin, New Mexico: The Chaco Shelters Project, edited by A.H. Simmons, pp. 167-185. University of Kansas Museum of Anthropology, Project Report Series, no. 53.

Betancourt, J.L., and O.K. Davis
1984 Packrat Middens from Canyon de Chelly, Northeastern Arizona: Paleocological and Archeological Considerations. Quarternary Research 21:56-64.

Betancourt, J.L., and T.R. Van Devender
1980 Holocene Environments in Chaco Canyon, New Mexico: The Packrat Midden Record. Ms. on file, Division of Cultural Research, National Park Service, Albuquerque.

1981 Holocene Vegetation in Chaco Canyon, New Mexico. *Science* 214:656-658.

Betancourt, J.L., J.S. Dean, and H.M. Hull
1984 Prehistoric Long-distance Transport of Spruce and Fir Construction Beams, Chaco Canyon, New Mexico. Ms. on file, Department of Geosciences, University of Arizona, Tucson.

Betancourt, J.L., P.S. Martin, and T.R. Van Devender
1983 Fossil Packrat Middens from Chaco Canyon, New Mexico: Cultural and Ecological Significance. In *1983 American Geomorphological Field Group Guidebook*, pp. 207-217.

Bradley, R.S.
1980 Secular Fluctuations of Temperature in the Rocky Mountain States and a Comparison with Precipitation Fluctuations. *Monthly Weather Review* 108:873-885.

Brakenridge, G.R.
1978 Evidence for a Cold, Dry Full-glacial Climate in the American Southwest. *Quaternary Research* 9:22-40.

Bryan, K.
1954 *The Geology of Chaco Canyon, New Mexico, in Relation to the Life and Remains of the Prehistoric Peoples of Pueblo Bonito*. Smithsonian Miscellaneous Collections 122. Washington.

Bryson, R.S., and W.M. Baerreis
1968 Climatic Change and the Mill Creek Culture of Iowa. *Journal of the Iowa Archaeological Society* 15-26:1-358.

Bryson, R.S., and T.J. Murray
1977 *Climates of Hunger: Mankind and the World's Changing Weather*. University of Wisconsin Press, Madison.

Bryson, R.S., and W.M. Wendland
1967 Tentative Climatic Patterns for some Late Glacial and Post-glacial Episodes in Central North America. In *Life, Land and Water*, edited by A.J. Mayer-Oakes, pp. 271-298. University of Manitoba Press, Winnipeg.

Carrara, P.E., W.N. Mode, M. Rubin, and S.W. Robinson
1984 Deglaciation and Post-glacial Timberline in the San Juan Mountains, Colorado. *Quaternary Research* 21:42-55.

Chang, Jen-Hu
1968 *Climate and Agriculture: An Ecologic Survey*, Aldine, Chicago.

Cordell, L.S.

1979 A Cultural Resources Overview of the Middle Rio Grande Valley, New Mexico. Copies available from Superintendent of Documents, Government Printing Office, Washington.

Donaldson, M.L.

1984 Botanical remains from Sheep Camp and Ashislepah Shelters. In Archaic Prehistory and Paleoenvironments in the San Juan Basin, New Mexico: The Chaco Shelters Project, edited by A.H. Simmons, pp. 136-166. University of Kansas Museum of Anthropology, Project Reports Series no. 53, Lawrence.

Euler, R.C., G.J. Gumerman, T.N.V. Karlstrom, J.S. Dean, and R.H. Hevly

1979 The Colorado Plateas: Cultural Dynamics and Paleoenvironment. Science 205:1089-1101.

Fredlund, G.

1984 Palynological Analysis of Sediments from Sheep Camp and Ashislapah Shelters. In Archaic Prehistory and Paleoenvironments in the San Juan Basin, New Mexico: The Chaco Shelters Project, edited by A.H. Simmons, pp. 186-209. University of Kansas, Museum of Anthropology, Project Report Series, no. 53, Lawrence.

Galloway, R.W.

1970 The Full-glacial in the Southwestern United States. Annals of the Association of American Geographers 60:245-256.

1983 Full-glacial Southwestern United States: Mild and Wet or Cold and Dry? Quaternary Research 19:236-248.

Gillespie, W.B.

1981 Ecological Implications of Faunal Remains from Archeological Sites in Chaco Canyon, New Mexico. Paper presented at the 46th Annual Meeting of the Society for American Anthropology, San Diego.

1982 Vertebrate remains from Atlatl Cave, Chaco Canyon, New Mexico. Ms. on file, Division of Cultural Research, National Park Service, Albuquerque.

1984a Excavations at Sheep Camp Shelter (29SJ178). In Archaic Prehistory and Paleoenvironments in the San Juan Basin, New Mexico: The Chaco Shelters Project, edited by A.H. Simmons, pp. 39-94. University of Kansas, Museum of Anthropology, Project Report Series, no. 53, Lawrence.

1984b Late Quaternary Small Vertebrates from Chaco Canyon Northwestern New Mexico. New Mexico Geology 6:16 abs.

Gillespie, W.B., and R.P. Powers

1983 Regional Settlement Changes and Past Environment in the San Juan Basin, Northwestern New Mexico. Paper presented at the 1983 Anasazi Symposium, Bloomfield, New Mexico.

Graham, R.W.
1976 Late Wisconsin Mammalian Faunas and Environmental Gradients of the Eastern United States. Paleobiology 2:343-350.

Hales, J.E.
1974 Southwestern United States Summer Monsoon Source--Gulf of Mexico or Pacific Ocean? Journal of Applied Meteorology 13:331-342.

Hall, S.A.
1977 Late Quaternary Sedimentation and Paleoecologic History of Chaco Canyon, New Mexico. Geologic Society of America Bulletin 88:1593-1618.

1981 Combined Pollen and Plant Macrofossil Evidence for Holocene Vegetation at Chaco Canyon, New Mexico. Paper presented at the XI INQUA Congress, Moscow, U.S.S.R.

Harris, A.H.
1965 The Origin of the Grassland Amphibian, Reptilian, and Mammalian Faunas of the San Juan-Chaco River Drainage. Unpublished Ph. D. Dissertation, University of New Mexico, Albuquerque.

Hastings, J.R., and R.M. Turner
1965 The Changing Mile: An Ecological Study of Vegetation Change with Time in the Lower Mile of an Arid and Semiarid Region. University of Arizona Press, Tucson.

Hayes, A.C.
1981 A Survey of Chaco Canyon Archeology. In Archeological Surveys of Chaco Canyon, New Mexico, by A.C. Hayes, D.M. Brugge, and W.J. Judge, pp. 1-68. National Park Service, Archeological Series 17-A. Washington.

Haynes, C.V.
1968 Geochronology of Late Quaternary Alluvium. In Means of Correlation of Quaternary Successions, edited by R.B. Morrison and H.E. Wright, pp. 591-631. Proceedings of the VII Congress of the International Association of Quaternary Research 8.

Hays, J.D., J. Imbrie, and N.J. Shackleton
1976 Variations in the Earth's Orbit: Pacemaker of the Ice Ages. Science 194:1121-1132.

Imbrie, J., and J.Z. Imbrie
1980 Modeling the Climatic Response to Orbital Variations. Science 207:943-953.

Irwin-Williams, C.
1973 The Oshara Tradition: Origins of Anasazi Culture. Eastern New Mexico University Contributions in Anthropology 5(1). Portales.

Judd, N.M.
1954 The Material Culture of Pueblo Bonito. Smithsonian Miscellaneous Collections vol. 124. Washington.

Judge, W.J.
1973 The Paleo-Indian Occupation of the Central Rio Grande Valley, New Mexico. University of New Mexico Press, Albuquerque.

1982 The Paleo-Indian and Basketmaker Periods: An Overview and Some Research Problems. In The San Juan Tomorrow, edited by F. Plog and W. Wait, pp. 5-58. National Park Service, Southwest Region, in cooperation with the School of American Research, Santa Fe.

Judge, W.J., and J. Dawson
1972 Paleo-Indian Settlement Technology in New Mexico. Science 176: 1210-1216.

Kutzbach, J.E.
1981 Monsoon Climate of the Early Holocene--Climate Experiment with the Earth's Orbital Parameters for 9000 Years Ago. Science 214:59-61.

1983 Modeling of Holocene Climates. In The Holocene, edited by H.E. Wright, pp. 271-227, Late-Quaternary Environments of the United States, vol. 2. University of Minnesota Press, Minneapolis.

La Marche, V.C., Jr.
1973 Holocene Climatic Variations Inferred from Treeline Fluctuations in the White Mountains, California. Quaternary Research 3:632-660.

Lamb, H.H.
1977 Climate: Present, Past, and the Future. Methuen, London.

Leopold, L.B.
1951 The Pleistocene Climate in New Mexico. American Journal of Science 249:152-168.

Love, D.W.
1980 Quaternary Geology of Chaco Canyon, Northwestern New Mexico. Unpublished Ph.D. Dissertation, University of New Mexico.

1983 Summary of Late Cenozoic Geomorphic and Depositional History of Chaco Canyon. In Chaco Canyon Country, edited by, S.G. Wells, D.W. Love, and T.W. Gardner, pp. 187-194. American Geomorphological Field Group, 1983 Field Trip Guidebook.

Lundeluis, E.L., Jr., R.W. Graham, E. Anderson, J. Guilday, J. Holman, D.A. Steadman, and S.D. Webb
1983 Terrestrial Vertebrate Faunas. In The Late Pleistocene, edited by S.C. Porter, pp. 311-353, Late-Quaternary Environments of the United States, vol. 1, University of Minnesota press, Minneapolis.

Markgraf, V., and L. Scott
1981 Lower timberline in Central Colorado During the Past 15,000 years. Geology 9:231-234.

Martin, L.D., and A.M. Neuner
1978 The End of the Pleistocene in North America. Transactions of the Nebraska Academy of Science 6:117-126.

Martin, P.S.
1963 The Last 10,000 Years: A Fossil Pollen Record of the American Southwest. University of Arizona Press, Tucson.

Martin, P.S., and P.J. Mehringer, Jr.
1965 Pleistocene Pollen Analysis and Biogeography of the Southwest. In Quaternary of the United States, edited by H.E. Wright, Jr., and D.G. Frey, pp. 433-451. Princeton, New Jersey.

Mead, J.I., R.S. Thompson, and T.R. Van Devender
1982 Late Wisconsinan and Holocene Fauna from Smith Creek Canyon, Snake Range, Nevada. Transactions of the San Diego Society of Natural History 20:1-26.

Miles, M.K.
1978 Predicting Temperatures Trends in the Northern Hemisphere to the Year 2000. Nature 276:356-359.

Mitchell, V.L.
1976 The Regionalization of Climate in the Western United States. Journal of Applied Meteorology 15:920-927.

Moore, J.L., and J.C. Winter (editors)
1980 Human Adaptation in a Marginal Environment: The UII Mitigation Project. University of New Mexico, Office of Contract Archaeology, Albuquerque.

Osborn, N.L.
1966 A Comparative Floristic Study of Mount Taylor and Redondo Peak, New Mexico. Unpublished Ph.D. Dissertation, University of New Mexico, Albuquerque.

Petersen, K.L.
1981 10,000 Years of Climatic Change Reconstructed from Fossil Pollen, La Plata Mountains, Southwestern Colorado. Unpublished Ph.D. Dissertation, Washington State University, Pullman.

Petersen, K.L., and P.J. Mehringer, Jr.
1976 Postglacial Timberline Fluctuations, La Plata Mountains, Southwestern Colorado. Arctic and Alpine Research 8:275-288.

Pfister, R.D., B.L. Kbalchik, S.R. Arno, and R.C. Presby
1977 Forest Habitat Types of Montana. United States Department of Agriculture, Forest Service, General Tech. Report INT-34.

Pippin, L.C.
1979 The Prehistory and Paleoecology of Guadalupe Ruin, Sandoval County, New Mexico. Unpublished Ph.D. Dissertation, Washington State University, Pullman.

Powers, R.P., W.B. Gillespie, and S.H. Lekson
1983 The Outlier Survey: A Regional View of Settlement in the San Juan Basin. National Park Service, Reports of the Chaco Center no. 3, Albuquerque, New Mexico.

Rose, M.R., W.J. Robinson, and J.S. Dean
1982 Dendroclimatic Reconstruction for the Southeastern Colorado Plateau. Ms. on file, Division of Cultural Research, National Park Service, Albuquerque.

Ruddiman, W.F. and A. McIntyre
1981 Oceanic Mechanisms for Amplification of the 23,000-Year Ice-Volume Cycle. Science 212:617-627.

Samuels, M.L., and J.L. Betancourt
1982 Modeling the Long-term Effects of Fuelwood Harvests of Pinyon-Juniper Woodlands. Environmental Management 6(6):505-515.

Schoenwetter, J., and A.E. Dittert
1968 An Ecological Interpretation of Anasazi Settlement Patterns. In Anthropological Archaeology in the Americas, edited by B.J. Meggers, pp. 41-66. Anthropological Society of Washington, Washington.

Sellers, W.D.
1960 Precipitation Trends in Arizona and Western New Mexico. Proceedings, 28th Annual Meeting, Western Snow Conference, pp. 81-94. Colorado State University, Ft. Collins.

Sellers, W.D., and R.H. Hill
1974 Arizona Climate, 1931-72. University of Arizona Press, Tucson.

Simmons, A.H. (editor)
1984 Archaic Prehistory and Paleoenvironments in the San Juan Basin, New Mexico: The Chaco Shelters Project. University of Kansas, Museum of Anthropology, Project Report Series, no. 53, Lawrence.

Sims, P.L., Jr., J.S. Singh, and W.K. Lauenroth
1978 The Structure and Function of Ten Western North American Grasslands. I: Abiotic and Vegetational Characteristics. Journal of Ecology 66:251-285.

Solomon, A.M., and T.J. Blasing,
1982 Modern Analogues for Holocene Climatic Regimes in the Desert Southwest: A Hot, Dry Altithermal. Bulletin, Ecological Society of America, Abstracts 63:167.

Spaulding, W.G., E.B. Leopold, and T.R. Van Devender
1983 Late Wisconsin Paleoecology of the American Southwest. In The Late Pleistocene, edited by S.C. Porter, pp. 259-293, Late-Quaternary Environments of the United States, vol. 1. University of Minnesota Press, Minneapolis.

Spaulding, W.G. and K.L. Petersen
1980 Late Pleistocene and early Holocene Paleoecology of Cowboy Cave. Appendix II, in Cowboy Cave, by J.D. Jennings, pp. 163-177. University of Utah Anthropological Papers 104, Salt Lake City.

Stuart, D.E., and R.P. Gauthier
1981 Prehistoric New Mexico: Background for Survey. Historic Preservation Bureau, Santa Fe.

Thompson, R.S., and J.I. Mead
1982 Late Quaternary Environments and Biogeography in the Great Basin. Quaternary Research 17:39-55.

Tuan, Yi-Fu, C. Everard, G.G. Widdison, and I. Bennett
1973 The Climate of New Mexico. New Mexico State Planning Office, Santa Fe.

Van Devender, T.R.
1977 Holocene Woodlands in the Southwestern Deserts. Science 198:189-192.

Van Devender, T.R., and W.G. Spaulding
1979 Development of Vegetation and Climate in the Southwestern United States. Science 204:701-710.

Van Devender, T.R., and F.M. Wiseman
1977 A Preliminary Chronology of Bioenvironmental Changes During the PaleoIndian Period in the Monsoonal Southwest. In PaleoIndian Lifeways, edited by E. Johnson. The Museum Journal 17:13-27.

Vivian, R. Gordon, and T.W. Mathews
1965 Kin Kletso: A Pueblo III Community in Chaco Canyon, New Mexico. Southwestern Monuments Association, Technical Series, vol. 6., no. 1.

Vivian, R. Gwinn
1974 Conservation and Diversion: Water-control Systems in the Anasazi Southwest. In Irrigation's Impact on Society, edited by T.E. Downing and M. Gibson, pp. 95-112. University of Arizona Anthropological Papers no. 25. Tucson.

Wells, P.V.
1979 An Equable Glacio-pluvial in the West: Periglacial Evidence of Increased Precipitation on a Gradient from the Great Basin to the Sonoran and Chihuahuan Deserts. Quaternary Research 12:311-325.

1983a Paleobiogeography of Montane Islands in the Great Basin Since the Last Glacio-pluvial. Ecological Monographs 53(4):341-382.

1983b Late Quaternary Vegetation of the Great Plains. Transactions of the Academy of Sciences II (Special Issue):83-89.

Wells, S.G., T.F. Bullard, L.N. Smith, and T.W. Gardner
1983 Chronology, Rates and Magnitudes of Late Quaternary Landscape Changes in the Southeastern Colorado Plataeu. In Chaco Canyon Country, edited by S.G. Wells, D.W. Love, and T.W. Gardner, pp. 177-185. American Geomorphological Field Group, 1983 Field Trip Guidebook.

Winstanley, D.
1973 Rainfall Patterns and General Atmospheric Circulation. Nature 245:190-194.

Wright, H.E., A.M. Bent, B.S. Hansen, and L.J. Maher, Jr.
1973 Present and Past Vegetation of the Chuska Mountains, Northwestern New Mexico. Bulletin Geological Society of America 84:1155-1180.

Chapter Two

Vegetative Cover, Diversity, and Annual Plant Productivity, Chaco Canyon, New Mexico

by

Anne C. Cully and Jack F. Cully,Jr.

Introduction

Chaco Canyon is located in the central San Juan Basin in northwestern New Mexico. The San Juan Basin is, in many respects, an extension of the Great Basin, although the Chihuahuan Desert to the south influences the climate and the composition of the vegetation. The soils of the San Juan Basin are generally shale and sandstone derived. The vegetation is dominated by members of the Compositae family, including sagebrush (*Artemisia* spp.) and rabbitbrush (*Chrysothamnus* spp.), and the Chenopodiaceae, especially various saltbushes (*Atriplex* spp.; Donart et al. 1978; Shreve 1942). As in the Great Basin, winter precipitation is a significant component of the total in northwestern New Mexico, but the summer monsoonal rains from the south provide a large proportion of the rainfall during the growing season (Tuan et al. 1973). A summary of weather data at Chaco Canyon over a 20-year period, from 1957-1977 (Cully 1984a), shows that annual precipitation averaged 20.6 cm. The heaviest precipitation occurs during July through September, with each of these months averaging >3 cm. The remainder of the rainfall is approximately evenly distributed throughout the rest of the year. The San Juan Basin can have two periods of plant productivity, one in spring, if there is normal or above normal precipitation, and another more predictable period during late summer and fall, in response to the monsoonal rains of late summer.

Early visitors described Chaco Canyon and the surrounding region. In 1849, scrub cedars (*Juniperus*), sagebrush (*Artemisia*), and grama grasses (*Bouteloua* spp.) were conspicuous plants in what Simpson (1964) described as a wide expanse of barren waste. Jackson (1878) described a deep arroyo in the canyon, although cottonwoods and willows lined the wash near Pueblo del Arroyo where he camped. "There was also considerable new grass just springing up among the willows and young cottonwoods, which extended half a mile above and below us, that was much relished by our half-starved mules, besides which the perpendicular sides of the arroyo served excellently as a corrall [sic] to restrain their wanderings." Judd (1954) found only a few cottonwoods in 1920 and stated that willows were continually decreasing with the erosion of sand bars in the wash. At the time of the boyhood of one of Judd's informants (just prior to Simpson's visit in 1849), the canyon was said to have been carpeted with high grass (probably alkali sacaton or galleta, both common today) and shallow pools of water stood throughout the year. Cottonwoods and willow were common near Peñasco Blanco and downstream. Because of variation in observer reports it is difficult to tell whether conditions were any different 100 years ago than they are today.

While Chaco Canyon has been grazed since the eighteenth century or possibly earlier (Brugge 1980), large-scale cattle and sheep operations did not begin until 1878 or 1879 (Judd 1954), when several stock companies moved into the area. (Brugge [1980] suggests that these dates are too early by a decade.) This apparently had a severe effect on the vegetative cover, particularly grasses and palatable shrubs. Heavy grazing continued into the twentieth century until the formation of the Chaco Canyon National Monument and the construction of a boundary fence in 1936 (Brugge 1980). Beginning about 1935, various planting, seeding, land treatment projects, and erosion control were initiated to restore the overgrazed vegetation and to combat the severe erosion taking place in the main channel and tributary arroyos within the park. Most of the reseeding was with species native to the area, e.g., western wheat grass (*Agropyron smithii*), galleta grass, blue grama, and drop seeds (*Sporobolus cryptandrus S. airoides*). Several species of willow (*Salix exigua*; *S. communis*; *S. amygdaloides*), cottonwood (*Populus fremontii*), and wild plum (*Prunus virginiana?*) were planted by the hundreds of thousands in the main wash. Some of the species were exotics, the most notable being tamarisk (*Tamarix pentandra*) (Balch [1949, 1950]; Brugge [1980]; Chaco Canyon National Monument [1949,1950]; Keefe [1950]). Many, if not all of these species were probably present before conservation activities began, although their numbers may have been considerably reduced by grazing and erosion. Western wheat grass, galleta grass, sand dropseed, alkalai sacaton, cottonwood trees, and willow (*Salix exigua*) are all abundant locally; however, most of the erosion control features and associated plantings have been washed away.

Recent biological work in the canyon has included ecological descriptions of the vegetation and habitat types. Jones (1972) established permanent vegetation sampling units in differing vegetation types. Potter (1974) also established permanent transects in various vegetation types delineated in the map produced by Kelley and Potter (1974). Scott (1980a, 1980b) and Scott and Duke (1980) report the results of several years work that include sampling perennial plant cover, measuring ephemeral plant populations, and evaluating the phenology of the perennial plants at a study area near Pueblo Alto.

The study sites for this report are five areas used by J. Cully (1984b, this volume) in his study of the bird and rodent communities. The areas were selected from Kelley and Potter's (1974) vegetation map of Chaco Canyon. The principal criteria for the choices were that each area include habitat sufficient to contain a transect 120 m wide by 1.6 km long, that the areas were different from one another, and that in combination they represent the major habitats in the park. The sites at Pueblo Alto and at the mouth of Werito's Rincon were added for this study to provide additional data on annual plant productivity. The main purposes of the botanical fieldwork reported here were to sample the vegetation of the major habitats in Chaco Canyon, to identify the dominant perennial plant species, estimate diversity, and to measure the variation in productivity of annual plants. The data gathered for this study provided a background for investigating ecological relationships in bird and mammal communities that exist in Chaco Canyon today. The characteristics of the vegetation may be equally relevant to the understanding of foraging behavior of prehistoric human populations who lived in Chaco Canyon; questions that apply to birds, mammals, and to humans include those relating to what plants would have been available, where they occur, and how these resources might vary spatially and temporally. Perennial plants are commonly used for measurements of dominance and diversity because they are a more stable component of the plant community than annual plants. Annual production is characterized by a fascinating cycle of years of low germination interspersed with years of super-abundant germination and reproduction. At Chaco Canyon, we had the opportunity to document one super-abundant year followed by several consecutive years of little or no annual production.

Study Areas

The Bench

The bench lies within the *Hilaria-Bouteloua* with *Atriplex* vegetation type, dominated by galleta grass and blue grama grasses, with a significant component of fourwing saltbush (Kelly and Potter 1974). The bench (Figure 2.1) is elevated above the floodplain and is bounded on the north and south by sandstone cliffs. Soils are thin and there is a great deal of exposed bedrock.

Casa Chiquita and Pueblo Bonito

Two study sites lie within the *Atriplex-Sarcobatus* vegetation type in the floodplain of the wash, which is dominated in the western portion of the park by fourwing saltbush, shadscale, and black greasewood (Kelley and Potter 1974). The sites are bordered on the south by the wash and on the north by sandstone cliffs and the bench habitat.

The Wash

The wash is the erosion channel of the Chaco River; it bisects the floodplain through the length of the park. Riparian, woody vegetation is characteristic of the wash habitat; the inner channel is dominated by rabbitbrush (*Chrysothamnus nauseosus*) and black greasewood (*Sarcobatus vermiculatus*). Coyote willow (*Salix exigua*), fourwing saltbush (*Atriplex canescens*), cottonwood (*Populus fremontii*), and tamarisk also occur (Kelley and Potter 1974).

Pinyon-Juniper

The woodlands of the higher elevations of Chacra Mesa are strongly dominated by one-seed juniper (*Juniperus monosperma*). Pinyon pine (*Pinus edulis*) is subdominant (Kelley and Potter 1974).

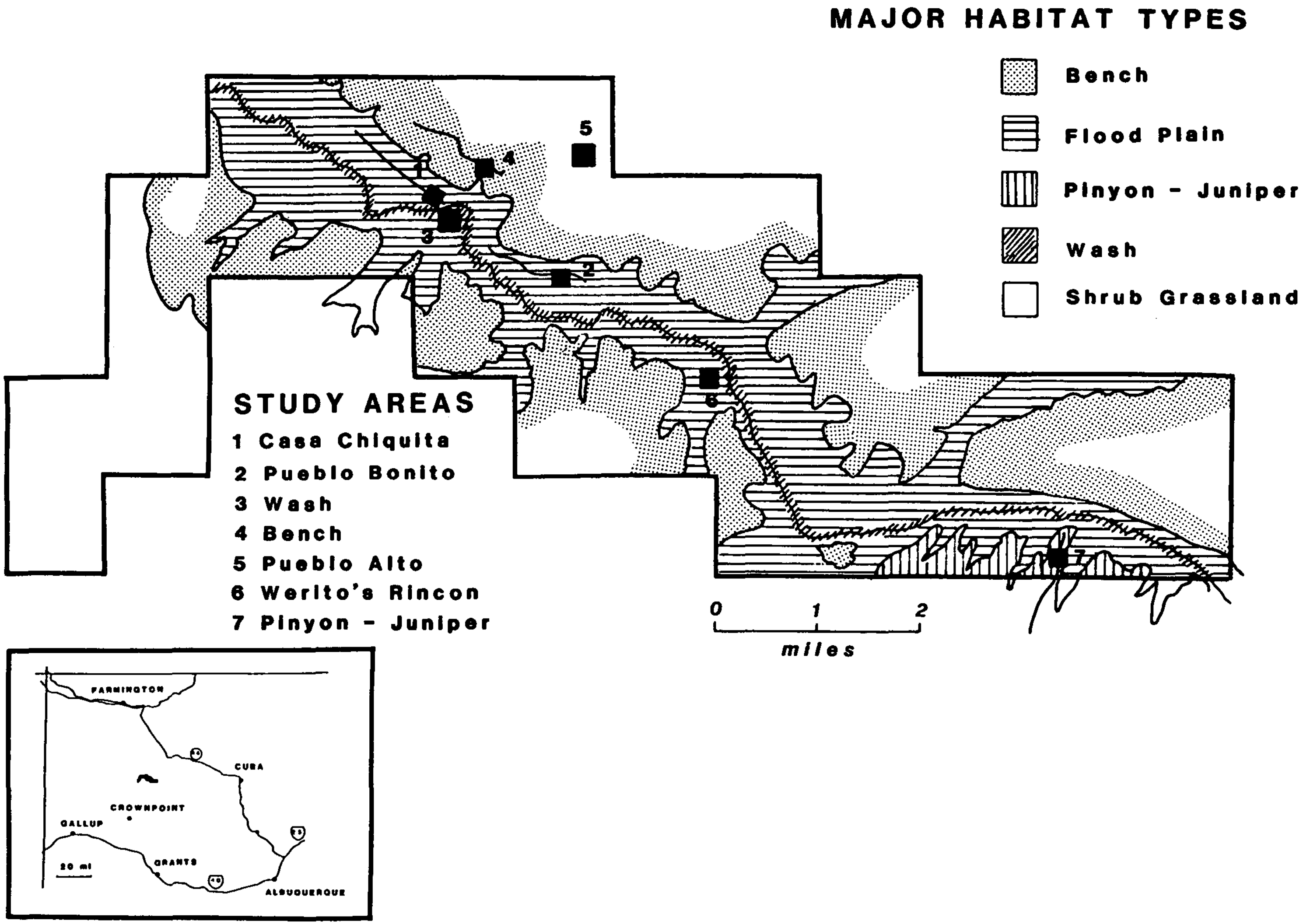

Figure 2.1 Chaco Canyon National Monument Study Area

Pueblo Alto

Pueblo Alto is located in a shrub grassland, the *Atriplex-Oryzopsis-Sporobolus* vegetation type, dominated by fourwing saltbush, Indian ricegrass, and sand dropseed (Kelley and Potter 1974). The site is located in the uplands to the north of the canyon proper.

Werito's Rincon

This study site is located at the mouth of a large rincon to the southwest of the main canyon. According to Kelley and Potter (1974), the vegetation type is similar to that surrounding the Pueblo Alto study area.

Methods

Perennial plant cover was measured using the line intercept method (Canfield 1941). Cover was measured on 25 10 m-lines stretched in alternate directions at 62 m intervals along a 1.6 km transect in each habitat. This yielded a total of 250 m sampled in each habitat. Each perennial plant species intercepted was measured to the nearest cm. The Bench, Casa Chiquita, and Pueblo Bonito were sampled during April, 1979. The Wash and the Pinyon-Juniper sites were sampled during May, 1981.

In order to identify the species that can be most easily used to distinguish between habitats, the cover data from each 10 m line segment in each habitat was subjected to discriminant function analysis. The habitats were the discriminating variables, and the 29 species of plants that were encountered on 3 or more (of a total of 125) segments, were the predictor variables. This analysis was done at the University of New Mexico Computing Center using BMDP (Dixon 1981).

The cover data at each transect were analyzed for species richness, S (number of species) = H_0, species diversity $1/\ \Sigma\ p_i^2$. = H_1 (Simpson 1949), and $\exp(-\ \Sigma\ p_i \ln p_i) = H_2$ (Shannon and Weaver 1949) and evenness, J, where $J = H_2/H_0$ (Peet 1974; Pielou 1974). Hill (1973) suggests that evenness as measured above is subject to change with change in sample size, and that the ratio H_1/H_0 is a better ratio to describe evenness. This is partly because H_2 always lies between H_0 and H_1. Since J is still common in the literature we present both measures of evenness. Species composition at each habitat is also presented in tabular form for comparison.

Annual plant densities were estimated at the Bench, Casa Chiquita, Pueblo Bonito, and Pueblo Alto in June 1979, 1980, and 1981, and at Werito's Rincon during June, 1979. At each area data were taken from 20 1/2 m^2 quadrats placed at 10 m intervals along 100 m tapes laid at random in a 1 ha area of the transect used to measure cover at Casa Chiquita, Pueblo Bonito, and the Bench. Cover was not measured at Pueblo Alto or at the site at the mouth of Werito's Rincon; however, a transect was laid out in the same way at these two sites to gather the annual plant data. The number of annual plants within each quadrat was counted by species; all vegetation was then picked and saved in plastic bags. The vegetation was air-dried at room temperature for a minimum of 2 months before storage. Each sample was weighed to the nearest 0.1 g. The seeds were separated from foliage, stems, and flower parts in a seed separator and weighed separately.

Results

Perennial Plant Species

According to the cover data, the dominant species on the bench are Mormon tea (*Ephedra viridis*), Bigelow's sagebrush (*Artemisia biglovii*), Greene's rabbitbrush (*Chrysothamnus greenei*), galleta grass, and Indian ricegrass (Table 2.1). The dominant species at Casa Chiquita are broadscale (*Atriplex obovata*), black greasewood, Torrey seepweed (*Sueda torreyana*), and alkalai sacaton. Pueblo Bonito is similar to Casa Chiquita, except that broadscale is missing, and fourwing saltbush is much more important than at Casa Chiquita (15% cover versus 1% at Casa Chiquita; see Table 2.1). Black greasewood and seepweed are also important at Pueblo Bonito. Galleta grass is absent at Casa Chiquita, but contributes 2% cover at Pueblo Bonito (Table 2.1). The Wash is dominated by rabbitbrush, tamarisk, coyote willow, big sagebrush, and fourwing saltbush. The pinyon-juniper habitat on Chacra Mesa is dominated by Bigelow's sagebrush, mountain mahogany (*Cercocarpus montanus*), three-leaved sumac (*Rhus trilobata*), pinyon, one-seed juniper, and Galleta grass (Table 2.1). Shrubs and forbs are the primary components of the vegetation at all the study sites sampled for perennial vegetation (Figure 2.2).

The discriminant function analysis (DFA) shows that there are 12 species that are important in discriminating between habitats (Table 2.2). The list includes all of the above species as dominants plus one additional species, *Artemisia dracunculoides*. One value of the DFA is its ability to show which habitats are most similar to each other, and by a jacknife procedure, to show how accurately the habitats can be distinguished on the basis of the predictor variables. The jackknife procedure takes each of the observations that were used to derive the discriminant functions and tests *a posteriori* the accuracy with which the cases are attributed to the correct groups; it is a test of the accuracy of the discriminant functions to discriminate between groups. Figure 2.3 shows the relationships of the observations from each habitat on canonical variables (discriminant function axes) 1 and 2. Casa Chiquita and Pueblo Bonito are similar to each other. The Bench and Pinyon-Juniper habitats are also very similar; in fact, they are almost completely overlapping on canonical axes 1 and 2. (They are separated on axis 4 where juniper is an important variable.) Although 8/25 observations from the Bench were misclassified to the Pinyon-Juniper, only one observation from the Pinyon-Juniper was misclassified to the Bench (Table 2.3). The Wash habitat was distinct from the others with a small area of overlap on canonical axes 1 and 2.

The analysis indicates that the habitats are sufficiently different to allow a 10 m line intercept measurement in each of the five habitats

Table 2.1 Cover at Five Habitats at Chaco Canyon

	Bench	Casa Chiquita	Pueblo Bonito	Wash	Pinyon-Juniper
Ephedra viridis	680	0	0	0	26
Artemisia bigelovii	1145	0	0	0	682
Atriplex canescens	164	187	3802	444	0
Atriplex obovata	0	1808	0	0	0
Chrysothamnus pulchellus	70	0	0	0	0
Cercocarpus montanus	0	0	0	0	376
Rhus trilobata	79	0	0	0	217
Opuntia spp.	6	0	0	0	18
Other	287	0	0	247	23
Gutierrezia sarothrae	23	0	21	0	100
Chrysothamnus greenei	450	0	0	0	0
Chrysothamnus nauseosus	0	0	0	2952	100
Eriogonum spp.	196	0	0	0	94
Artemisia dracunculoides	0	0	0	190	35
Artemisia tridentata	1	0	0	573	51
Sarcobatus vermiculatus	0	1211	2260	220	0
Suaeda torreyana	0	286	202	0	0
Tamarix pentandra	0	0	0	2917	0
Lycium pallidum	0	0	44	0	29
Pinus edulis	0	0	0	0	229
Juniperus monosperma	2	0	0	0	2117
Hilaria jamesii	252	0	456	53	269
Sporobolus spp.	101	0	0	309	0
Oryzopsis hymenoides	250	10	4	73	10
Bouteloua gracilis	0	0	0	5	110
Agropyron spp.	0	51	0	175	0
Sporobolus airoides	0	714	131	0	0
Salix spp.	0	2	0	1772	0
Total	3542	4259	6920	9210	4486
% cover	14%	17%	28%	37%	18%

The values are the number of cm intercepted for each species at 25, 10 m lines in each habitat. To calculate percent cover, divide by 25,000.

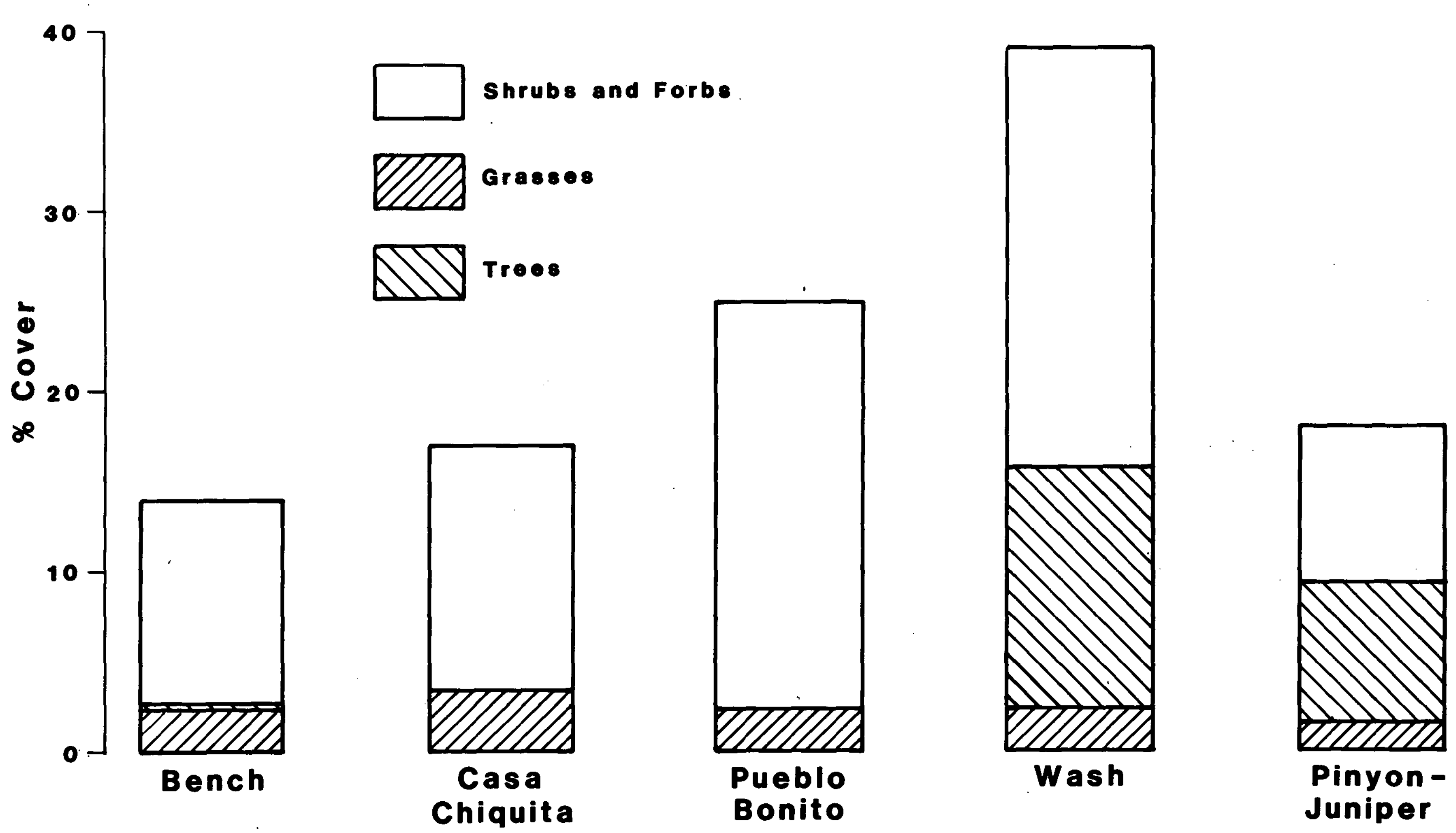

Figure 2.2 Tree, Grass, Shrub, and Total Cover for the Bench, Casa Chiquita, Pueblo Bonito, the Wash, and Werito's Rincon Area

Table 2.2 List of Species Utilized by the Discriminant Function Analysis

Step Number	Species	F to Enter
1	*Atriplex obovata*	27.03
2	*Atriplex canescens*	15.96
3	*Artemisia bigelovii*	12.88
4	*Chrysothanmus nauseosus*	10.87
5	*Sarcobatus vermiculatus*	6.88
6	*Juniperus monosperma*	5.60
7	*Hilaria jamesii*	4.79
8	*Oryzopsis hymenoides*	4.90
9	*Artemisia dracunculoides*	4.27
10	*Salix exigua*	4.25
11	*Tamarix pentandra*	4.40
12	*Ephedra viridis*	4.13

Table 2.3 BMDP7M Discriminant Function Analysis to Determine Which Species are Important in Discriminating Between Habitats

		Number of Classes Classified into Group				
Group	% Correct	Bench	Casa Chiquita	Pueblo Bonito	Wash	Pinyon-Juniper
Bench	60	15	0	0	1	9
Casa Chiquita	64	0	16	5	0	4
Pueblo Bonito	84	0	0	21	0	4
Wash	60	3	0	3	15	4
Pinyon-Juniper	88	2	0	0	1	22
Total	71	20	16	29	17	43

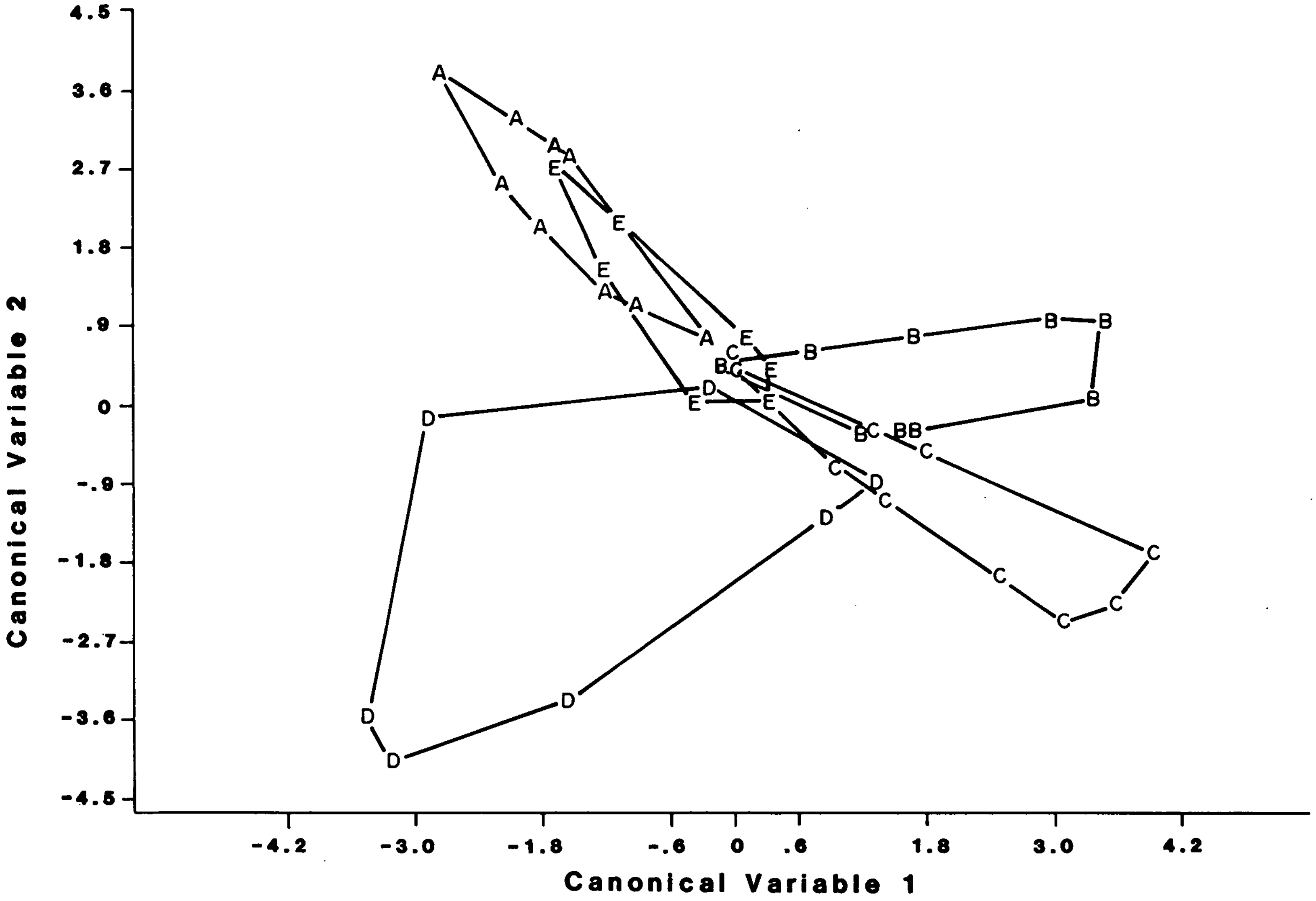

Figure 2.3 Relationships of Observations from Each Habitat on Canonical Variables

sampled to be classified correctly a high percentage of the time (see Table 2.3).

Diversity

The Bench has the second highest richness and the highest diversity according to the two diversity indices (Table 2.4). It also has the lowest cover of the five habitats. Casa Chiquita has considerably lower diversity than the Bench but cover that is similar in value. The diversity of Pueblo Bonito is similar to Casa Chiquita but with much higher cover. The Wash has similar cover and greater diversity. The Pinyon-Juniper habitat resembles the Bench in its high species diversity, particularly richness, and low cover values.

Annual Plant Species and Biomass Measures

At all five areas sampled for annual plant densities, the total densities were considerably higher in 1979 than in the following two years (Table 2.5-2.6; Figures 2.4-2.6). Annual species diversity (measured as richness) was also higher during 1979, with most species occurring only in that year. When biomass is compared between sites and years, the picture is not so clear. At Casa Chiquita and Pueblo Bonito the pattern for biomass was similar to the pattern for annual plant density; however, at Pueblo Alto and the Bench, the totals of both plant and seed biomass were higher in 1980 than in 1979. The differences in biomass and seed production may be due to local species composition, soil conditions, and water availablity. The biomass figures include grasses, a component of the perennial vegetation that may be affected by increased moisture later in the year or even the following year.

The species composition at Werito's Rincon was different from that at the other sites (Table 2.5; Figure 2.7). In 1979, pinnate tansy-mustard (*Descurainia pinnata*) was the dominant annual in terms of density at all sampling locations save Werito's Rincon, where stickleaf (*Mentzelia* spp.) was the most abundant (Figure 2.7). In spite of the similar densities, the total biomass and seed biomass are much lower at Werito's Rincon than at the Casa Chiquita site (Figure 2.6). Pinnate tansy-mustard apparently produces more seed and foliage than stickleaf (seed biomass was not separated by species, however). Further studies are needed to determine whether or not these results are due to phenological difference in the two species.

Discussion

Habitat Types

The results of this study suggest that the wash, the floodplain, the bench, and the mesa tops are distinct habitat types. Individual species distribution may overlap habitat types, but each type is distinguished either by the presence of species unique to that habitat, or by the greater dominance of particular species over others.

Table 2.4 Cover and Diversity at Five Habitats at Chaco Canyon

	% Cover	S	$\frac{1}{\sum P_i^2} = H_1$	$- \sum P_i L_n P_i = H_0$		$\frac{\frac{1}{\sum P_i^2}}{S}$
Bench	14	15	6.05	8.08	.5388	0.40
Casa Chiquita	17	7	3.3939	4.0786	.5822	0.48
Pueblo Bonito	28	8	2.4147	3.0224	.3778	0.30
Wash	37	13	4.8509	6.4900	.4992	0.37
Pinyon-Juniper	18	17	3.7918	6.4958	.3821	0.22

S = species richness. Data are derived from total cover for each species found in each habitat.

Table 2.5 Annual Plant Densities at Chaco Canyon

	Casa Chiquita			Pueblo Bonito			Bench			Pueblo Alto			Werito's Rincon
	1979	1980	1981	1979	1980	1981	1979	1980	1981	1979	1980	1981	1979
Astragalus	0	0	1.6	0	0	0	2.7	2.7	1.6	11.9	0	0	4.7
Atriplex	0	0.1	0	5.7	0	0	0	0	0	0	0.2	0	0
Chenopodium	0.2	0	0.1	1.4	0	0	0	0	0	0.2	0	0	0
Cryptantha crassisepala	23.3	0	0	15.8	0	0.2	0.2	0.1	0	18.6	0	0	1.5
Descurainia	144.3	0	0	45.1	0	0	7.1	0	0	41.1	0	0	29.1
Ipomopsis	0.4	0	0	0	0	0	0	0	0	0	0	0	0.6
Lappula	1.0	0	0	3.7	0.2	0	0.4	0	0	0.2	0	0	0.1
Mentzelia	0	0.3	0	0	0	0	0	0	0	0.5	1.5	0	96.1
Phacelia	0	0	0	0.2	0	0	1.4	0	0	3.7	0	0	0
Plantago	0	0	0	0	0	0	0	0	0	3.5	0	0.1	49.5
Portulaca	0	0	0	1.4	0	0	0	0	0	0	0	0	0
Salsola	5.4	0	0	2.7	2.1	5.9	0	0	0	0.3	0	0	3.9
Senecio	0.4	0	0	0	0	0	0	0	0	2.3	0	0	16.3
Solanaceae	0.7	0	0	0.4	0	0	0	0	0	0	0	0	0
Sphaeralcea	0	0	0	0	0	0	0	0	0	0.2	0	0	8.1
Stephanomeria	0	0	0	0	0	0	0	0	0	0	0	0	2.3
Streptanthella	0	0	0	0	0	0	3.2	0	0	0.7	0	0	0
Townsendia	37.2	0	0	6.2	0	0	0	2.1	0	1.4	0.6	0	0
Other*	0	0	0	0.7	0.4	0.2	0.7	0	0.1	0.7	0.1	0	0.1
Unknown	7.1	0.3	0.1	1	0	0	1.2	0	0	0.9	0	0	10.6
Number of Species	10	2	3	12	3	3	8	3	2	15	4	1	13
Total Density	220	0.7	1.8	84.3	2.7	6.3	16.9	4.9	1.7	86.2	2.4	0.1	222.9

Densities were counted in 20 plots that measured 1.0 x 0.5 m. All plots were sampled during June of the year indicated.

*other includes all identified species that never reached a density of 0.5 per m^2.

Table 2.6 Vegetation Biomass of Annual Plants and Grasses at Five Locations

Location	Year	Total Plant Biomass Mean	Total Plant Biomass Se	Seeds Mean	Seeds Se
Casa Chiquita	1979*	98.8	12.68	21.8	2.52
	1980	28.6	6.93	4.6	1.12
	1981	3.8	0.97	0	0
Pueblo Bonito	1979	126.8	9.65	20.56	1.82
	1980	24.26	5.02	2.9	0.55
	1981	26.18	4.26	0	0
Bench	1979	5.52	0.88	0.74	0.12
	1980	13.46	2.12	1.98	0.32
	1981	5.08	0.74	0	0
Pueblo Alto	1979	32.50	2.27	5.44	0.53
	1980	57.46	4.51	8.84	0.75
	1981	15.94	1.29	0.10	0.02
Werito's Rincon	1979	42.34	2.91	4.72	0.45

Biomass is expressed as g/m^2

*We only collected biomass samples from 10 plots at Casa Chiquita in 1979.

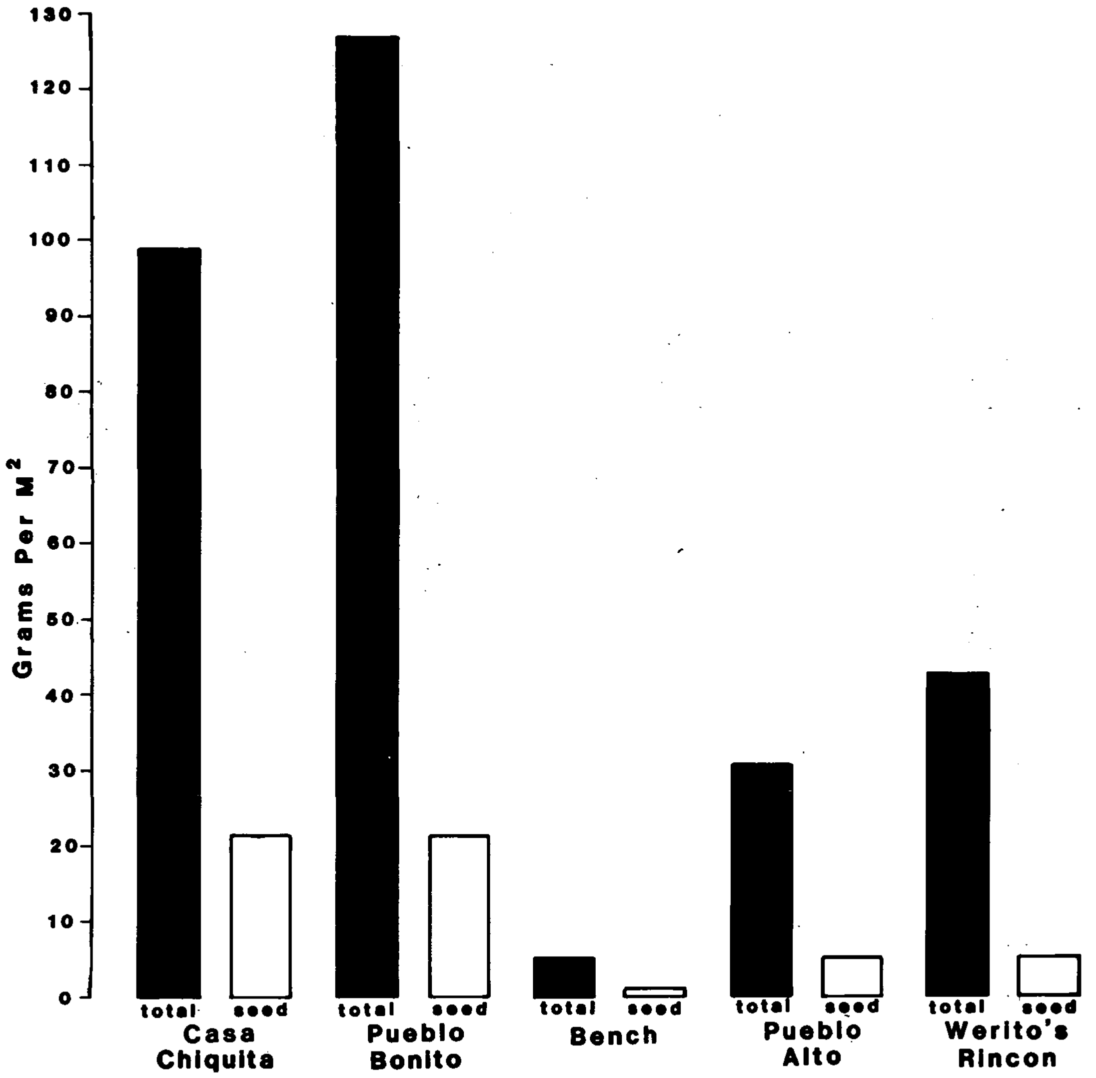

Figure 2.4 Total Plant and Seed Biomass at Casa Chiquita, Pueblo Bonito, the Bench, Pueblo Alto, and Werito's Rincon, June 1979

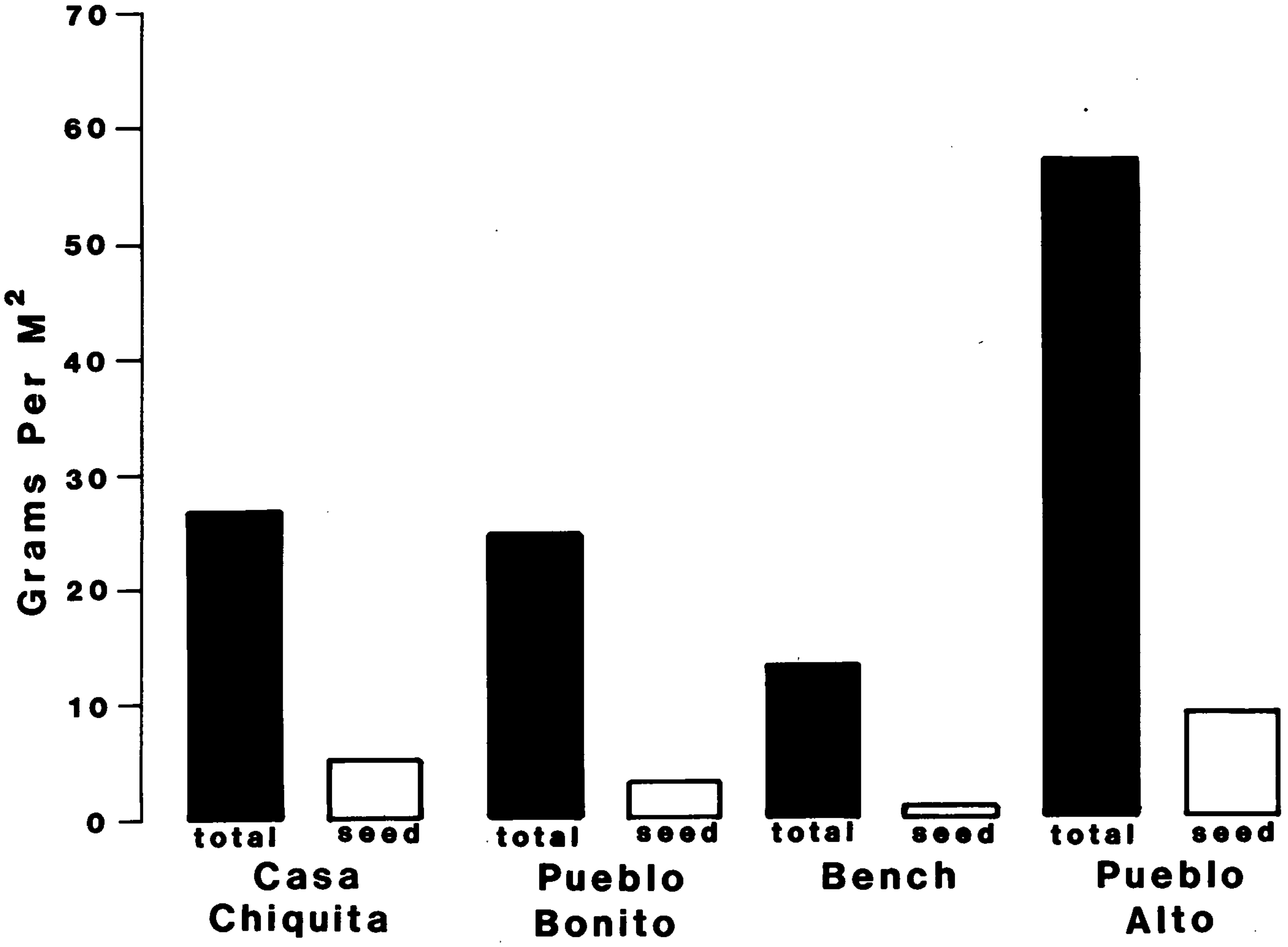

Figure 2.5 Total Plant and Seed Biomass at Casa Chiquita, Pueblo Bonito, the Bench, and Pueblo Alto, June 1980

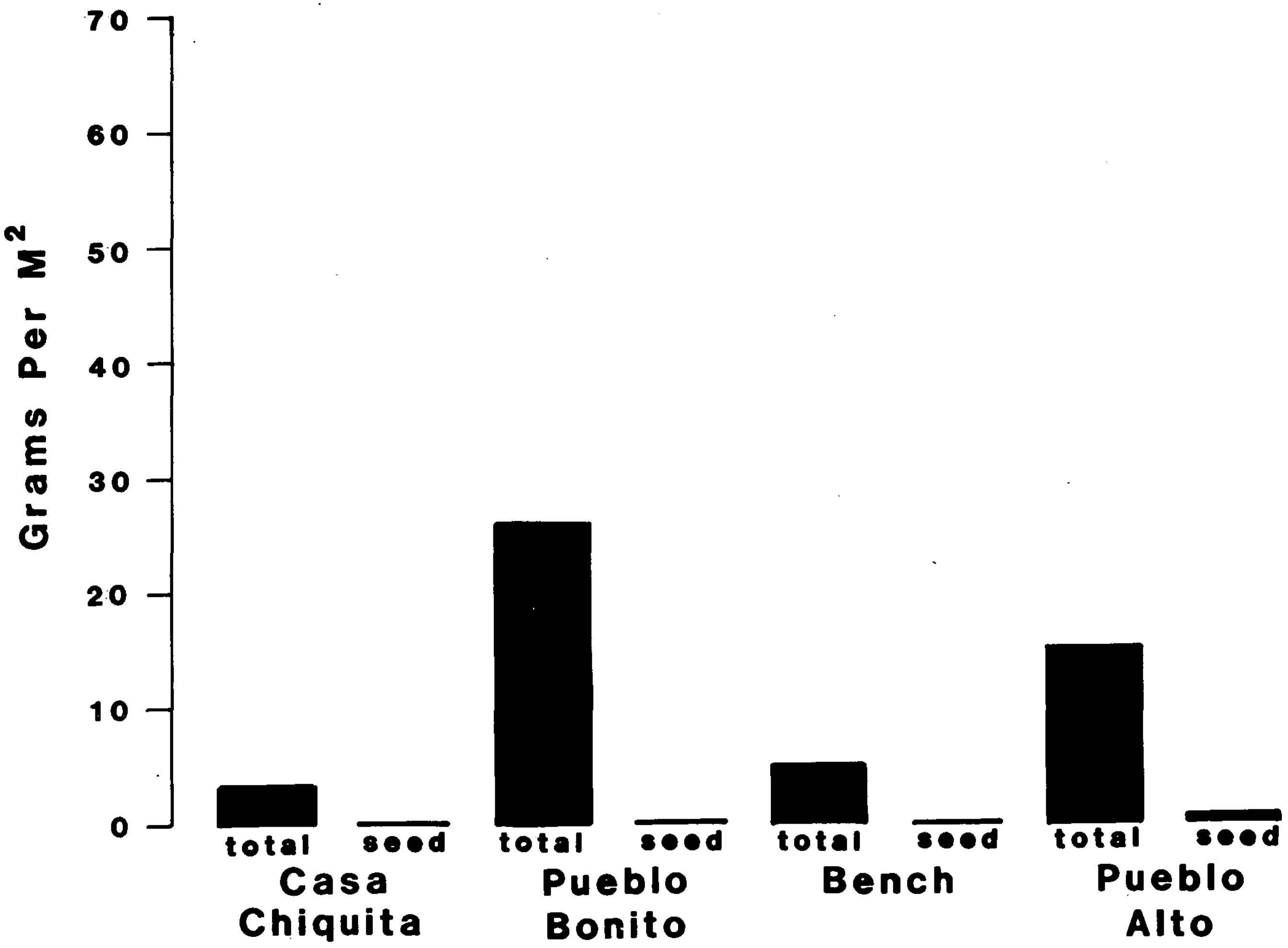

Figure 2.6 Total Plant and Seed Biomass at Casa Chiquita, Pueblo Bonito, the Bench, and Pueblo Alto, June 1981

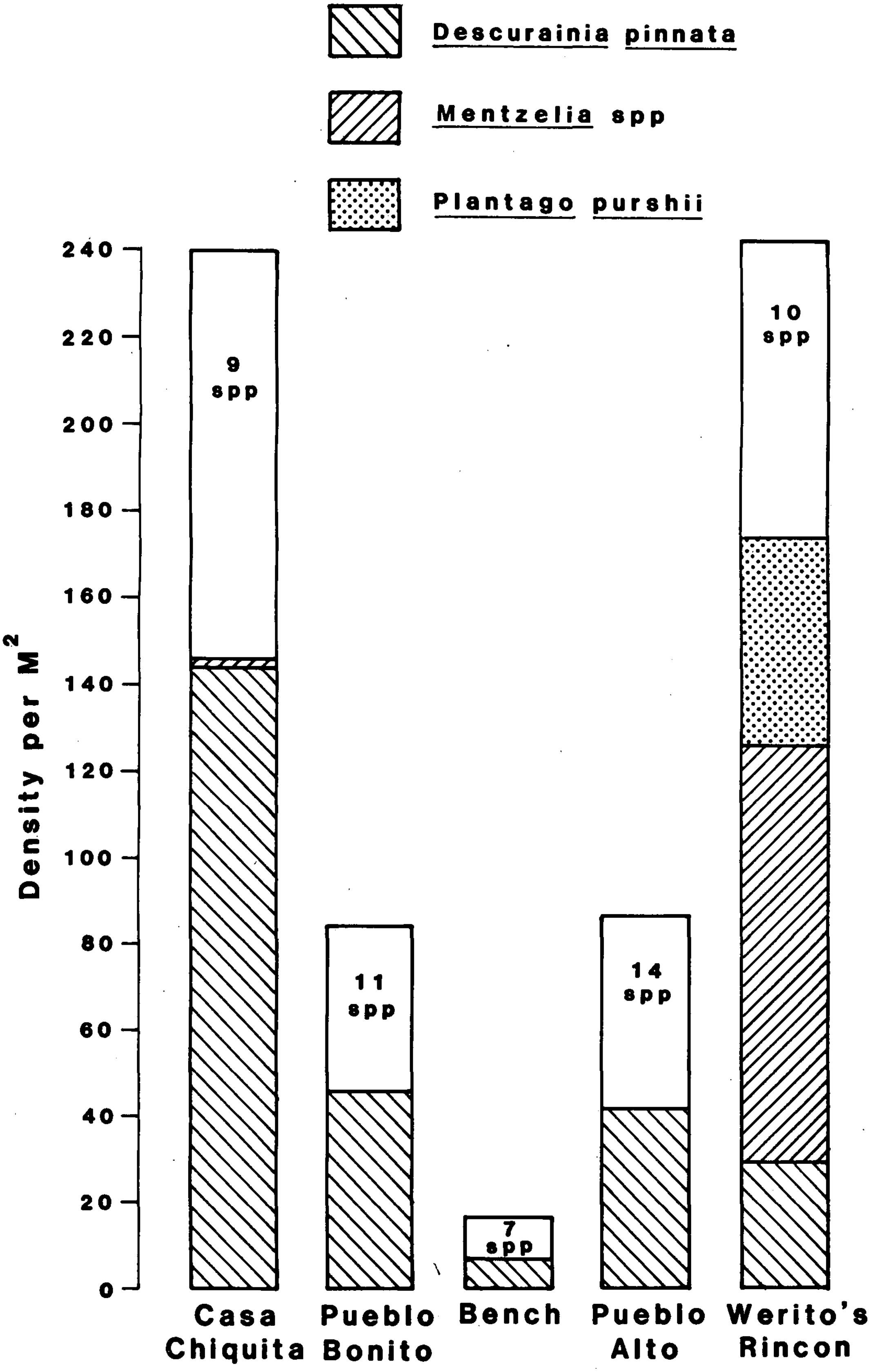

Figure 2.7 Total Density and Density of Dominant Annual Species, Casa Chiquita, Pueblo Bonito, Bench, Pueblo Alto, and Werito's Rincon

The results of our sampling are somewhat different from those of Potter (1974) and Jones (1972) for the study sites. This can be accounted for in several ways. Although based on the line intercept technique, the methodologies chosen by each investigator were different; the criteria for choosing study site locations, the length of the transects, and the locations of the transects were determined by the goals of each study. In addition to these factors, differences may be attributed to actual changes in the abundance of perennial plant species. Jones (1972) was the first to note changes in perennial cover over a two-year period along permanent sampling transects. In a more rigorously controlled study, Scott (1980b) reports the death of many perennials in his study plots, particularly big sagebrush, fringed sagebrush (Artemisia frigida), broom snakeweed (Gutierrezia sarothrae), Greene's rabbitbrush (Chrysothamnus greenei), and bottlebrush squirreltail (Sitanion hystrix), during a period of low rainfall in 1976. Similar changes may go undocumented from year to year and result in changes in plant cover and dominance of plant species in local areas. Organisms depending on resources that suffer a large-scale die-off would be forced to shift their foraging to other, less preferred species, to leave the area, or to die. For human populations, perennial plants provided food, fuel, and material for construction. Many species may actually serve all three purposes. Table 2.7 indicates the perennial species of major ethnobotanic importance that we encountered on sampling transects and the habitat in which they were found at the highest cover values. This table does not include all the perennials of importance to prehistoric human populations (see Cully [1984] and Toll [1985a] for archeobotanical evidence of plant resources from Chaco Canyon), however, it does give some idea of the location of these species.

The Bench habitat provides a favorable environment for Indian ricegrass. The floodplain offers alkalai sacaton for food and many species useful for fuel. The Wash provides several food species, some fuel, and construction materials. Food, fuel, and construction materials are found on the mesa.

Annual Plant Productivity

One of the most conspicuous characteristics of annual plant productivity is the variability from year to year. Jones (1972) measured annual plant cover along with perennial cover and noted drastic changes in total cover over a two-year period, due in large part to differences in annuals, but also to the death of some of the perennial shrubs. Potter (1974) reports that several plant communities in Chaco Canyon are particularly good for annual plant production when conditions are suitable for germination. Scott (1980a) also records variability in annual plant populations from 1975 to 1977.

Annual spring plant densities fluctuated drastically from year to year during the period 1979 to 1981. We believe that the dramatic abundance of annuals in 1979 was due to late winter and spring precipitation that fell at Chaco Canyon in 1978-1979. During December and January, mean monthly temperatures were low (Figures 2.8 and 2.9). Together, these climatic variables resulted in favorable conditions for the germination and

Table 2.7 Perennial Plant Species of Major Ethnobotanic Importance and Habitats Where They Had the Highest Cover Values

	Bench	Floodplain	Wash	Mesa Top
Food				
Oryzopsis hymenoides	+			
Agropyron spp.			+	
Sporobolus spp.			+	
Sporobolus airoides		+		
Pinus edulis				+
Opuntia spp.				+
Fuel				
Atriplex canescens		+		
Atriplex obovata		+		
Artemisia tridentata		+		
Sarcobatus vermiculatus		+		
Chrysothamnus nauseousus			+	
Pinus edulis				+
Juniperus monosperma				+
Construction				
Salix spp.			+	
Pinus edulis				+
Juniperus monosperma				+

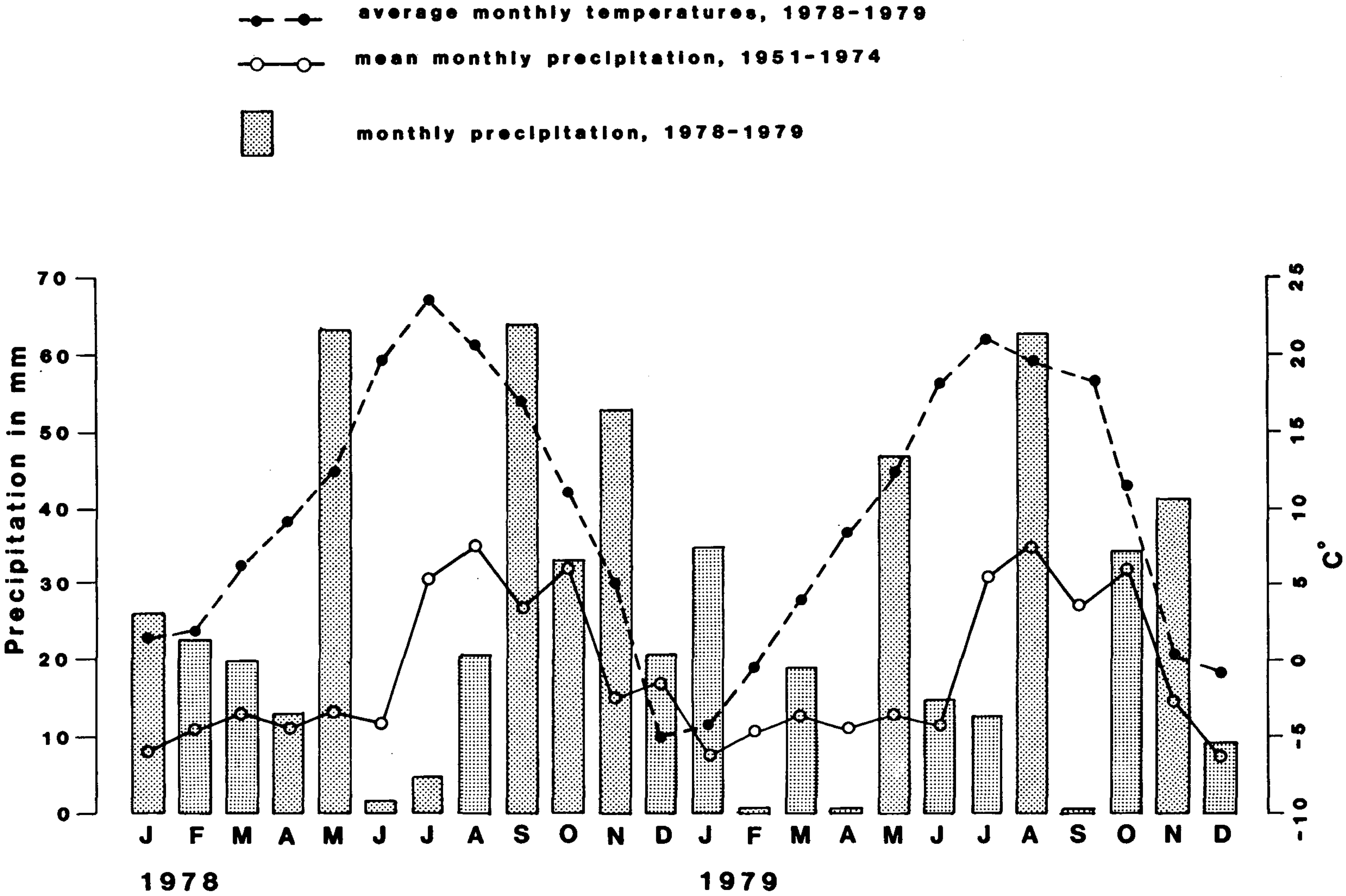

Figure 2.8 Average Monthly Temperature Chart, 1978-1979

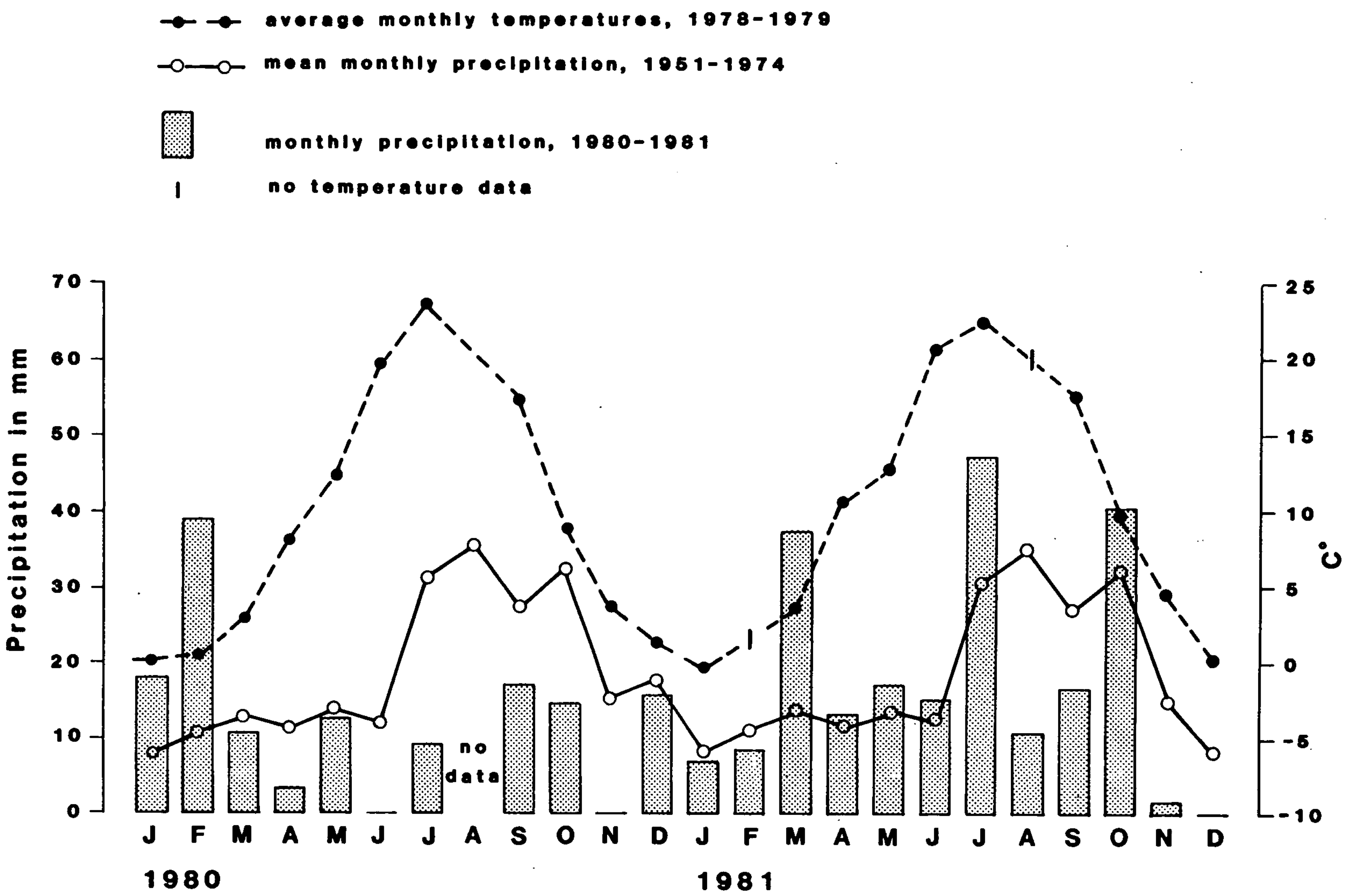

Figure 2.9 Average Monthly Temperature Chart, 1980-1981

growth of various spring and summer annuals to reproductive maturity. Conditions were particularly favorable for pinnate tansy-mustard. The annual plant species probably account for most of the increase in total biomass and seed biomass on the study plots, although perennial grass biomass also contributed to the total biomass. Different climatic conditions may produce different dominant species in the annual plant populations from year to year: there may also be years when all species are few in number or absent.

Compared to the results of our density sampling for early summer Scott (1980a) reports far fewer plants per square meter in spring 1977, after removing herbaceous perennials (Figure 2.10). The dominant annuals of June, 1979 were pinnate tansy-mustard and hiddenflower (Cryptantha crassisepala). Pinnate tansy-mustard did not occur at all during spring, 1977, and hiddenflower was recorded in very low densities in two plots. The dominant annual in spring, 1977 was goosefoot (Chenopodium dessicatum); goosefoot appeared only in very low densities in 1979 (Table 2.8). Our results in 1980 and 1981 were similar to Scott's for 1977.

Because of their ephemeral nature, annual plant species are often ignored as important components of plant communities; however, their sudden occurrence during favorable years may affect many other organisms. At Chaco Canyon, rodents may undergo population increases that are based on annual plant resources (Cully 1984a). For human populations, archeobotanical evidence indicates the importance of annual species such as Chenopodium, Portulaca, Amaranthus, Descurainia, Mentzelia, and others to prehistoric populations (Cully and Clary 1985; Toll 1985b; Toll and Cully 1985). At Chaco Canyon, annuals like pinnate tansy-mustard that do well in fine clay soils, when winter and spring moisture is available, could have been efficiently harvested along the floodplain in productive years because of the high densities. Sandier soils characteristic of the uplands around Pueblo Alto and the outwash areas like the mouth of Werito's Rincon may provide another group of annual resources that are available during other years. The highest plant densities of species (with major ethnobotanical importance) that we encountered were on the floodplain and at Werito's Rincon (Table 2.9). Other habitats may have also provided such resources, but would require greater expenditure of energy to harvest because of lower densities.

Habitat Diversity

The relationship between environmental diversity and animal populations has been of interest to ecologists in their attempt to understand the factors which control the composition of biotic communities (Pielou 1974). Whitaker (1972) and Pielou (1974) discuss several different types of diversity. Alpha diversity is applied to small, homogeneous areas, such as plant communities or habitat types, defined by more or less natural boundaries. Beta diversity is the measurement of differences between these small, homogeneous areas. Gamma diversity applies to a large, heterogeneous area, such as a geographic region. Our measurements were of alpha diversity. The results show that the bench habitat has the highest diversity. Rather than suggesting that this would be the best area for

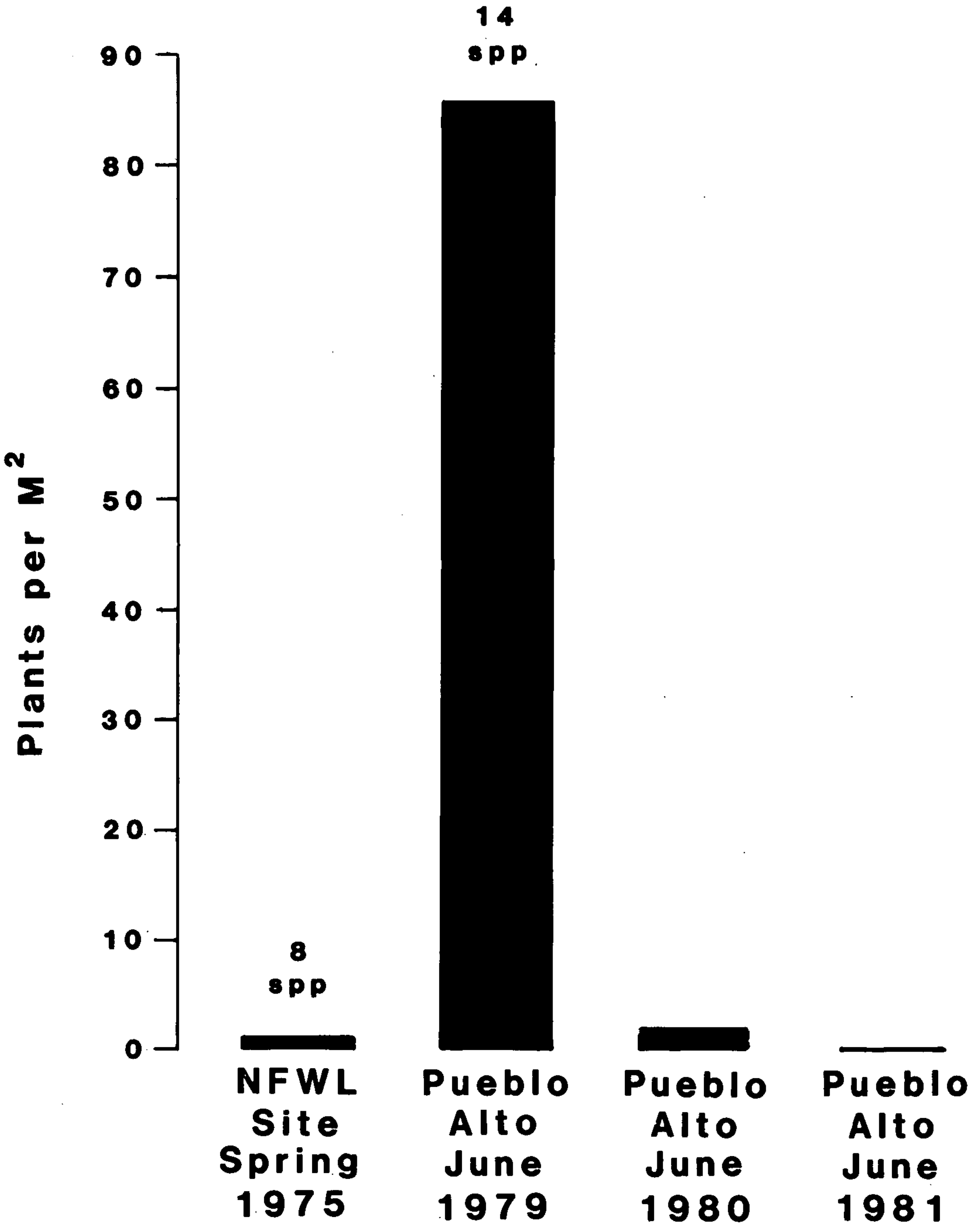

Figure 2.10 Total Annual Densities, NFWL Site, Spring 1975, and Pueblo Alto, June 1979-1981. NWFL Average for Five Study Plots.

Table 2.8 Densitites of Annual Plant Taxa, NFWL Study Area, Spring 1977, and Pueblo Alto Study Area, June, 1979

	LOCATION							
	NFWL Site Spring, 1977					Pueblo Alto		
	Plot I	Plot II	Plot III	Plot IV	Plot V	June, 1979	June, 1980	June 1981
Astragalus spp.						11.9		
Atriplex spp.							0.2	
Chenopodium spp.	0.36	0.01	0.25	5.35	0.05	0.2		
Cryptantha crassisepala	0.06				0.02	18.6		
Descurainia pinnata						41.1		
Ipomopsis spp.			0.01					
Lappula redowski					0.15	0.2		
Mentzelia spp.			0.01	0.12	0.04	0.5	1.5	
Phacelia spp.						3.7		
Plantago purshii	0.72				0.01	3.5		0.1
Salsola spp.					0.02	0.3		
Senecio spp.						2.3		
Streptanthella longirostris						0.7		
Townsendia spp.						1.4	0.6	
Lupinus pursillus				0.03				
Other*						0.7	0.1	
Unidentified						0.9		
Total Density	1.14	0.01	0.27	5.5	0.29	86.0	2.4	0.1

Table 2.9 Annual Plant Species of Major Ethnobotanic Importance and Locations where They Occurred in Highest Densities, June, 1979

	Bench	Floodplain	Pueblo Alto	Werito's Rincon
Chenopodium spp.		+		
Cryptantha crassisepala		+		
Descurainia pinnata		+		
Plantago purshii				+
Portulaca spp.		+		
Mentzelia spp.				+

foraging because of the great number of different plant species available to consumer organisms, we suggest that the low total cover and biomass production make this an area that would support low numbers of animals. Cully (1984a) found the lowest populations of rodents in this habitat over a two-year period. We suggest that high alpha diversity is a poor predictor of consumer populations. On the contrary, in an area where abundant plant resources are found, low alpha diversity for either perennials or annuals may indicate an excellent foraging site where energy expended in harvesting yields the greatest reward. Depending on the consumer groups and the distance the consumers are able to travel to find food, beta and perhaps even gamma diversity may be more meaningful than alpha diversity. As suggested by Cully (1984a) and Toll and Cully (1985), beta diversity may be of significance to dispersal of rodent populations. Beta and perhaps gamma diversity are important variables underlying the movements of prehistoric hunting and gathering populations.

Summary

We measured perennial plant cover in five habitats in Chaco Canyon and found that the highest cover occurred in the wash where rubber rabbitbrush, tamarisk, and coyote willow were the dominant species. At the time the measurements were made, cover grasses were uncommon, probably as a result of flooding that had scoured the wash the previous winter. Species diversity in the wash was intermediate between the other habitats. Annuals were not sampled in this habitat. The two floodplain sites, Casa Chiquita and Pueblo Bonito, were dominated by black greasewood and fourwing saltbush, but they differed in the relative abundance of the two species. Pueblo Bonito had higher cover than Casa Chiquita and both had low species diversity.

Annual plant species density, diversity, and biomass were high on the floodplain sites during 1979 but low during the other two years. This habitat produces potentially valuable food resources during wet years. The Bench and Pinyon-Juniper habitats were most similar in the discriminant function analysis of perennial vegetation. Both habitats had low cover and very high perennial species diversity. Annual plants on the Bench had the lowest production measured during 1979, when the floodplain sites were producing their peak. At the pinyon-juniper site annual plants were not measured, but the pattern for annual plants was probably similar to that for the bench.

Annual plant density at Pueblo Alto and Werito's Rincon was high during 1979. The greatest biomass at Pueblo Alto was measured in 1980, the year following the wet winter-spring of 1978-1979. This apparently reflects the development of grasses which responded to the wet period more slowly than annual plants. Thus, while the floodplain habitats are the most productive during exceptionally wet years, the upland habitats may provide better foraging sites during other years.

The major conclusion to be drawn from this study is that both annual and perennial plant species vary between habitats and that resources may be available during different years in different habitats. The second conclusion is that those habitats with the highest alpha diversity may be the poorest in terms of flood production, and that the variety of species present is accompanied by low biomass.

Acknowledgments

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References Cited

Balch, Paul L.
1949 Balch to Superintendent, 30 June 1949, Memorandum on file, Chaco Culture National Historical Park, New Mexico.

1950 Balch to Benham, 21 February 1950. Letter on file, Chaco Culture National Historical Park, New Mexico.

Brugge, David
1980 A History of the Chaco Navajos. Reports of the Chaco Center no. 4. Division of Cultural Research, National Park Service, Albuquerque.

Canfield, R.
1941 Application of the Line Interception Method in Sampling Range Vegetation. Journal of Forestry 39:388-394.

Chaco Canyon National Monument
1949 Chaco Canyon National Monument Report for the Fiscal Year. Ms. on file, Chaco Culture National Historical Park, New Mexico.

1950 Monument Report for the Fiscal Year. Ms. on file, Chaco Culture National Historical Park, New Mexico.

Cully, Anne C.
1984 Prehistoric Subsistence and Environment at Chaco Canyon: Evidence from Pollen Analysis. Ms. on file, Division of Cultural Research, National Park Service, Albuquerque.

Cully, Anne C., and Karen H. Clary
1985 Pollen Evidence of Subsistence Practices in the NMAP Study Area. In Economy and Interaction on the Lower Chaco River, edited by Patrick C. Hogan and Joseph C. Winter, pp. 351-365. Office of Contract Archeology, University of New Mexico, Albuquerque.

Cully, Jack F., Jr.
1984a Diversity, Stability, and the Deermouse: Implications for the Vegetative Diversity Model. In Recent Research on Chaco Prehistory, edited by W. James Judge and John D. Schelberg, pp. 213-224. Reports of the Chaco Center no. 8, National Park Service, Albuquerque.

1984b A Multivariate Analysis of Niche Relationships Within a Nocturnal Rodent Community in Northwestern New Mexico. Unpublished Ph. D. Dissertation, Biology Department, University of New Mexico. Albuquerque.

Dixon, W. J. (editor)
1981 BMDP Statistical Software, 1981. University of California Press, Berkeley, Los Angeles.

Donart, G. B., D. D. Sylvester, and W. C. Hickey
1978 Potential Natural Vegetation, New Mexico. United States Department of Agriculture, Soil Conservation Service, Albuquerque.

Hill, M. O.
1973 Diversity and Evenness: A Unifying Notation and its Consequences. Ecology 54(2):427-432.

Jackson, W. H.
1878 Ruins of the Chaco Canyon, Examined in 1877. In Survey of the Territories Embracing Colorado and Parts of Adjacent Territories, by F.V. Hayden, pp. 411-450. Tenth Annual Bulletin of the United States Geologic and Geographic Survey for the Year 1876.

Jones, Kirkland
1972 Ecology of Chaco Canyon. Ms. on file, Division of Cultural Research, University of New Mexico, Albuquerque.

Judd, Neil M.
1954 The Material Culture of Pueblo Bonito. Smithsonian Miscellaneous Collections vol. 24. Smithsonian Institution, Washington.

Keefe, Sylvester Ju.
1950 Project Completion Report, Soil and Moisture Conservation, 6 October 1950. Ms. on file, Chaco Culture National Historic Park, New Mexico.

Kelley, Edmund, and Loren D. Potter
1974 Preliminary Vegetation Type Map of Chaco Canyon. Ms. on file, Division of Cultural Research, National Park Service, University of New Mexico, Albuquerque.

Peet, Robert K.
1974 The Measurement of Species Diversity. Annual Review of Ecology and Systematics 5:285-308.

Pielou, E.C.
1974 Population and Community Ecology: Principles and Methods. Gordon and Breach, Science Publishers, Inc., New York.

Potter, Loren D.
1974 Ecological Survey of Chaco Canyon. Ms. on file, Division of Cultural Research, National Park Service, University of New Mexico, Albuquerque.

Scott, Norman J., Jr.
1980a The Ecology of Seeds and Their Predators on Three Arid Sites in Arizona and New Mexico: Ephemeral Plant Populations. National Fish and Wildlife Laboratory, Museum of Southwestern Biology, University of New Mexico, Albuquerque.

1980b *The Ecology of Seeds and Their Predators on Three Arid Sites in Arizona and New Mexico: Perennial Plant Coverage*. United States Fish and Wildlife Laboratory, Museum of Southwestern Biology, University of New Mexico, Albuquerque.

Scott, Norman J., Jr., and Jean M. Duke
1980 *The Ecology of Seeds and Their Predators on Three Arid Sites in Arizona and New Mexico: Phenology of the Perennial Plants*. National Fish and Wildlife Laboratory, Museum of Southwestern Biology, University of New Mexico, Albuquerque.

Shannon, C. E., and W. Weaver
1949 *The Mathematical Theory of Communication*. University of Illinois Press, Urbana.

Shreve, Forrest
1942 The Desert Vegetation of North America. *The Botanical Review* 8 (4):195-246.

Simpson, E. H.
1949 Measurment of Diversity. *Nature* 163:688.

Simpson, James H., Lt.
1964 Navajo Expedition: *Journal of a Military Reconnaissance from Santa Fe, New Mexico to the Navaho Country, Made in 1849*. Edited by Frank NcNitt. University of Oklahoma Press, Norman.

Toll, Mollie S.
1985a Plant Utilization at Pueblo Alto, a Chacoan Town Site: Flotation and Macrobotanical Analysis. Ms. on file, Division of Cultural Research, National Park Service, University of New Mexico, Albuquerque.

1985b Changing Patterns of Plant Utilization for Food and Fuel: Evidence from Flotation and Macrobotanical Remains. In *Economy and Interaction on the Lower Chaco River*, edited by Patrick C. Hogan and Joseph C. Winter, pp. 331-350. Office of Contract Archeology, University of New Mexico, Albuquerque.

Toll, Mollie S., and Anne C. Cully
1985 Archaic Subsistence in the Four Corners Area: Evidence for an Hypothesized Seasonal Round. In *Economy and Interaction Along the Lower Chaco River*, edited by Patrick Hogan and Joseph C. Winter. pp. 385-391. Office of Contract Archeology, University of New Mexico, Albuquerque.

Tuan, Yi-Fu, Cyril E. Everard, Jerold G. Widdison, and Ivan Bennett
1973 *The Climate of New Mexico*. New Mexico State Planning Office, Santa Fe.

Whitaker, R. H.
1972 Evolution and Measurement of Species Diversity. Taxon 21:213-237.

Chapter Three

Experimental Corn Plots in Chaco Canyon:

The Life and Hard Times of *Zea mays* L.

by

H. Wolcott Toll
Mollie S. Toll
Marcia L. Newren
William B. Gillespie

> "With plenty of rain and no wind, worms, or rats to destroy our crops, and no weeds to choke them, we would never need to work so hard."
>
> Don Talayesva, Sun Chief
> (Simmons 1942:231)

Even among those who have grown accustomed to the idea that the Anasazi produced enough food to sustain substantial populations for hundreds of years, and did so under very difficult agricultural conditions, Chaco Canyon seems to be an extreme case. There is an archeological tradition of sorts for setting out to try growing corn under such conditions, and this study is in that tradition. In the course of the effort we gained some practical knowledge about farming in Chaco and the results provide graphic illustration of problems that attend that pursuit. These experiments were designed to address a number of questions:

1) How, in fact, does corn fare in the minimal precipitation conditions of Chaco? This question is of heightened interest when it is realized that normal annual moisture at Chaco (1951-1974; mean=8.48 in. Inches are used here because that is the unit used by the National Weather Service) is less moisture than in a year of drought at Mesa Verde, such as 1934 (10.19 in) that occasioned a crop failure in the long-lived Mesa Verde experimental plot (Franke and Watson 1936:23). Hopi country, as well, receives substantially more moisture than does Chaco, with an annual mean of around 11 in. (Hack 1942). Thus, both Chaco and the Hopi are below the standard accepted minimum of 12 in. per annum for dry farming.

2) How do the corn growing techniques proposed for the topographically and perhaps socially divergent north and south sides of the canyon compare in success? Vivian (1970, 1974) and others suggest that the inhabitants of the large sites on the north side of the canyon practiced intensified irrigation agriculture using the extensive slickrock catchments on that side of the canyon. On the south side, the presence of more dunes and less bare rock may have been better suited to agriculture on a more individual scale, which, some say, corresponds to the smaller sites generally in evidence on the south.

3) Related to and stemming from (2), have the soils in the intensively cultivated north side fields been exhausted and/or is the high clay content and high alkalinity of the soils in the main canyon bottom prohibitive to corn agriculture (the "black alkali" of Judd [1954:60])?

4) Are other potential farming locations capable of producing substantial crops?

Nine locations were planted with Hopi corn during 1977, 1978, and 1979. Beans and gourds were planted in some of these and other locations in 1977 with little success. In subsequent years only corn was planted. While these plots were observed and tended, it should be clearly recognized that they probably did not receive the full attention that they would have were they our sole source of subsistence. Further, we are the first to admit that we are anything but seasoned Hopi farmers. Nonetheless, the plots received attention at least equal to that described for other such experiments (see Appendix). Field size and preparation increased from year to year, as techniques were refined. Our procedures and measurements do not approach the control of a laboratory experiment, but was Anasazi corn ever grown in a laboratory?

Plot Locations

The plots used were located in several topographic situations around the canyon (see Figure 3.1); summary data on soil, locations, and wild vegetation association may be found in Table 3.1. Only one of these locations was used in two different years.

Plot 1, 1977. Two hills were placed in a sand-filled depression in the bedrock between Pueblo Alto and Pueblo Bonito. An Anasazi retaining wall is present on the downslope side of the sandy area. The excavator of both this feature and an associated stone circle suggested that this was an artificially filled garden plot (29SJ 1976, Windes [1978:69-72, 104-105]). Not included in these tabulations is a plot briefly in existence in 1978 located on some dunes on the bench just below Plot 1. The area planted is in the vicinity of several archeological features including Navajo habitations, Anasazi roads and stairways, and some very large retaining walls of unknown function. In addition, heavy growth of Ephedra on the dunes and in depressions suggest unusual growing conditions. While corn germinated in the plot, it was very short-lived. Difficulty in watering, brevity of survival, and lack of documentation preclude more than this mention.

Plot 2, 1977. This plot is located within the Chetro Ketl Fields, an area proposed to have been gridded by earth berms to form a "waffle garden" or a system of bordered gardens (Loose and Lyons 1976; Vivian 1974). It has been suggested that the soil here will no longer support crops (Judd 1954:60; Love 1980:65); indeed, modern wild vegetation is stunted and sparse.

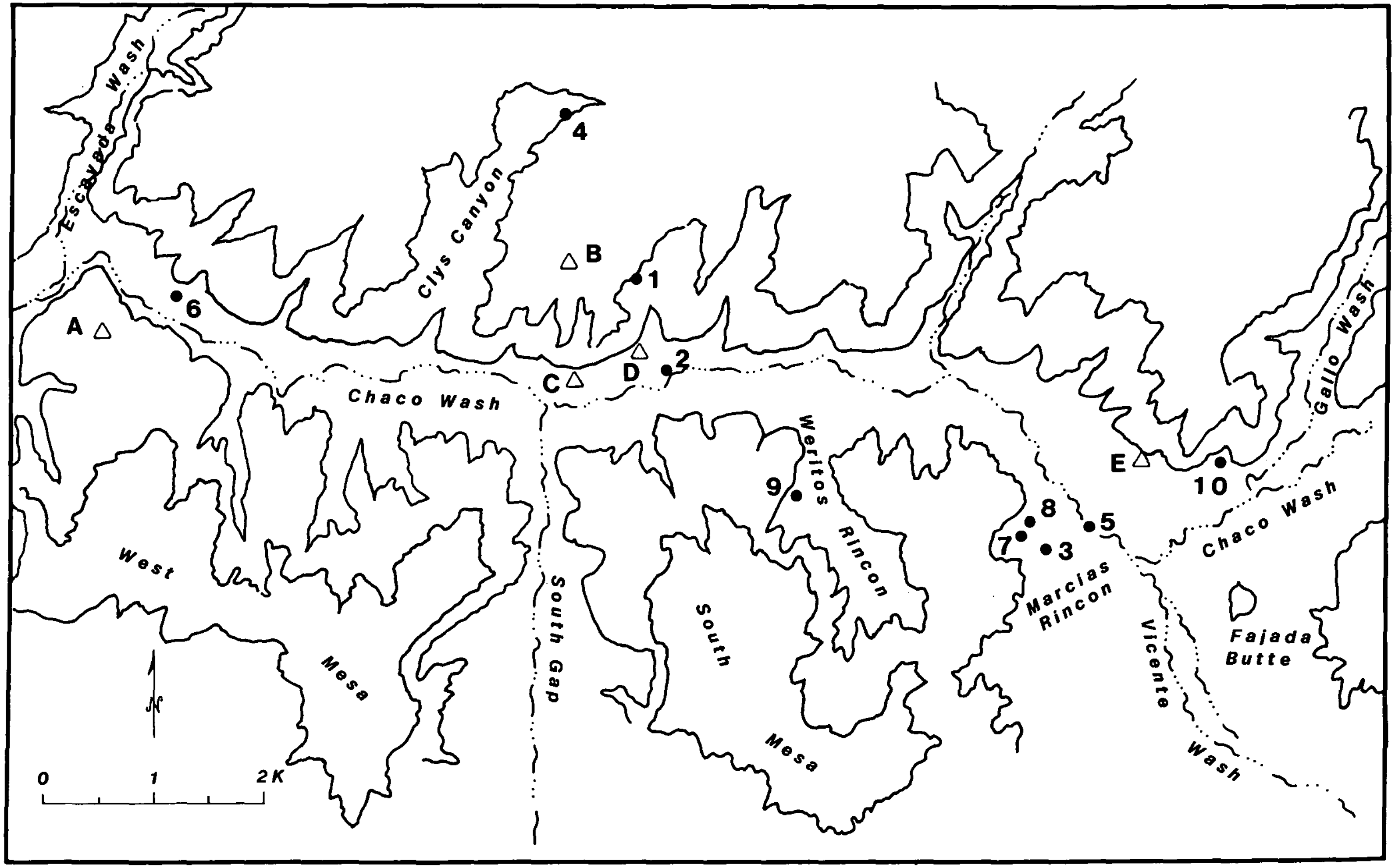


Figure 3.1 Map of Chaco Canyon, northwestern New Mexico, showing selected large sites and the locations of experimental corn plots. Large sites (triangles) shown are: A Peñasco Blanco; B Pueblo Alto; C Pueblo Bonito; D Chetro Ketl; E Una Vida. Corn plots (solid dots) are: 1-5 1977 plots; 6 Peñasco Blanco Plot; 7 Dune Side Plot; 8 Dune Toe Plot; 9 Werito's Rincon Plot; 10 residence area garden.

Table 3.1 Chaco Canyon Corn Plot Locations

Plot	Location	Soil	Wild Vegetation	Corn Hills
1977 PLOTS				
Plot 1	Canyon bench between Pueblo Bonito and Pueblo Alto	Sand--possibly humanly deposited behind Anasazi retaining wall	*Atriplex*, *Sporobolus*, *Oryzopsis* (*Hilaria*, *Bouteloua*, *Artemesia*)	2
Plot 2	Chetro Ketl field	"Black Alkali"--sand and clay	sparse and small: *Sarcobatus*, *Atriplex*, *Sporobolus*	8
Plot 3	Marcia's Rincon (large cliff-bordered erosion feature)	Sand and clay--alluvium below talus	*Atriplex*, *Salsola*, *Oryzopsis*, *Sporobolus*, *Rumex*	8
Plot 4	Mesa Top N of Pueblo Alto	Aeolian sand	*Hilaria*, *Bouteloua*, *Atriplex*, *Erigonum*	8
Plot 5	Chaco Wash near Visitor's Center	Alluvial clay and sand; alkaline	Riparian, woody: *Salix*, *Populus*, *Tamarix*, (*Chrysothamnus*, *Sarcobatus*, *Agropyron*)	8
1978 PLOTS				
Dune Toe (8)	Marcia's Rincon	Dune sand, some alluvium	*Atriples*, *Artemesia*, *Sarcobatus*	16
Dune Side (7)	Marcia's Rincon	Dune sand, some alluvium	*Atriplex*, *Oryzopsis*, *Sporobolus* (*Rumex*, *Mentzelia*)	16
Peñasco Blanco (6)	Canyon floor, north side	Sand, some clayey alluvium	*Sarcobatus*, *Atriplex*, *Oryzopsis*, *Sporobolus*	16
1979 PLOTS				
Peñasco Blanco (6)	(above)			32
Werito's Rincon (9)	north-facing	Dune sand, very sandy alluvium	*Atriplex*, *Descurainia* *Cryptantha*, *Bromus* (*Oryzopsis*, *Sporobolus*)	28

Plot 3, 1977. Corn and beans were planted in Marcia's Rincon across the Chaco Wash from the site of Una Vida. The plot was located adjacent to several small sites excavated by the Chaco Project; occupation of the rincon spans that of the canyon in general (Basketmaker III through Pueblo III). The soil type was the sandy alluvium below the talus, a type common on the south side drainages to the Chaco.

Plot 4, 1977. This plot was located in the mildly alluviated bottom of a shallow drainage on the sandy mesa top north of old Pueblo Alto; in addition to corn, this plot contained two bean plants that grew mature pods.

Plot 5, 1977. This field was placed in the main Chaco Wash arroyo between the Visitor Center and Marcia's Rincon, below the bridge across the wash. Located above the main streamcourse on a low alluvial terrace, this plot was an attempt to utilize the more available ground water of the wash.

While many soil-related questions remained relevant, the focus of the 1978 plantings was a comparison of the potential of dune farming on the south side of the canyon with that of irrigation farming on the north side. Plot sizes were increased and the number of plots was reduced to three. Two plots were placed in Marcia's Rincon, but this time to the north of the excavated sites on a large dune stabilized by vegetation. Both plots were placed near the bottom of the dune on the premise that precipitation falling on the highly permeable dune quickly infiltrates to subsurface sediments where it is not susceptible to evaporation (Hack 1942:25, 32). Percolation of ground water through the dune may bring about a significant concentration of subsurface moisture near the toe of the dune, especially if underlying finer-grained sediments impede continued downward movement of the ground water.

Dune Side (Plot 7), 1978. Placement of the Dune Side plot was such that it could potentially benefit from runoff in a major rincon drainage as well as from the dune moisture (Figure 3.2a). Wild vegetation here was smaller than at the Dune Toe, but abundant *Rumex* at the time of planting was taken to indicate good soil moisture. This plot was placed farther up the side of the dune and had a more southerly exposure than the Dune Toe Plot.

Dune Toe (Plot 8), 1978. In hopes of reducing insolation and evaporation and thus increasing moisture retention, this plot was placed with an eastern exposure (Figure 3.2b). The Dune Toe plot was located on the margin between the pure sand of the dune and the alluvium of the rincon floor.

Peñasco Blanco (Plot 6), 1978 and 1979. As part of his research on water control systems in the late sixties and early seventies, Gwinn Vivian excavated a portion of a canal system on the canyon floor across the canyon from the large site of Peñasco Blanco. A 2 x 4 m "multiple headgate" is proposed to have held and distributed water from a canal into a bordered garden area (Figure 3.3a) (Lagasse et al. 1984:188, 192-202;

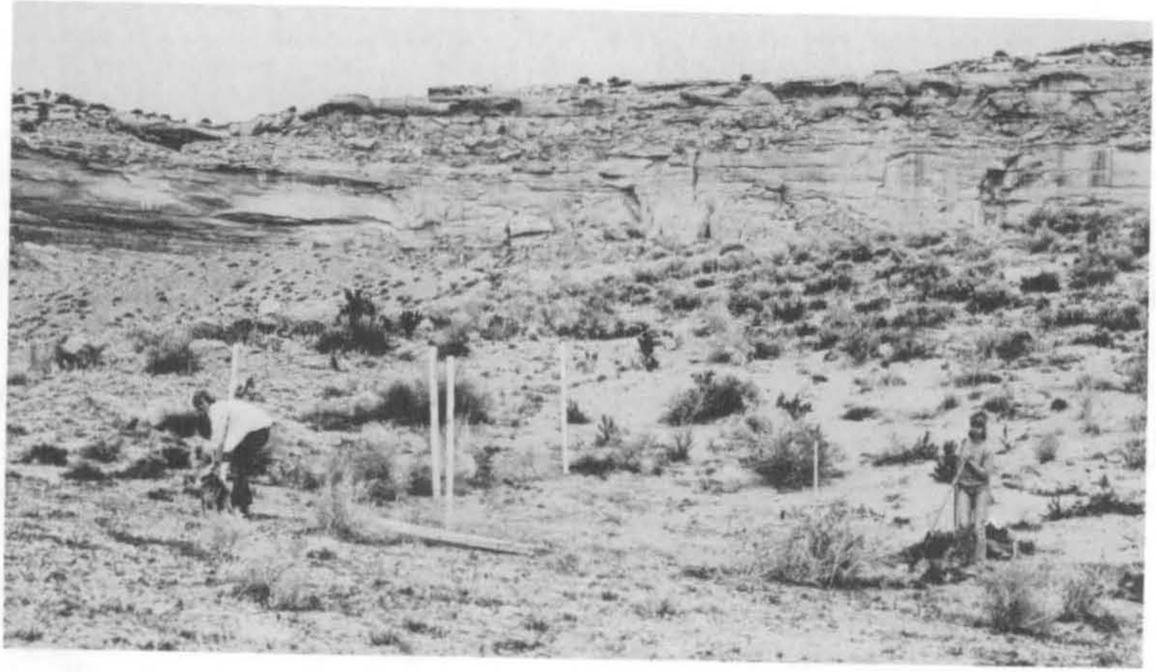
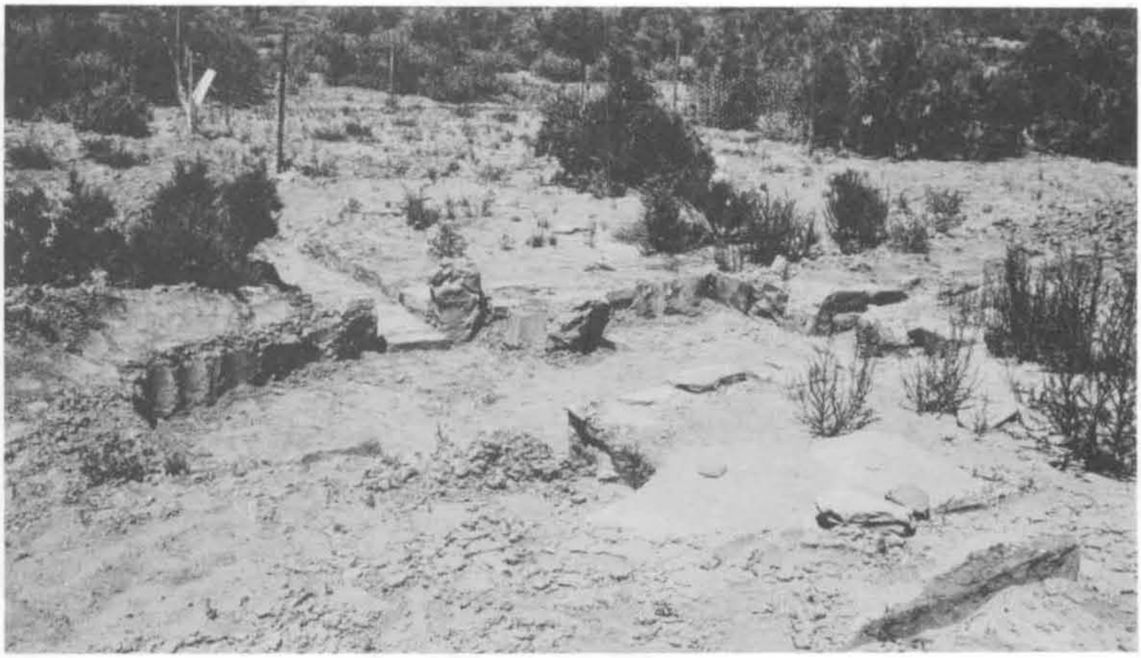


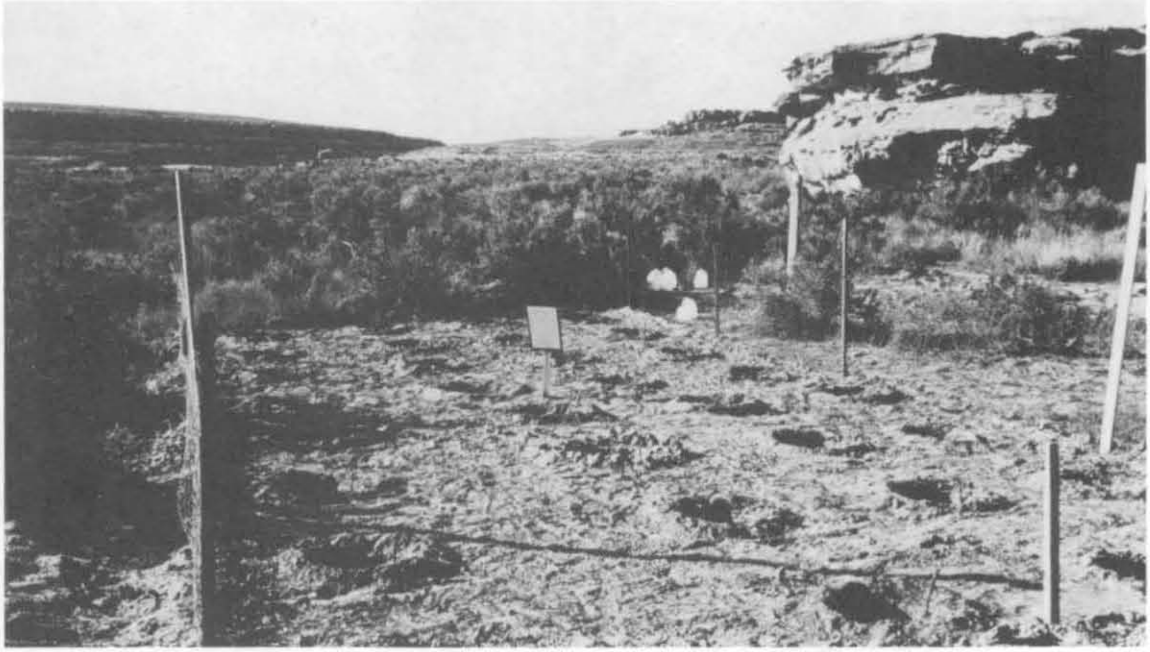
Figure 3.2 a Dune Side plot (#7) showing southerly exposure and placement on the dune's side (looking NW)

Figure 3.2 Marcia's Rincon dune on which plots 7 and 8 were located in 1978

Figure 3.2 b Dune Toe plot (#8) location showing adjacent canyon floor and heavier vegetation (looking NE)



a. Prehistoric headgate with adapted modern supply ditch to the corn plot (looking southwest)



b. Corn plot in 1979; headgate to right; note bedrock exposure to right (looking west); see also cover photo

Figure 3.3 Peñasco Blanco Plot

Vivian 1974:104-108). The feature was re-excavated in order to use the gate as a collecting and holding tank. A prehistoric gate opened toward our corn plot, placed just downslope (Figure 3.3b). A collecting ditch was extended from an original inlet gate for about 30 m to the west below the nearby low slickrock cliff (see cover, Figure 3.3). While this ditch clearly did not replace the proposed prehistoric feeder canal, the scale of our efforts was considerably smaller than the original system. Eventually this adaptation of the prehistoric set-up did capture and distribute some water. Gwinn Vivian suggests that considerable alluviation has raised the level of the canyon floor relative to the headgate, one of the few gates that remains at usable level; however, sufficient slope remains to distribute water to the plot area. This plot was used in successive years, but was expanded from 16 to 32 hills in the second year (1979).

Werito's Rincon (Plot 9), 1979. This plot was an attempt to further improve a dune farming location. A spot with full northern exposure was chosen at the base of a large dune and near the small inner channel of a substantial side drainage (Figure 3.4). Half of the hills were on the dune slope and the other half on the flatter drainage bottom. Within 100 m of the plot there are a hogan site and a possible Navajo check dam.

Procedures

Plot Preparation

In all three years each plot was fenced with chicken wire (1 in mesh). The fence at Werito's Rincon was augumented in some areas with finer mesh due to the high level of rodent activity experienced in dune plots in preceding years. The bottom of the fencing was buried and weighted with dirt, rocks, and timbers. Each plot was cleared of wild vegetation (see Table 3.1). In 1978 the subsurface remains of a large *Sarcobatus* seemed to have inhibited crop growth in one portion of the Dune Toe plot. In 1979 vegetation was cleared more thoroughly, and an additional area (0.5-0.75 m wide) was stripped beyond the fence on all sides.

Planting

In 1977 four plots were planted in mid to late May (Table 3.2). In 1978 and 1979 planting was done in two stages, the first in mid-April, and the second in mid-May; this schedule roughly corresponds with Hopi planting times (Hack 1942:21; Titiev 1938). The hills were spaced 1 to 1.5 m apart each year, except at Werito's Rincon where the hills were 2 m apart. The 1977 plots each contained 8 hills, the 1978 plots 16 hills, and the 1979 plots 28 (Werito's Rincon) and 32 (Peñasco Blanco) hills. In the dunes each hill consisted of a sump 10-15 cm deep with seven or eight kernels of corn placed 20-25 cm deep. In the Peñasco Blanco plot the corn was again planted in multiple seed "hills," but shallow ditching was put in place to deliver irrigation water. In 1977 and 1979 only Hopi blue corn was planted; in 1978 each of the three plots contained a different Hopi variety (see Table 3.3).

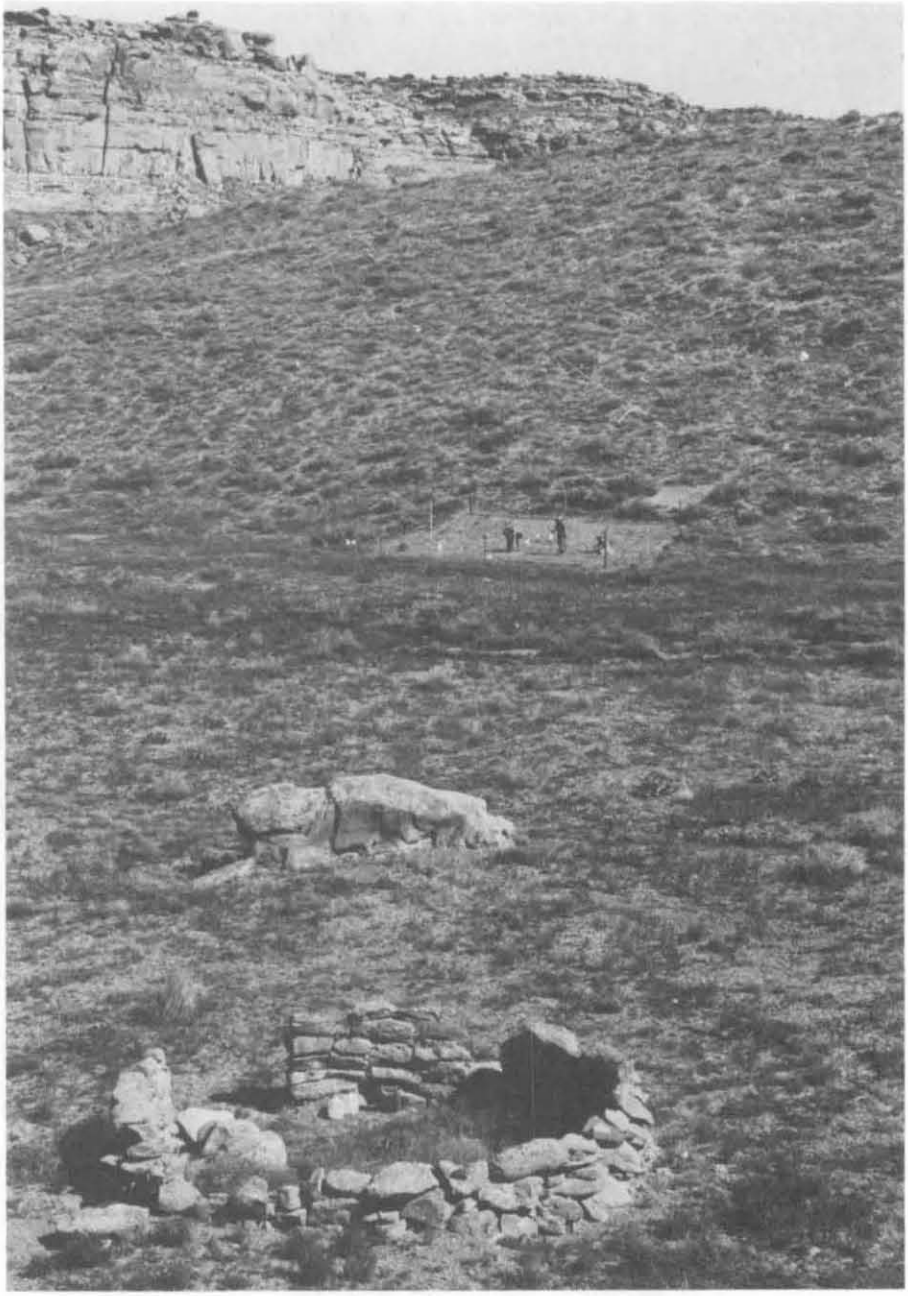


Figure 3.4 Werito's Rincon Plot, showing location at the base of a large stabilized dune, next to drainage bottom; not the hogan in the foreground (looking south)

Table 3.2 1977 Chaco Canyon Experimental Corn Plots, all Planted with Hopi Blue Corn

	PLOT #2 (Chetro Ketl field)			PLOT #3 (Marcia's Rincon)			PLOT #4 (Pueblo Alto)			PLOT #5 (Chaco Wash)		
GERMINATION SUCCESS* (no. sprouted/no. planted)												
Watered at planting (no. of seeds)	21/32 = 65.6%			23/32 = 71.9%			21/32 = 65.6%			16/32 = 50.0%		
Watered from 6/20/77 (no. of seeds)	8/32 = 25.0%			0/32 0%			9/32 = 28.1%			9/32 = 28.1%		
whole plot - no. of seeds	29/64 = 45.3%			23/64 = 35.9%			30/64 = 46.9%			25/64 = 39.1%		
Watered at planting (no. of hills)	4/4 = 100%			4/4 = 100%			4/4 = 100%			4/4 = 100%		
Watered from 6/20/77 (no. of hills)	3/4 = 75%			- -			4/4 = 100%			4/4 = 100%		
Whole plot - no. of hills	7/8 = 87.5%			4/8 = 50%			8/8 = 100%			8/8 = 100%		
VIABLE PERIOD												
Range (of sprouted hills)	31 - 113 days			18 - 30 days			22 - 109 days			26 - 43 days		
	n	$\bar{x}$	s.d.	n	$\bar{x}$	s.d.	n	$\bar{x}$	s.d.	n	$\bar{x}$	s.d.
Watered at planting	4	85	38.19	4	25	6.98	4	93.2	3.15	4	41.5	1.73
Watered from 6/20/77	3	70	24.25	0	-	-	4	53	35.79	4	25	1.54
Whole plot	7	78.6	31.46	4	25	6.98	8	73.1	37.91	8	33.2	8.92
MEAN PLANT HEIGHT (cm)												
Watered at planting	7	29.8	3.58				8	36.2	12.79			
Watered from 6/20/77	8	26.2	3.37				5	39.4	11.71			
Whole plot	15	27.9	3.82	Not measured -			13	37.1	11.98	Not Measured -		
MEAN MAX. SIZE (by hill, in cm)				field burned up						field flooded		
Watered at planting	2	34	4.24				3	47.1	13.31			
Watered from 6/20/77	3	29.6	3.05				2	48.5	10.60			
Whole plot	5	30.6	4.34				5	48.0	10.81			
RANGE IN MAX. SIZE (by hill, in cm)												
Watered at planting	26 - 37						23 - 63					
Watered from 6/20/77	23 - 33						23 - 56					

*Plot #1 - none sprouted

Table 3.3 1978 Chaco Canyon Experimental Corn Plots

	Cherry Flour (Peñasco Blanco)			Hopi Blue (Dune Toe)			Kokoma (Dune Side)		
GERMINATION SUCCESS (no. sprouted/no. planted)									
1st planting - no. seeds	31/56 = 55.4%			29/64 = 45.3%			25/56 = 44.6%		
2nd planting - no. seeds	24/56 = 42.8%			18/61 = 29.5%			32/56 = 57.1%		
whole plot - no. seeds	55/112 = 49.1%			47/125 = 37.6%			57/112 = 50.9%		
1st planting - no. hills	8/8 = 100%			6/8 = 75.0%			7/8 = 87.5%		
2nd planting - no. hills	7/8 = 87.5%			4/8 = 50/0%			7/8 = 87.5%		
whole plot - no. hills	15/16 = 93.8%			10/16 = 62.5%			14/16 = 87.5%		
LONGEVITY									
Range (of sprouted hills)	31 - 129 days			41 - 66 days			1 - 75 days		
	n	$\bar{x}$	s.d.	n	$\bar{x}$	s.d.	n	$\bar{x}$	s.d.
1st planting	8	68.4	25.78	6	55.8	9.02	7	27.0	28.32
2nd planting	7	45.4	10.29	4	50.2	6.45	7	30.3	26.25
whole plot	15	57.7	22.76	10	53.6	8.21	14	28.6	26.29
MEAN MAXIMUM SIZE (by hill, in cm)									
1st planting	8	31.2	11.13	6	26.7	5.03	7	13.6	8.41
2nd planting	7	22.2	4.10	4	21.6	3.17	7	14.5	10.93
whole plot	15	27.0	9.52	10	24.6	4.92	14	14.0	9.38
RANGE IN MAXIMUM SIZE (by hill, in cm)									
1st planting	20.5 - 52.0			21.5 - 35.5 (+0)			4.0 - 28.0 (+0)		
2nd planting	18.0 - 30.0 (+0)			18.0 - 25.5 (+0)			2.5 - 35.5 (+0)		

Watering

Each plot was to have both watered and unwatered hills. In the first two years this plan was followed at first but later abandoned when it became clear that the choice was between watering and complete loss; watering of all surviving plants was begun on June 20, 1977, and July 9, 1978. The dosage was approximately one liter per hill per watering, though this was increased in later 1978. Plots were watered 8 to 12 times per month in 1977 and 6 to 7 times per month in 1978. Watering procedures were altered somewhat in 1979, based on the observations that the quantities provided in the preceding years were apparently insufficient to make a difference in success. The preferred water dosage in 1979 was two liters per hill, and that amount was delivered in the absence of significant precipitation. Due to the necessity of carrying water some distance to the plots, in some instances it was only possible to use one liter.

Except for one row (4 hills) at Peñasco Blanco, each hill received a 2-liter watering at the time of planting in 1979. Thereafter two rows were watered twice a week throughout. Two rows were watered on weekends for May and June, and two rows were watered on weekends until the summer rains began in early August; in the ensuing discussion these hills are treated together as having been watered once a week. While the 1978 plots are thus evenly divided between watered and unwatered hills, the 1979 plots contained 4 (Werito's Rincon) and 8 (Penasco Blanco) unwatered hills, 16 hills watered once a week, and 8 hills watered twice a week.

Weeding

Weeds were removed occasionally in 1977 and 1978, and more rigorously in 1979. The historically introduced *Salsola kali* was the most aggressive weed, but natives also appeared. When the Peñasco Blanco plot was recleared in spring, 1979, densities of *Descurainia* and *Cryptantha* were two to three times the densities of those taxa in undisturbed areas outside the plot. The presence of other plants in the 1977 and 1978 plots probably reduced the amount of moisture available to the corn (Hack 1942:33; Litzinger 1976), but it is unlikely that the difference in weeding in 1979 explains the greatly increased yields.

Thinning

Only in 1979 was thinning a necessity (and a difficult task it was after 1977 and 1978). Hills were thinned to a maximum of five plants at Peñasco Blanco beginning on June 14. Attempts to transplant thinned plants to empty hills failed. Less thinning was necessary at Werito's Rincon, but, due to greater plant size, hills were reduced to a maximum of four plants per hill on June 22 and on July 14 to a maximum of three plants per hill.

Recording

Detail and intensity of recording also increased in successive years. The 1977 size data were gathered from dried specimens. In 1978 and 1979 measurements were taken in the field from live plants, with the exception of the cob data that were collected from dried materials. The 1978 and 1979 measurements were made by extending the longest leaf of the largest plant in each hill and measuring to ground level. Hills that either never germinated or dried out were not included in the means given in Figures 3.5–3.9. In addition to size data, temperature ranges and precipitation at the plots themselves were collected in 1979 (rainfall in Chaco is notoriously localized, see below and Table 3.9). Fluctuations in the numbers of plants seen in Figures 3.10–3.14 are attributable to several causes: resprouting of gnawed or thinned plants, perhaps late germinations, and the fact that judgments as to whether or not a plant was alive were required and were not always the same.

Results

Germination

Tables 3.2–3.4 show the percentages of seeds successfully germinating in the various plots. Only the very small planting at Plot 1 failed to show any germination at all. In the other plots the seed germination for whole plots (or perhaps more correctly those sprouting above ground level) runs from 35 to 50%, though the percentage of hills in all plots is considerably higher, usually above 80%. Watering at planting time can be seen to improve the germination rate in the 1977 and 1978 plots (Tables 3.2–3.3); nearly all were watered at planting in 1979. Given the ultimate success of the Werito's Rincon plot, the seed germination percentages (Table 3.4) are low; all are less than the 1979 Peñasco Blanco figures. Both 1979 plots show improved germination rates for the second planting, which is probably attributable to the cumulative effects of the very wet May of that year (Figure 3.20). Better germination performance of the early planting in two of the three 1978 fields can likely be linked to that year's relatively wet winter. The germination rates of all years attest to the hardiness of Hopi corn and its ability to sprout under a wide variety of situations. It is noteworthy that the germination <u>by hill</u> is as good as it is, since this implies that given adequate growing conditions plants will be well distributed around a plot. Each of the three years experienced temperatures of well below freezing in mid to late May, including 17°F (-8^0 C) on May 29, 1977. The late planting in 1977 was thus fortuitous, though we recorded no damage to sprouted plants in 1978 when 24°F (-4^0 C) was reached on May 17 by which time a few sprouts had appeared.

Longevity

Plant survival varied most significantly among the plots in the 1977 experiments. While the rincon plot (# 3) experienced good germination, the plants rapidly succumbed to the sun, even though small sun shelters were erected. The plot in the wash (# 5) survived until July, at which time an inundation of silt from the wash suffocated the plants. The mesa top wash site (# 4) performed the best of any plots in 1977 and 1978, with plants up to 63 cm in height, and tasseling on 3 of 13 plants. The relative success of this plot is of interest because of its proximity to Pueblo Alto. It is generally assumed that water availability on the open

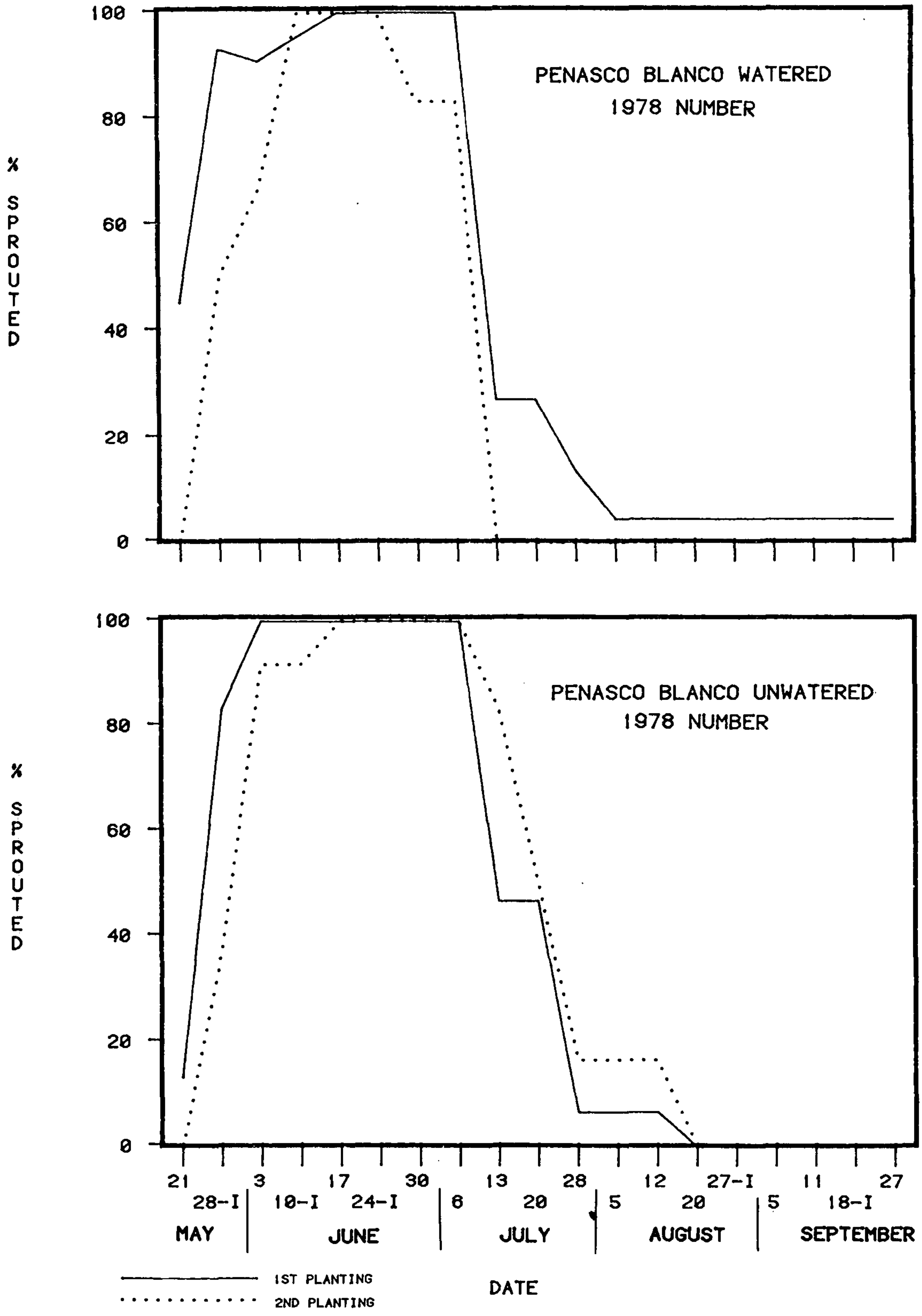


Figure 3.5 Percentage of sprouted plants alive at approximate 1 week intervals at the Peñasco Blanco Plot in 1978. Percentages are based on the following numbers of sprouts: A Watered first planting: 22; watered second: 6. B unwatered first: 15; unwatered second: 12.

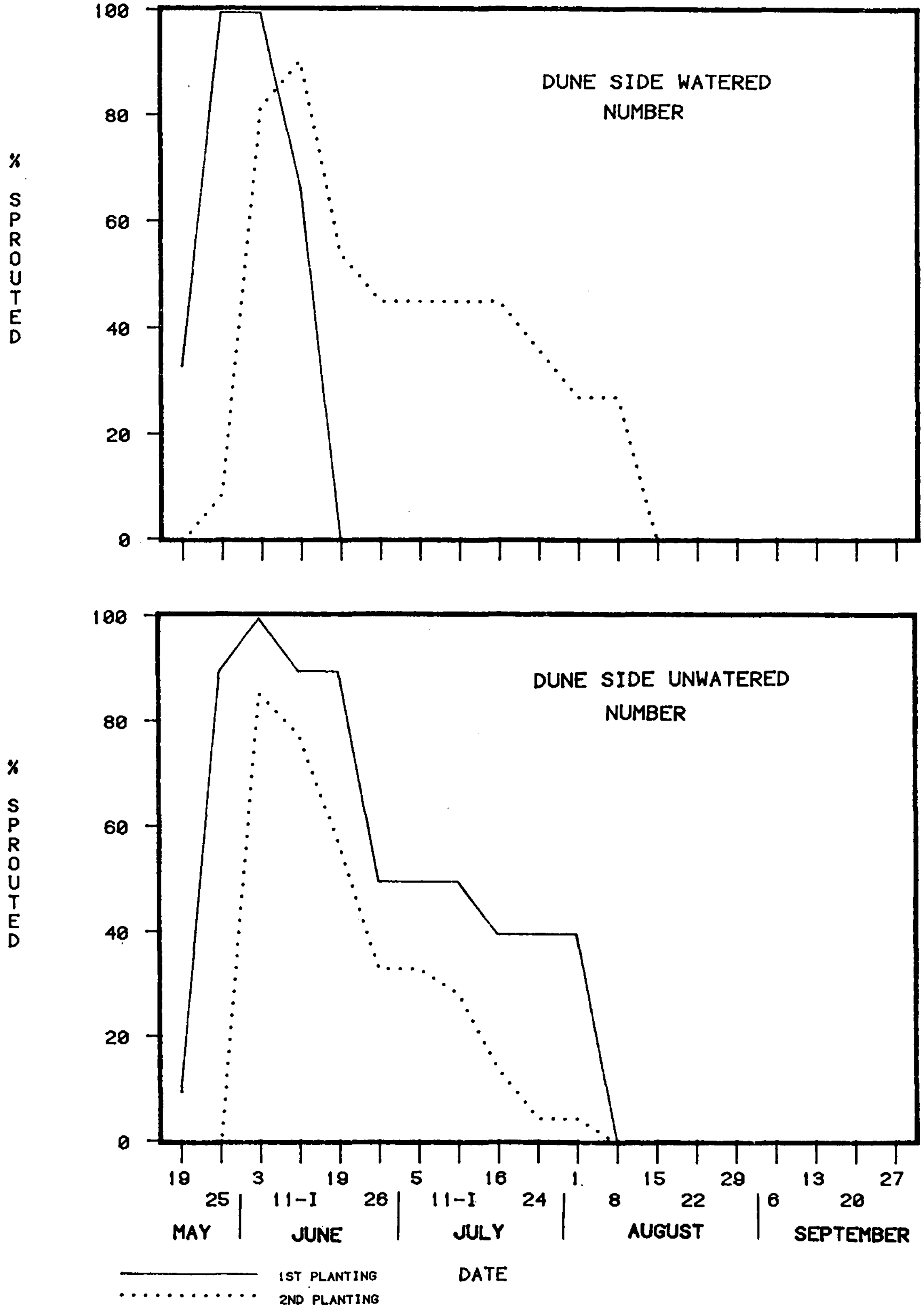


Figure 3.6 Percentage of sprouted plants alive at approximate 1 week intervals at the Dune Side Plot, 1978. Percentages are based on the following numbers of sprouts: A watered first planting: 9; watered second: 11. B unwatered first: 10; unwatered second: 21.

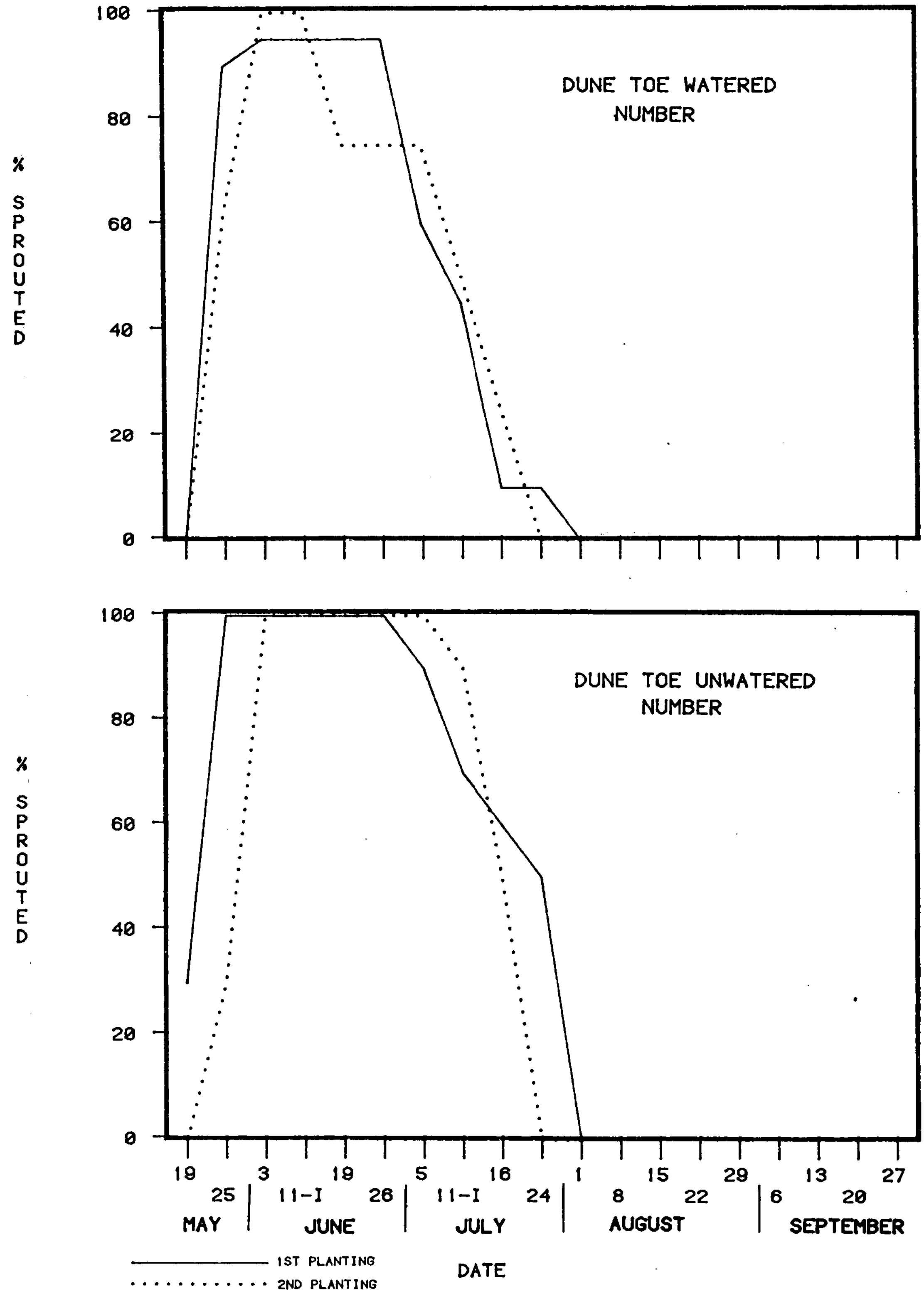


Figure 3.7 Percentages of sprouted plants alive at approximate 1 week intervals at the Dune Toe Plot, 1978. Percentages are based on the following numbers of sprouts: A watered first planting: 20; watered second: 8. B unwatered first and second: 10.

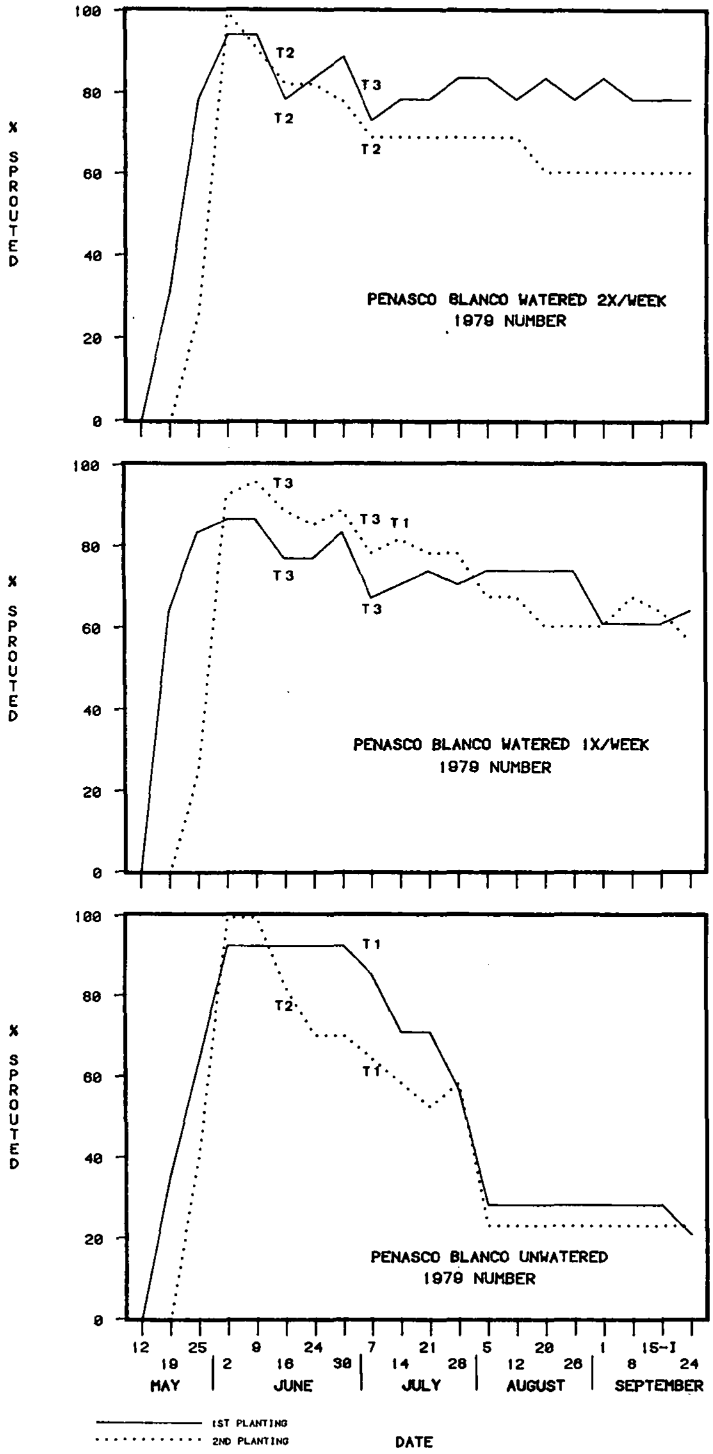


Figure 3.8 Percentages of sprouted plants alive at approximate 1 week intervals at the Peñasco Blanco Plot, 1979; thinning is indicated by a "T" followed by the number of plants removed. Percentages are based on the following numbers of sprouts:
A watered twice weekly first planting: 19; second planting: 23.
B watered once weekly first planting: 31; second planting: 28.
C unwatered first planting: 14; unwatered second planting: 2.

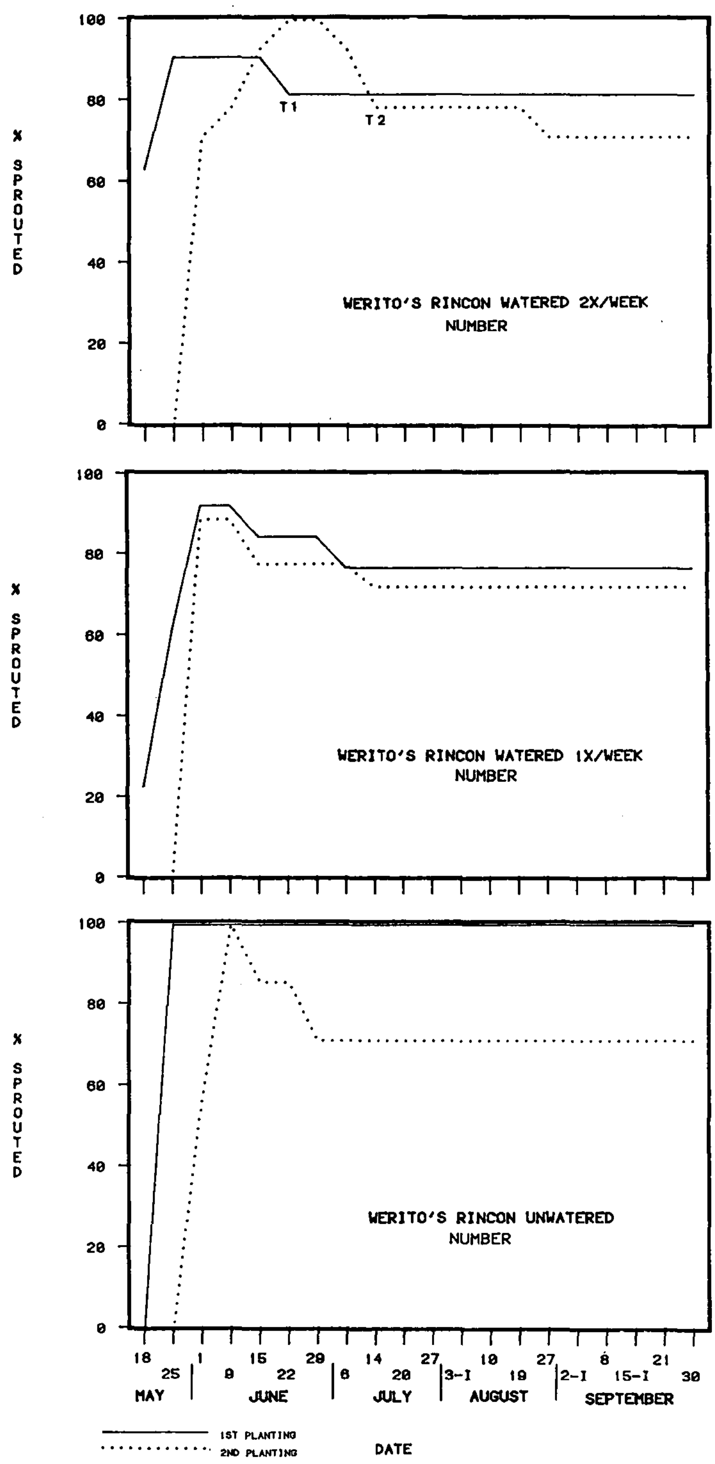


Figure 3.9 Percentages of sprouted plants alive at approximate 1 week intervals at the Werito's Rincon Plot, 1979; thinning is indicated by a "T" followed by the number of plants removed. Percentages are based on the following numbers of sprouts:
A watered twice weekly first planting: 11; second planting: 14.
B watered once weekly first planting: 13; second planting: 18.
C unwatered first planting: 2; second planting: 7.

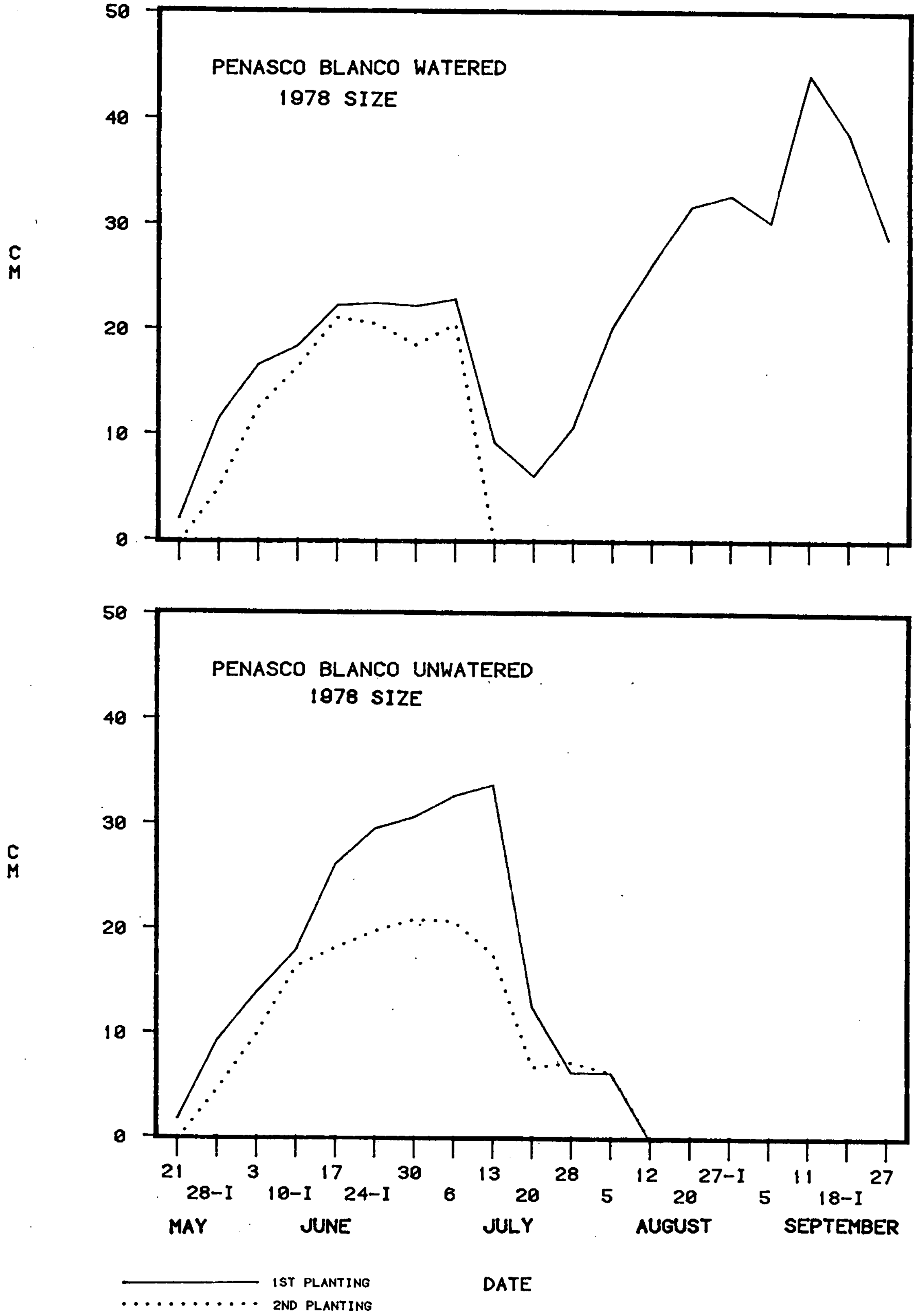


Figure 3.10 Plant size in the Peñasco Blanco Plot 1978, based on the means of the largest plant in each surviving hill, by watering and planting; a watered, b unwatered.

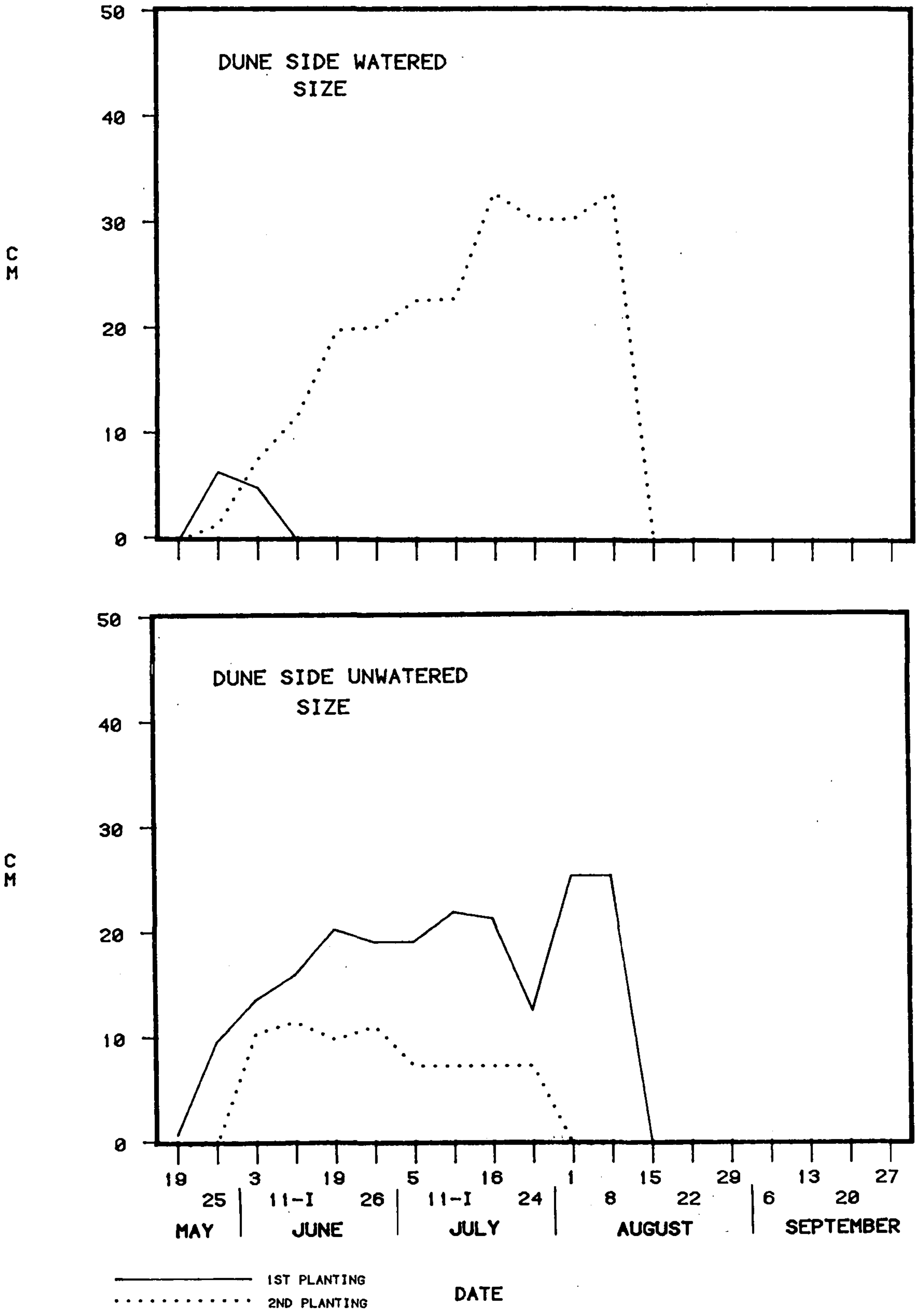


Figure 3.11 Plant size in the Dune Side Plot 1978, based on the means of the largest plant in each surviving hill, by watering and planting; a watered, b unwatered.

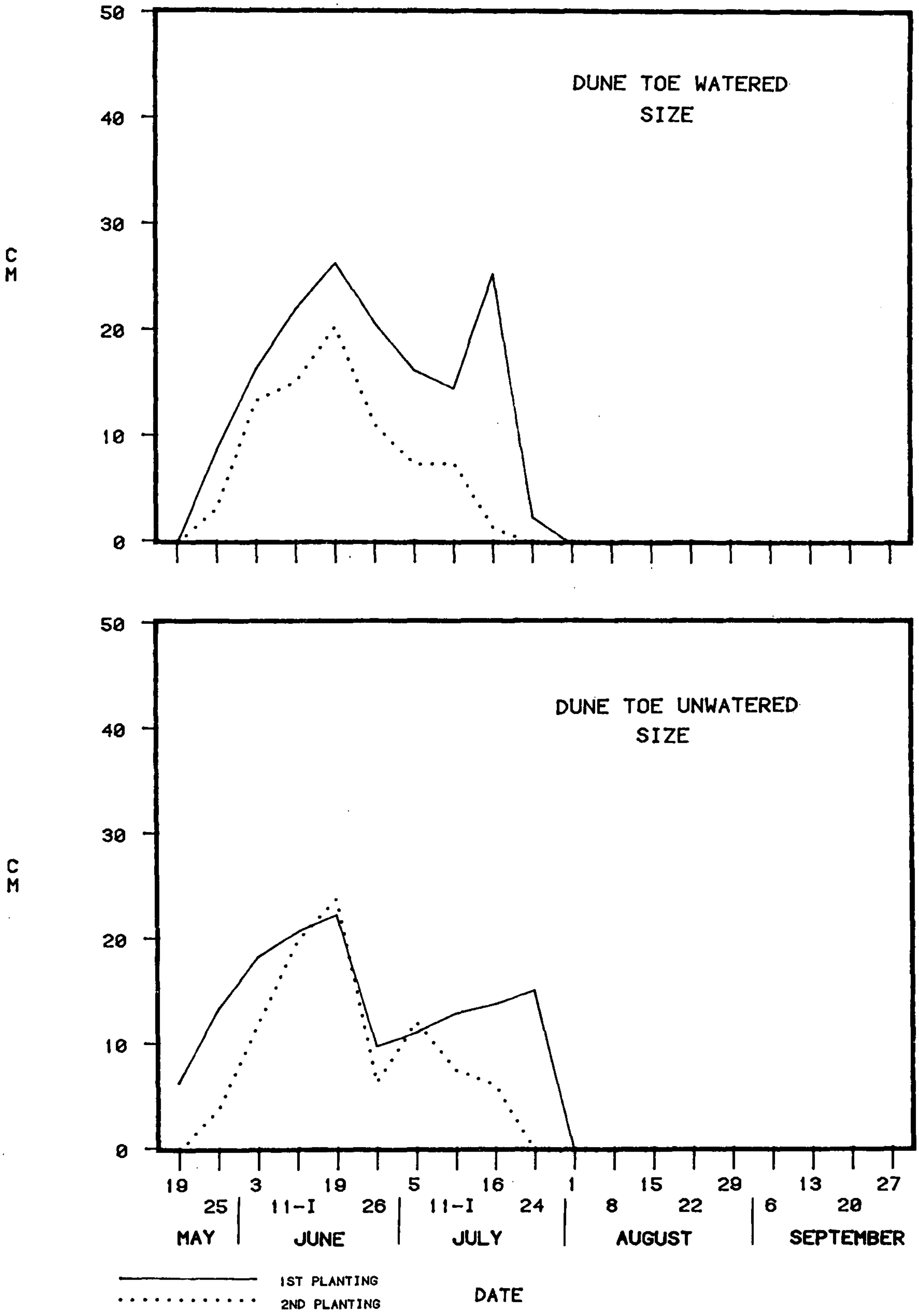


Figure 3.12 Plant size in the Dune Toe Plot 1978, based on the means of the largest plant in each surviving hill, by watering and planting; a watered, b unwatered.

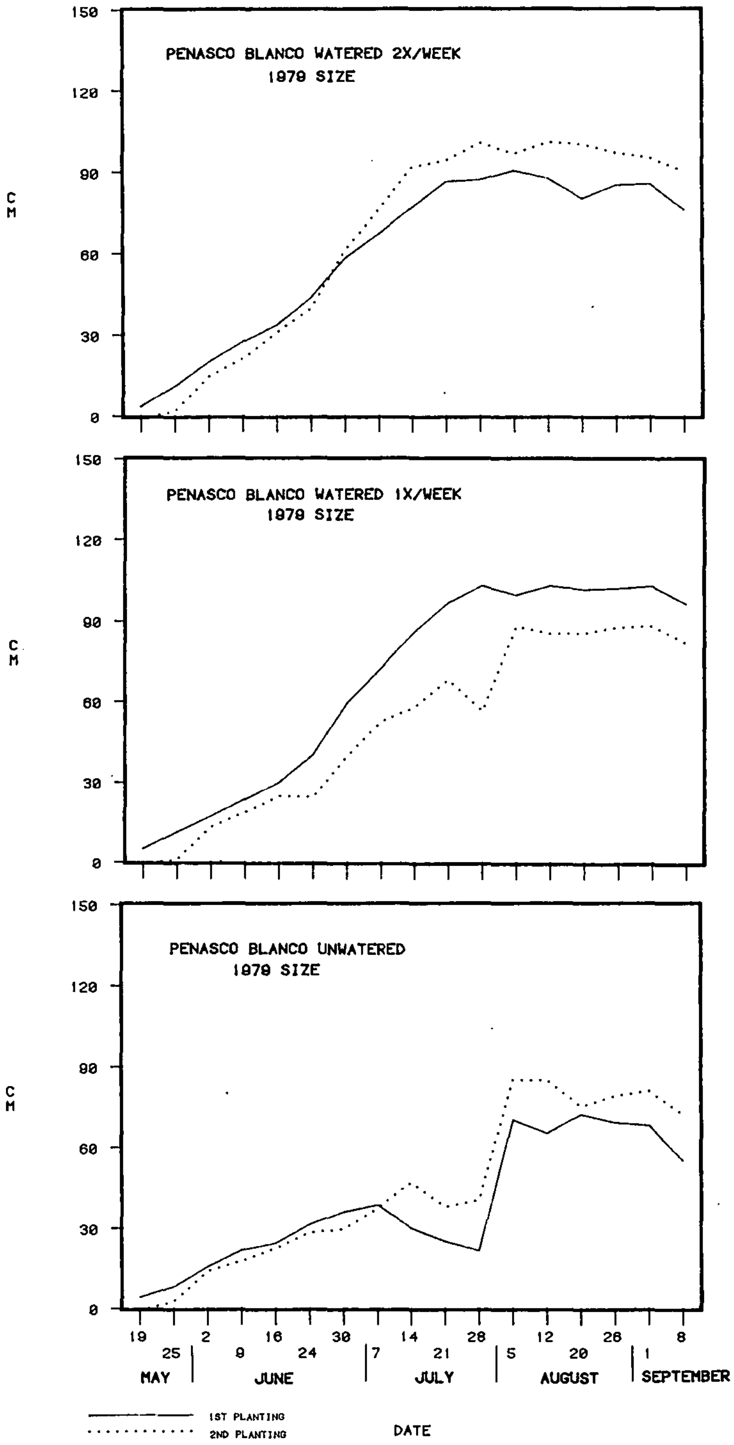


Figure 3.13 Plant size in the Peñasco Blanco Plot 1979, based on the means of the largest plant in each surviving hill, by watering and planting; a watered twice weekly, b watered once weekly, c not watered.

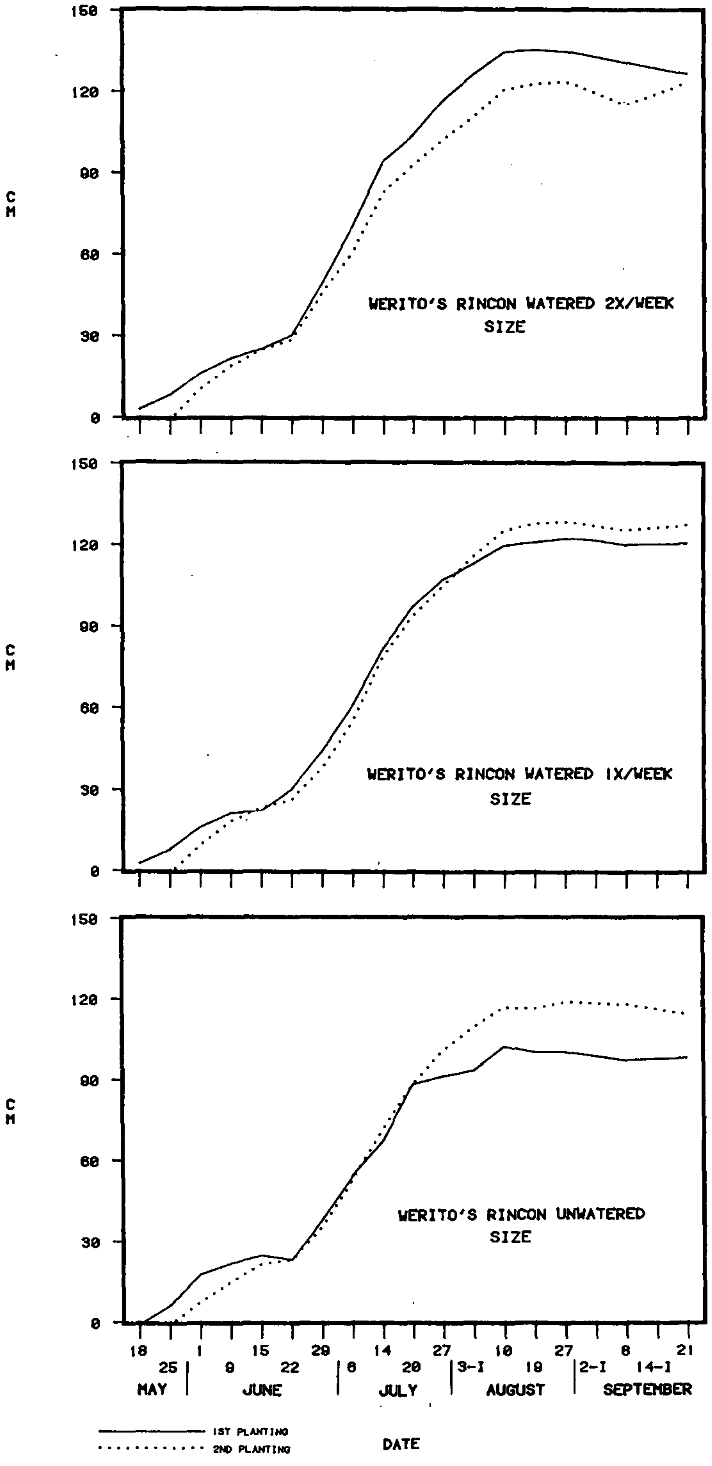


Figure 3.14 Plant size in the Werito's Rincon Plot 1979, based on the means of the largest plant in each surviving hill, by watering and planting; a watered twice weekly, b watered once weekly, c not watered.

Table 3.4 1979 Chaco Canyon Experimental Corn Plot Germination Viability and Plant Size

	Werito's Rincon		Penasco Blanco	
GERMINATION SUCCESS (n sprouted/n planted)	n	%	n	%
1st planting--seeds	26/112	23.2	62/128	48.4
2nd planting--seeds	39/112	34.8	69/128	53.9
maximum water--seeds	25/64	29.0	42/64	65.6
whole plot--seeds	65/224	29.0	131/256	51.2
1st planting--hills	13/14	92.9	15/16	100.0
2nd planting--hills	13/14	92.9	15/16	93.8
maximum water--hills	8/8	100.0	8/8	100.0
whole plot--hills	26/28	92.9	31/32	96.9

	Werito's Rincon					Penasco Blanco				
LONGEVITY PERIOD OF HILLS (DAYS)*	n	x	s.d.	range	C.V.	n	x	s.d.	range	C.V.
1st planting	13	123.7	43.1	11-137	34.8	16	123.4	29.5	60-138	23.9
2nd planting	13	125.7	2.4	119-126	1.9	15	113.2	33.8	35-130	29.9
maximum water	8	131.1	5.6	126-139	4.3	8	133.3	4.1	128-138	3.1
whole plot	26	124.7	23.7	11-139	19.0	31	118.5	31.5	35-138	26.6
Shortest hill removed	25	129.2	5.0	126-137	3.9	30	121.2	27.9	50-138	23.0
MEAN MAXIMUM PLANT SIZE BY HILL										
1st planting	13	118.2	36.4	12-150	30.8	16	87.1	34.1	22-140	39.2
2nd planting	13	127.3	9.1	115-151	7.1	15	77.9	36.0	20-124	46.2
maximum water	8	131.9	9.5	123-150	7.2	8	97.8	17.0	74-124	17.4
whole plot	26	122.8	26.4	12-151	21.5	31	82.6	34.8	20-124	42.1
Smallest hill removed	25	127.2	13.9	87-151	10.9	29	87.0	31.5	22-124	36.3

*plants alive when collected were all counted to 10/1 (collected 9/24-10/1) expanses around Pueblo Alto would have precluded agriculture there, but this result in a low moisture year shows that the area may have some potential. Location of the plot in a small drainage presumably provided somewhat more moisture than was available in the general vicinity. The Chetro Ketl Field location (# 2) was second best in 1977 in terms of both longevity and plant size; one plant formed a small tassel there.

Figures 3.10-3.14 show the percentages of plants alive at given points through the 1978 and 1979 seasons, and Figures 3.5-3.9 show the mean maximum sizes of the plants at the same intervals. The lines in Figures 3.10-3.14 express the survivorship in each plot in terms of the maximum number of plants that germinated in a particular watering regime and planting. Thus, if 20 plants sprouted from the first planting in the watered portion of a plot, and 15 were alive on June 10, the entry for June 10 was 75%; percentages on the same graph for a different planting will be calculated from a different number of sprouts. Decreases caused by thinning in 1979 are marked by "T" followed by the number of plants removed. The observation dates are not perfectly spaced, but they approximate one week intervals. Where possible actual observation dates are used, although, interpolations (marked by I on the x-axis) have been made where intervals of greater than nine days are present; none are of fewer than five days. The value for a given date (Figures 3.5-3.9) is the mean of the maximum height from each hill conforming to a watering-planting set. Note that the y-axis scales for 1978 and 1979 are very different (maxima of 50 cm as opposed to 150 cm); all of the graphs from a given year are similarly calculated. The surges in size in the late July (1979) Peñasco Blanco unwatered plants result from the loss of struggling hills, leaving only larger hills.

The two dune plots of 1978 performed differently, with less growth in the more exposed Dune Side Plot, though two plants survived longer there. As can be seen in Figures 3.12-3.13, most of the plants had expired by about the first of August. Of the 1978 plantings, the Peñasco Blanco plot (# 6) had the longest viability, the largest plants, and the best germination. This was apparently due to fewer rodent and insect pests than in the dune plots, and to better soil moisture. The more favorable moisture conditions are probably attributable to the greater clay content of the soil, since the irrigation system never collected enough water to run during the 1978 growing season. The long survival of the Peñasco Blanco plot was just that: one small plant lived a great deal longer than any of the dune plants and its companions at Peñasco Blanco. This plant, incidently, was in the hill closest to a sprig of evergreen from the Hotevilla Niman ceremony. No tassels formed in 1978; no ears formed in either 1977 or 1978.

While germination rates were very similar in all three years, both survival and size in 1979 were of a completely different order. Plants in both plots survived the entire season, reached full size, tasseled, and bore ears. There was, nonetheless, a substantial difference between the two plots, with health, size, and productivity greater in the dune plot at Werito's Rincon. Plant number and size statistics document this divergence in plot performance (Table 3.4, Figures 3.13-3.14), but there is a definite qualitative difference in appearance as well. This is of some interest, because the Peñasco Blanco plants presumably received more moisture than those at Werito's Rincon since the ditch system provided water on at least three well-spaced dates (May 27, July 1, and August 16). While there are small differences in the results by planting, the two plantings show remarkable convergence and similarity at both plots. Artificial watering was not a critical variable; those hills that were unwatered were more likely to perish, and those that received the maximum water were more consistent and slightly larger.

Crops

Though plant sizes and longevity indicate a difference between the two 1979 plots, the critical test is of course production, and the difference between plots is very marked. The data we have on production are not as complete as they might have been due to severe predation, presumably birds, rodents, and even deer. The problem is much more pronounced at Peñasco Blanco, where a single major assault on September 20 removed many cobs from their plants and severely damaged plants. Kernel loss to animals at Werito's Rincon was also considerable, but less information was jeoparized. Fortunately field counts of cobs on plants had been taken September 8 and could be compared to counts from the lab (Table 3.5). This tabulation shows that nearly all of the ears observed in the field on September 8 at Werito's Rincon are accounted for in the measurements. Because of the depredations at Peñasco Blanco and the high frequency of small and/or immature cobs, the lab representation of cobs is less complete. The most depleted is the watered once weekly group, around which the unprovenienced cobs were found. At the risk of some misplacements, the unprovenienced cobs from Peñasco Blanco are included with those from the hills watered once weekly.

Not only is the number of cobs from Werito's Rincon more than twice that from Peñasco Blanco (and the former had four fewer original hills), the mean cob size is nearly twice that of Peñasco Blanco's as well. Pollination was far better, so that usable production would have been far greater at Werito's Rincon (see Table 3.7, Figures 3.15-3.16). Cob size at Peñasco Blanco may be seen to be smaller and more variable than at Werito's Rincon; although some cobs reached lengths within the latter's range, nearly all at the lower end, and many fall below it (there are only two Peñasco Blanco cobs more than 150 mm long). The production at Peñasco Blanco would probably be very low regardless of increased protection or increased acreage, unless increased acreage vastly increased pollination. Even if every ear from Peñasco Blanco were full, the per-acre yield there would have been far less than at Werito's Rincon in 1979.

Another gauge of relative productivity of the two plots may be seen in Table 3.6. Noting that the Peñasco Blanco and Werito's Rincon ears are not qualitatively equivalent units, the ratios of ears per plant and per hill are consistently higher at Werito's Rincon, especially when whole plots are considered. All surviving hills at Werito's Rincon contained plants that formed ears, while plants in only 15 of 24 surviving hills at Peñasco Blanco formed ears. A larger number of plants were still alive at

Table 3.5 Comparison of Field and Lab Counts of Ears from 1979 Plots

	Field Counts		Lab Counts	
	1st plant.	2nd plant.	1st plant.	2nd plant
Werito's Rincon				
no water	1	5	1	2
water once a week	20	21	19	22
water twice a week	14	11	11	9
Totals	35	37	31	33
	72		64	
Peñasco Blanco				
no water	0	0	0	0
water once a week	13	3	0	2*
water twice a week	7	10	7*	3
Totals	20	13	7	5
unknown			11	
	33		23	

*Each includes one immature cob not entered in the measurements in Tables 3.7 and 3.8

Table 3.6 Ratios of Ears to Plants and Hills using September 8, 1979, Field Counts

	Hills			Ears	Ratios--Ears to:		
	Original	Surviving	n of Plants	n	All Hills	Live Hills	Plants
Weritos Rincon							
no water	4	3	7	6	1.50	2.00	.86
watered once/week	16	14	23	41	2.56	2.93	1.78
watered twice/week	8	8	19	25	3.13	3.13	1.32
Total	28	25	49	72	2.57	2.88	1.47
Penasco Blanco							
Bearing hills only							
watered once weekly	16	7	17	16	1.00	2.29	.94
watered twice weekly	8	8	29	17	2.13	2.13	.59
All hills							
no water	8	2	8	0	0	0	0
watered once weekly	16	14	38	16	1.00	1.14	.42
watered twice weekly	8	8	29	17	2.13	2.13	.59
Total	32	24	75	33	1.03	1.38	.44

Table 3.7 1979 Chaco Canyon Experimental Corn Plot Cob Data

	Werito's Rincon					Peñasco Blanco				
VARIABLE/conditions	n	$\bar{x}$	s.d.	range	C.V.	n	$\bar{x}$	s.d.	range	C.V.
COB LENGTH										
Whole plot	64	194.8	39.4	81-292	20.2	20	103.5	45.5	32-211	44.0
1st planting	31	197.1	39.4	107-265	20.0	16	99.6	41.0	32-164	41.2
2nd planting	33	192.6	39.9	81-292	20.7	4	119.2	65.6	57-211	55.0
no water	3	189.3		182-195		0				
1 watering/week	41	189.6	43.4	81-292	22.9	12	108.8	53.2	32-211	48.9
2 waterings/week	20	206.3	31.4	160-262	15.2	8	95.6	32.4	49-142	33.9
1st planting no watering	1	191				0				
2nd planting no watering	2	188.5		182-195		0				
1st planting 1 watering	19	187.7	42.2	107-265	22.5	11	99.5	44.4	32-164	44.7
2nd planting 1 watering	22	191.2	45.2	81-292	23.7	1	211			
1st planting 2 waterings	11	213.8	31.2	260-261	14.6	5	99.8	36.9	49-142	37.0
2nd planting 2 waterings	9	197.7	30.8	167-262	15.6	3	88.7		57-114	
NUMBER OF ROWS										
Whole plot	64	13.0	2.2	8-22	16.9	18	12.4	1.6	10-14	13.0
1st planting	31	12.8	1.9	10-18	14.6	14	12.3	1.7	10-14	14.1
2nd planting	33	13.3	2.5	8-22	18.8	4	13.0	1.2	12-14	8.9
no water	3	13.0		12-15		0				
1 watering/week	41	12.7	2.4	8-22	18.9	10	12.2	1.8	10-14	14.4
2 waterings/week	20	13.8	1.7	12-18	12.4	8	12.8	1.5	10-14	11.7
1st planting no watering	1	15				0				
2nd planting no watering	2	12.0		12		0				
1st planting 1 watering	19	12.2	1.6	10-16	13.3	9	12.0	1.7	10-14	14.4
2nd planting 1 watering	22	13.1	2.9	8-22	22.0	1	14			
1st planting 2 waterings	11	13.4	2.0	12-18	14.4	5	12.8	1.8	10-14	14.0
2nd planting 2 waterings	9	14.0	1.4	12-16	10.1	3	12.7		12-14	

Table 3.7 continued

	Werito's Rincon					Peñasco Blanco				
VARIABLE/conditions	n	$\bar{x}$	s.d.	range	C.V.	n	$\bar{x}$	s.d.	range	C.V.
MID COB DIAMETER										
Whole plot	64	21.4	4.0	13-34	18.9	21	14.6	4.0	6-21	27.4
1st planting	31	20.9	3.7	13-29	17.7	17	15.2	2.9	10-20	19.2
2nd planting	33	21.8	4.3	13-34	20.0	4	11.8	6.9	6-21	58.7
no water	3	20.3		20-21		0				
1 watering/week	41	20.9	4.6	13-34	21.8	12	15.7	3.7	10-21	23.6
2 waterings/week	20	22.5	2.8	17-28	12.6	9	13.1	4.1	6-17	31.3
1st planting no watering	1	20				0				
2nd planting no watering	2	188.5		20-21		0				
1st planting 1 watering	19	20.1	4.0	13-29	19.8	11	15.2	3.5	10-20	22.8
2nd planting 1 watering	22	21.67	5.0	13-34	23.1	1	21			
1st planting 2 waterings	11	22.4	2.9	17-28	13.2	6	15.3	1.9	13-17	12.1
2nd planting 2 waterings	9	22.7	2.9	17-26	12.7	3	8.7		6-13	
MAXIMUM BASAL DIAMETER										
Whole plot	64	22.2	5.9	11-35	26.5	20	10.6	3.1	6-17	29.6
No water	3	23.7		15-34		0				
1 watering/week	41	22.6	5.7	11-35	25.0	12	11.4	3.3	8-17	29.3
2 waterings/week	20	21.0	5.9	12-32	28.1	8	9.2	2.4	6-13	25.7
MAXIMUM SHANK DIAMETER										
Whole plot	60	23.1	6.3	11-35	27.2	11	9.9	4.0	5-17	40.0
No water	2	25.0		15-35		0				
1 watering/week	38	23.1	5.9	13-35	25.7	4	13.0	4.7	8-17	36.1
2 waterings/week	20	22.8	6.5	11-32	28.6	7	8.1	2.3	5-12	27.8

Table 3.7 continued

VARIABLE/conditions		Werito's Rincon					Peñasco Blanco			
	n	$\bar{x}$	s.d.	range	C.V.	n	$\bar{x}$	s.d.	range	C.V.
KERNEL WIDTH										
Whole plot	60	8.3	.7	7-10	8.0	3	7.7		7-9	
No water	3	8.7		8-9		0				
1 watering/week	37	8.2	.7	7-10	8.2	2	8.0		7-9	
2 waterings/week	20	8.3	.7	7-9	7.9	1	7			
KERNEL THICKNESS										
Whole plot	60	5.9	1.2	4-8	21.0	3	6.3		6-7	
No water	3	6.7		6-7		0				
1 watering/week	37	5.9	1.3	4-8	22.3	2	6.0		6	
2 waterings/week	20	6.0	1.2	4-8	20.0	1	7			
KERNEL WIDTH/THICKNESS RATIO										
Whole plot	60	1.4	.3	1-2	18.8	3	1.2		1-1.5	
No water	3	1.3		1.3		0				
1 watering/week	37	1.5	.3	1-2	20.3	2	1.3		1.2-1.5	
2 waterings/week	20	1.4	.3	1.1-1.8	16.8	1	1			

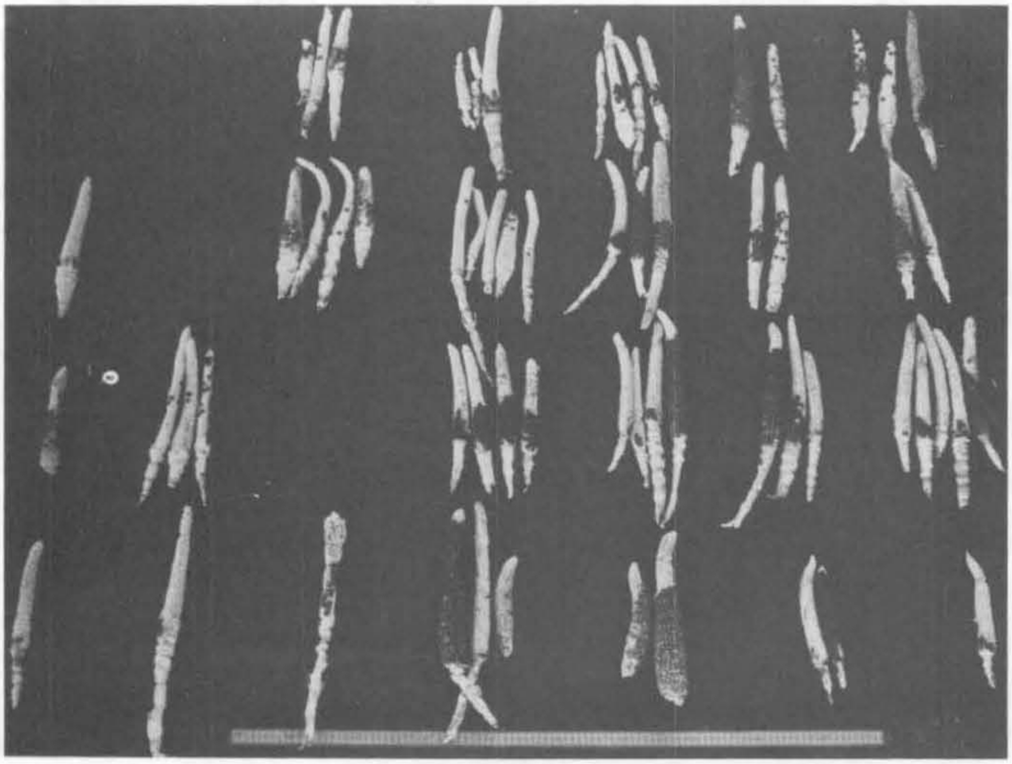


Figure 3.15 Werito's Rincon cobs from 1979, arranged in hill groups; unwatered hills first row on the left, twice weekly watered hills right two rows; middle four rows watered once weekly (1 m stick for scale).

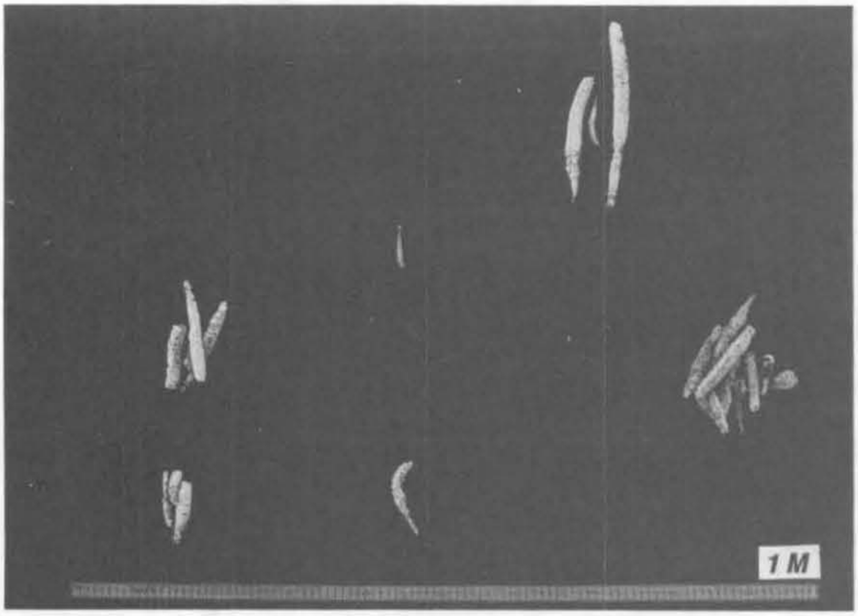


Figure 3.16 Peñasco Blanco cobs from 1979, also arranged by hill order; two groups on left watered twice weekly; remainder watered once weekly (group at right of unknown hill provenience). Photo contains a 1 m stick.

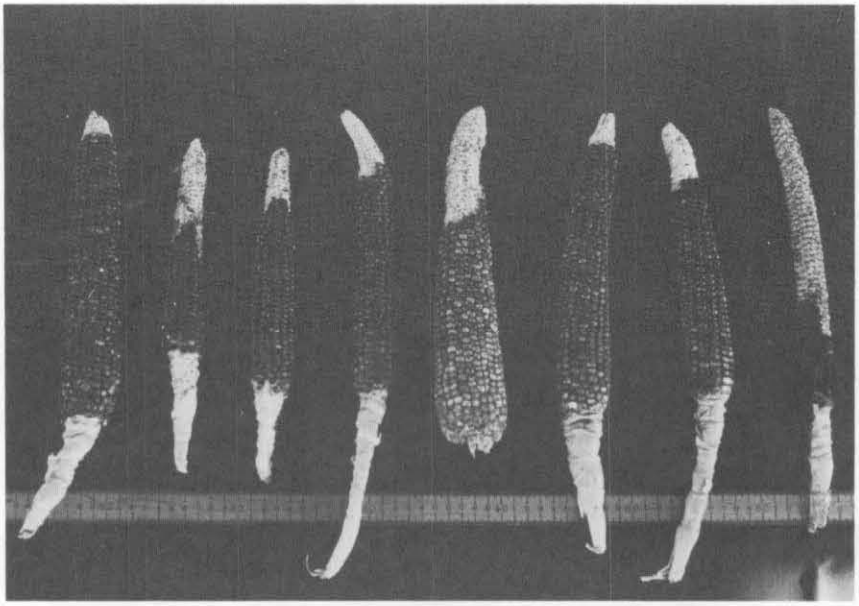
Peñasco Blanco in early September, but they looked much worse and bore much less than those at Werito's Rincon. Both size and productivity indicate considerably greater stress at Peñasco Blanco, and show a greater importance of artificial water there.

The more fully developed ears from Werito's Rincon were more variable, for example, in kernel color, which ranges from a deep blue black to gray blue with some white marbling (Figure 3.17a); one ear has purple kernels and indurated glumes (Figure 3.17a, far right), suggesting some crossing in the previous generation or perhaps an errant Cherry Flour kernel in the seed. Row number is also quite variable. Robins and Domingo (1953) have correlated such variability with moisture stress; there is some suggestion of that here. Thus, the means from the maximum watering hills are greater and the modal value is 14 rows (n=9 of 20), while the mode for the single watering group is 12 rows (n=21 of 41). Still, the ear with the most rows was from a hill watered once a week and there is not a great difference between the two watering regimes. Even at the more successful Werito's Rincon plot, incomplete pollination was a problem (Figure 3.17b, Table 3.8). Only about a fourth of the ears collected were fully pollinated, with a somewhat higher percentage of complete pollination in the hills watered twice a week.

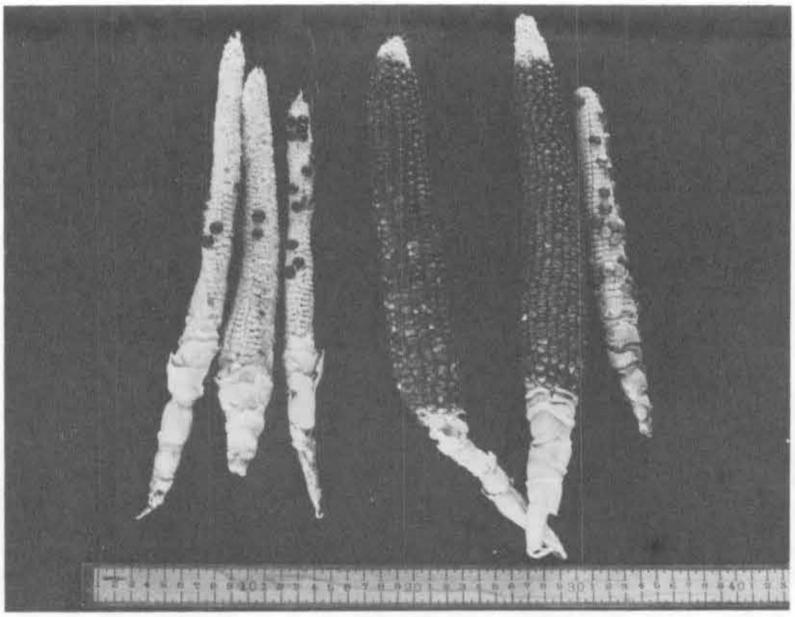
Position in the Werito's Rincon plot seems to influence the results. Dividing the plot into east and west halves, which places all the maximum watering regime on the west, shows a fairly even split both in numbers of cobs (30 east, 34 west) and percentages of completely pollinated cobs (20% east, 29% west). A more noteworthy difference may be seen in an upslope-downslope (south-north) division, which equally distributes watering regimes. The numbers of cobs are again evenly split, 31 and 33 respectively; complete pollination, however, only occurred in 10% (3) of the upslope cobs, while the downslope groups shows 39% (13). (The cobs are arranged in hill order in Figure 3.15). It is likely that moisture is greater lower in this plot, due to the presence of both the dune and the drainage. Air movement may also contribute to pollination, but the east-west split suggests otherwise. The upslope-downslope division is also visible in the measurements--mean cob length, mid cob diameter, and row numbers of the lower plants are greater in all watering regimes and for entire halves:

	Cob Length	Mid Cob	Row Number
Upslope means	183.5	21.9	13.5
Downslope means	205.3	20.9	12.6

The extremely poor pollination in the Peñasco Blanco cobs (Figure 3.16) probably reflects moisture availablity as well. The hills receiving maximum water produced at the rate of 2.13 ears per hill (per total number of hills in the regime), while hills being watered once a week yielded ears only at the rate of 1.14 per hill (Table 3.6). The first planting produced 17 ears (20 field count) to 4 (13 field count) for the second, indicating a much greater difference in "success" by planting time than was present at Werito's Rincon.



a. Variability in ear size, shape, and color; 5 on left watered once weekly, 3 on right watered twice. Cob at far right has indurated glumes and purple kernels, the remainder have variations of blue kernels. From left 1, 2, 4, 5 from lower half, others from upper.



b. Pollination variability; 3 cobs on left watered once weekly, lower half hill; fourth from once weekly lower hill; two on right from the same watered twice weekly upper half hill.

Figure 3.17 Werito's Rincon cobs.

Table 3.8 1979 Chaco Experimental Corn Non-metric Data

VARIABLE/states	Werito's Rincon Watering/week None	 Once	 Twice	Peñasco Blanco Watering/week Once	 Twice
CURVED COBS					
Curved	0	15	5	3	3
Not curved	3	26	15	9	6
ROW ARRANGEMENT					
Straight	2	26	12	4	5
Spiral	0	3	0	0	0
Irregular	1	12	8	8	4
UNDEVELOPED ROWS					
Present	1	17	13	10	9
Absent	2	24	7	2	0
POLLINATION					
Incomplete <10 kern.	0	5	0	4	6
Incomplete 10-25 k.	0	9	0	3	1
Incomplete 25+ kern.	2	19	13	5	2
Complete pollination	1	8	7	0	0
BIRD AND RODENT DAMAGE (Whole plots)					
None		12		1	
Some		12		2	
Severe		40		17	

Position within the Peñasco Blanco plot can also be seen to be important. All 8 hills in the rows watered twice weekly formed at least some ears. In contrast, 7 of the 16 hills watered once a week formed cobs, including the largest and only really complete specimen from this plot. All of the ear-bearing, watered-once-weekly hills were located around the inlet from the irrigation feature. The system delivered water at least three occasions, and there is little doubt that especially with less precipitation the hills nearest the delivery point would receive more moisture than the rest of the plot. The two unwatered rows were probably at an added disadvantage by being located at the edges of the plot.

Given sample size, projection of production from the Werito's Rincon data must be considered tentative. The animals left very few cobs with all their kernels; a sample of seven with all kernels (4) or more than half (3, excluding the largest cob which gives an overly large projected kernel weight) give a range of 36.2 to 146.8 g of kernels per ear. The mean length of the sample is 222 mm, 27 mm longer than the plot's mean, so the projected figure is likely to be somewhat above the actual one. The mean kernel weight per cob comes to 95 g (s.d.=42). Given 64 harvested cobs and good protection, then, the production of this plot as it grew in 1979 would have been slightly over 6 kg from this 0.034 ha plot, but this value should be reduced by around 20% due to pollination problems (see Table 3.8), or about 145 kg of shelled corn per hectare.

Comparisons

Soils

Given the actual production obtained in three years it is difficult to compare soils in terms of fertility. Some observations about soils may, however, be made (Cully et al. [1982:127-133] for much more detailed discussion of soils in the area).

1) Corn will grow on the floor of the main canyon, even in fine-grained, sodium rich "black alkali" locations such as the Chetro Ketl Fields. In the more severe years of 1977 and 1978, plants in both of the canyon floor locations where we had plots did quite well relative to plants in other locations the same season, though their success was one more of survival than anything else. It is thought likely that winter moisture may be better retained in these soils because of their higher clay content. Any conclusion about the productivity of these soils must be withheld, however. Even in more favorable 1979, larger plants at Peñasco Blanco produced very poorly relative to the dune plot at Werito's Rincon. The inferior performance of plants at Peñasco Blanco in 1979 may have been due to a soil problem, but it may also have been a moisture problem. Superficially, it seems contradictory that plants did better at Peñasco Blanco than elsewhere in drier 1978, possibly because of better soil moisture, and worse in wetter 1979, possibly because of moisture stress. It is conceivable that the fine-grained sediment apparently creates favorable moisture retention which promotes plant growth when conditions are generally dry. At the same time, such soil makes moisture extraction by roots more difficult because of reduced permeability and

increased ionic attraction of water to the soil, which, in turn, induces moisture stress more readily in adult plants.

2) South side locations--dunes in particular--are also capable of supporting corn, as the Hopi demonstrate so much more graphically. In 1979, at least, the dune situation was much more favorable to healthy, productive plants than the canyon floor. Apparently the least favorable south side location was the open alluvial slopes below the talus (Plot 3, 1977).

Pests

On the whole the canyon bottom location seemed less prone to pest damage than the dune locations. In the dunes, the nibbling of young plants by animals was a significant cause of plant loss. Also noted as active pests were ants (in 1979 modern chemical warfare was inflicted on ant hills adjacent to the Werito's Rincon plot). The Peñasco Blanco plot's relatively charmed existence ended when the surviving vestige of a crop, was decimated by an unknown, large predator. The absence of corn fields in Chaco for many past generations certainly did not preclude the predators present from taking advantage of a new food source.

Moisture and Precipitation

While soils are undeniably important and in need of further study, the factor that seems to be of paramount importance is that of effective moisture. In examining the progress of the 1978 plots a basically similar pattern may be observed (Figures 3.10-3.12): seeds sprouted quite well and plants persisted through the end of June, followed by rapid attrition in the first half of July. Generally, seeds planted in late April did better than did seeds planted in mid-May, regardless of whether or not the plants were watered, possibly as a result of the arrival of the last major moisture event of the entire summer in early May (see Figure 3.19). The salient feature of the 1978 summer precipitation is its virtual absence--note that there were only 6 measureable precipitation events between May 22 and August 13, with a mean of 0.04 in. (official measurements are taken at a station near Una Vida). This is not extraordinary in June, but August and very notably July were markedly subnormal months (Figure 3.21). The moisture that arrived in August arrived after all but one of the plants were dead.

The weather data collected at the 1979 plots support a suggestion as to a possible cause of the poorer performance of the Peñasco Blanco plot in that year and show the variability possible on a small scale (Table 3.9). The thermometers at these locations were shaded, but subject to conditions in the plot. The maximum temperatures are a good deal higher than those recorded at the official station. The north side canyon bottom experiences greater high and low temperature extremes. Possibly the greater variations and more intense exposure to the sun have a cumulative negative effect. Note also that rainfall varies at the three stations, suggesting that within-canyon meteorological variation could have contributed to differences in crop production. That the Peñasco Blanco location

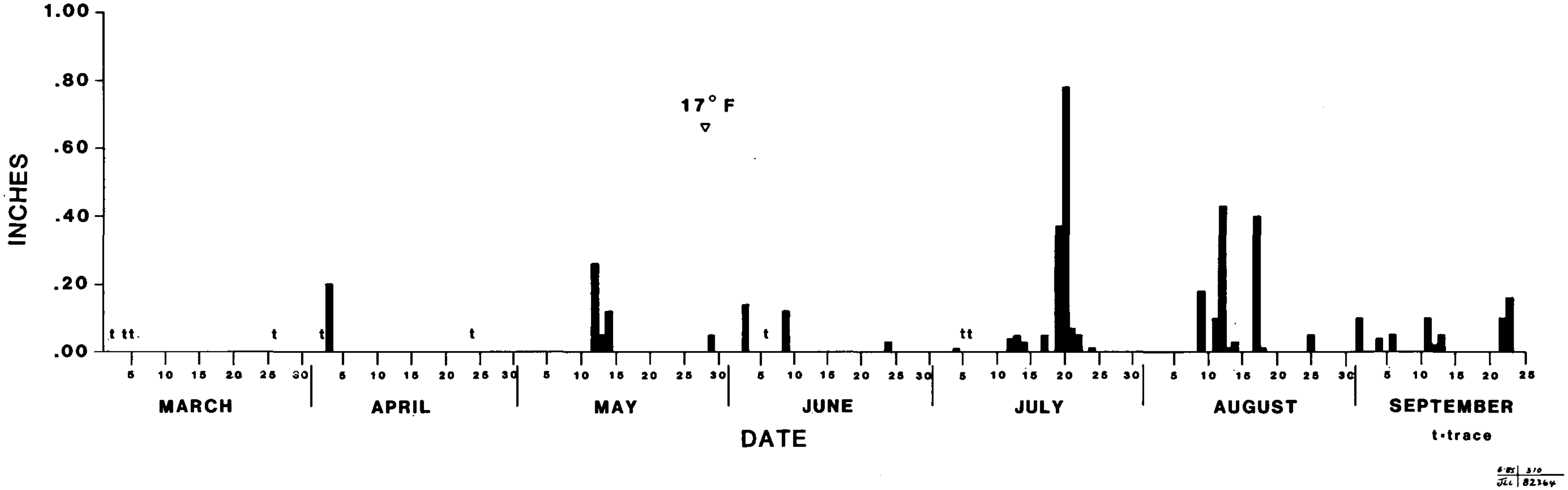


Figure 3.18 Daily precipitation at the Chaco Canyon station, March through September 25, 1977; "t" indicates trace precipitation

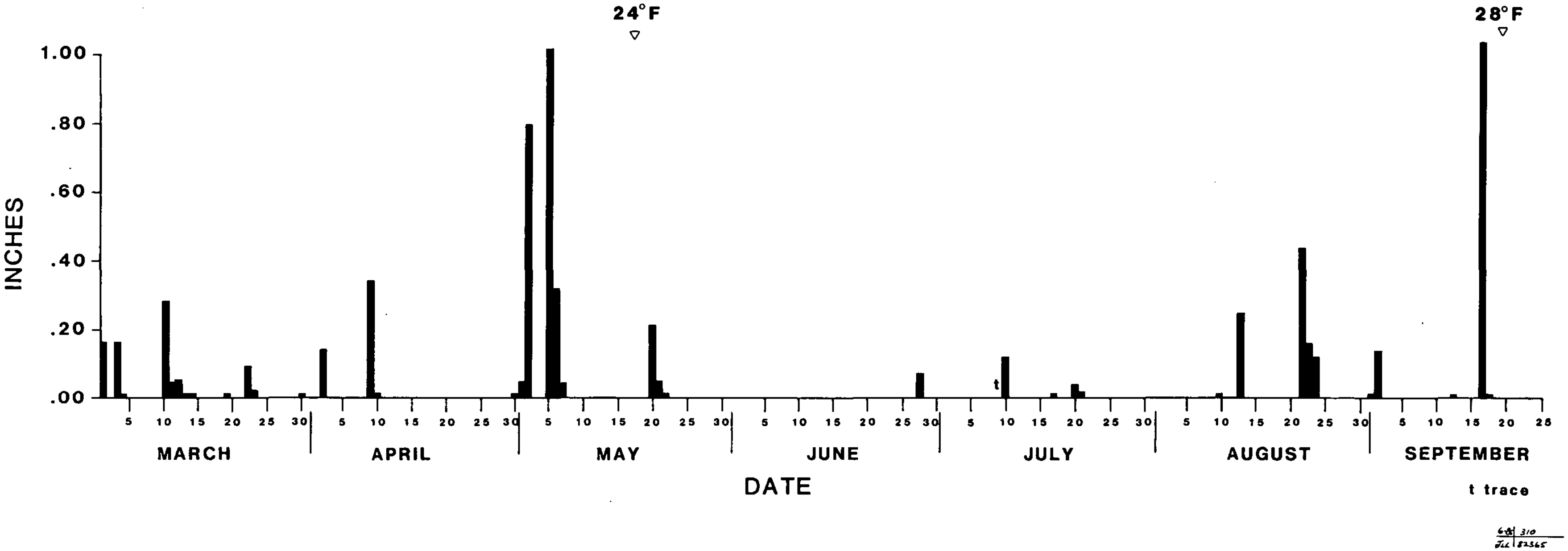


Figure 3.19 Daily precipitation at the Chaco Canyon station, March through September 25, 1978; "t" indicates trace precipitation.

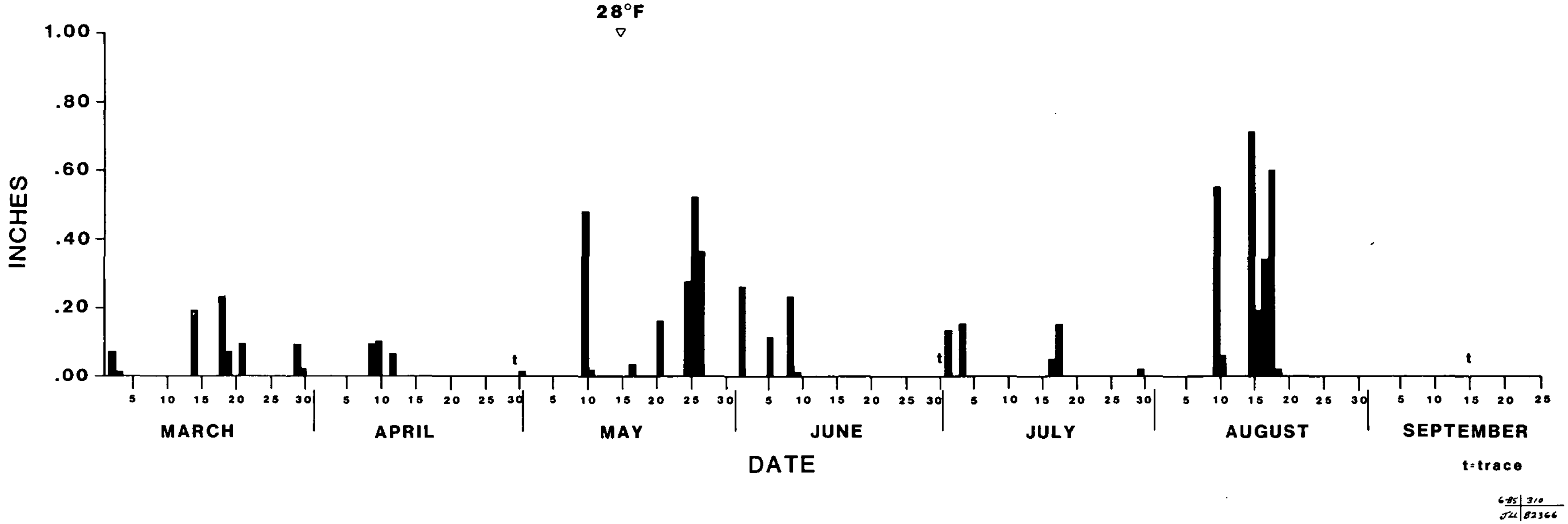


Figure 3.20 Daily precipitation at the Chaco Canyon station, March through September 25, 1979; "t" indicates trace precipitation

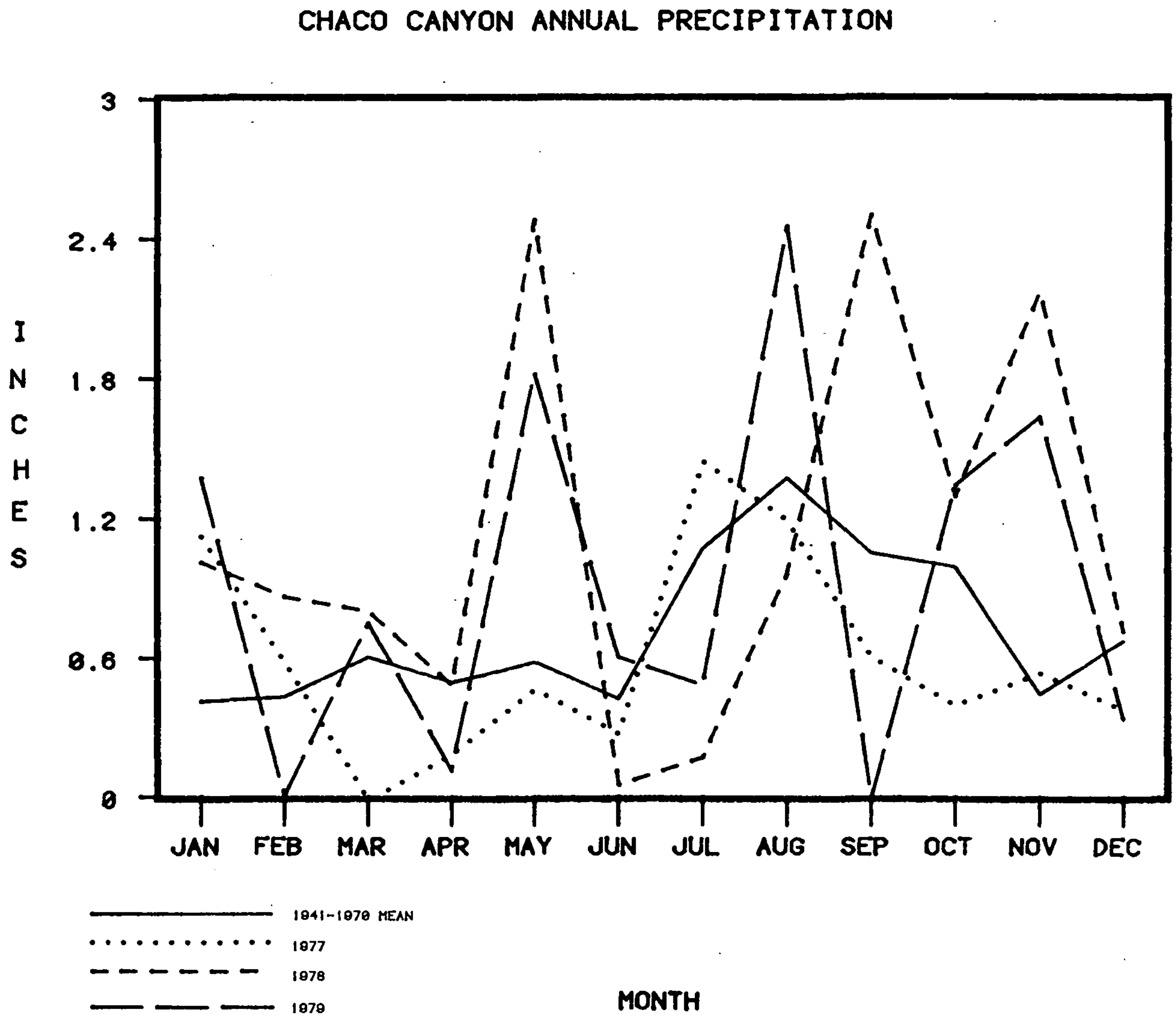


Figure 3.21 Yearly precipitation for Chaco Canyon for 1977-1979, compared to the 1941-1970 mean. Annual totals are Mean--8.76"; 1977--7.35"; 1978--13.72"; 1979--11.11".

Table 3.9 Temperature and Precipitation Readings at the Peñasco Blanco and Werito's Rincon Plots, 1979

MONTH/ Plot	Temperature				Precipitation			
	Readings	Minimum	Maximum	Diurnal Range	Events	Amount (inches)	Total	Official Data
MAY								
Werito's Rincon								
Ranges	6	39-54	81-92	28-52	5	.02-.90	1.74	1.84(8)
Means		44.5	84.1	39.7	(1T)	.435		.230
Standard deviations		6.7	7.9	9.9		.368		.209
Peñasco Blanco								
Ranges	6	38-46	74-97	32-57	5	.03-.75	1.55	
Means		41.3	85.0	43.7	(1T)	.388		
Standard deviations		3.3	9.1	10.0		.294		
JUNE								
Werito's Rincon								
Ranges	10	34-51	81-102	32-67	5	.01-.16	.30	.62(5)
Means		40.8	92.9	52.7	(1T)	.075		.124
Standard deviations		5.9	8.4	9.6		.069		.118
Peñasco Blanco								
Ranges	10	32-47	81-109	42-66	3	.02-.18	.30	
Means		39.0	96.5	57.6		.100		
Standard deviations		5.5	9.8	8.3		.080		
JULY								
Werito's Rincon								
Ranges	10	42-64	92-108	37-64	3	.08-.21	.29	.50(5)
Means		50.6	101.5	50.9	(1T)	.145		.100
Standard deviations		7.7	5.3	9.5				.061
Peñasco Blanco								
Ranges	10	40-69	96-113	40-72	4	.18-.28	.46	
Means		50.7	105.7	55.0	(2T)	.230		
Standard deviations		9.8	6.1	10.0				

Table 3.9 continued

MONTH/ Plot	Temperature				Precipitation			
	Readings	Minimum	Maximum	Diurnal Range	Events	Amount (inches)	Total	Official Data
AUGUST								
Werito's Rincon								
Ranges	10	41-63	74-106	21-58	6	.02-.70	1.05	2.47(7)
Means		49.9	92.8	44.9	(2T)	.263		.353
Standard deviations		6.4	11.9	14.1		.308		.274
Peñasco Blanco								
Ranges	10	40-56	87-109	35-61	5	.01-.70	1.14	
Means		47.9	98.8	50.9		.228		
Standard deviations		6.3	8.6	8.8		.313		
SEPTEMBER								
Werito's Rincon								
Ranges	7	34-46	90-102	55-63	0		0	.01(1)
Means		38.6	97.6	59.0				
Standard deviations		4.5	4.7	3.1				
Peñasco Blanco								
Ranges	7	35-44	94-107	42-60	0		0	
Means		38.9	100.4	58.7				
Standard deviations		3.2	5.6	8.9				

Diurnal ranges may be somewhat exaggerated because readings were not taken every day; it is also conceivable that precipitation events may be lumped, but unlikely.

(T) indicates the number of unmeasurable "trace" events; trace events are included in the number of events.

is indeed a more severe one is emphasized by the probability that in 1979 the plants there received more surface moisture than those at Werito's Rincon, because they were supplied by the irrigation system and received equivalent artificial waterings. The success at Werito's Rincon must be attributed to both the less severe conditions and the effectiveness of the dune in supplying and retaining moisture.

If water is the critical variable, how did the plants respond to artificial watering? In 1978 the dune plots reacted about as would be expected, i.e., watered plants were larger and lived longer, with the exception of the pest-ridden Dune Side first planting (Figures 3.10 and 3.11). At Peñasco Blanco, however, an interesting reversal of this trend occurred: the initially unwatered plants were consistently better looking and larger than the watered plants. During June a very notable leaf rolling and decline in growth rate were visible in watered plants, while unwatered plants retained flat leaves and attained greater size (Figure 3.12). This disparity did not last, as eventually nearly all plants developed droughtrelated rolled leaves and died. As in all these experiments, this pattern may relate to sample size or unknown soil differences. The one plant that survived until the killing frost (late September) was one that received water throughout the summer, but its endurance was the result of repeated appearances of new growth from the severely affected original plant.

The effects of watering on the 1979 plant size and cob yield may show that, in the quantities provided, artificial watering will make some improvement, but adequate natural precipitation is required for plant survival and production of mature cobs. The success of the unwatered plants at Werito's Rincon supports this interpretation.

A rough calculation, considering each hollow around each corn hill to be 30 cm in diameter and each watering to be 1 liter per hill, shows the depth of water within the hollow to be 1.4 cm for each watering. The plots were watered five (dune plots) and six (Peñasco Blanco) times in June, 1978, providing approximately 7 to 8.5 cm of water per hill. Since the 1951-1974 (June) mean total precipitation is 1.09 cm, the moisture provided artificially was considerably greater than the amount that would have fallen naturally in a "normal" June, but that additional moisture is extremely localized and is still less than the potential water loss through evapotranspiration. Factors such as general soil moisture versus highly local soil moisture, the use of water diversion, and dune moisture retention all make any equation of artificial with natural moisture beyond the present scope. We were not providing the quantities described by Kirkby (1973) for Oaxacan riego a brazo (see below). The minimal effects of our watering make it likely that some critical threshold was not being reached (Litzinger 1976). Indeed, Blaney and Hanson's (1965) calculations of consumptive use coefficients indicate that corn grown at nearby Bloomfield should require some 12.4 cm of water in the month of June (and 60 cm for an entire summer). Our artificial watering amounts combined with the meager amount of meteoric water are still shy of this amount, suggesting that moisture stress could have affected the plants despite our best intentions. As a sidelight on the importance of moisture, hybrid corn and other deep-planted crops (beans, squash, chiles, tomatoes) were grown productively with regular, copious irrigation in Chaco in 1978 on soil similar to that at Peñasco Blanco though manure had been added (location 10 on Figure 3.1).

Precipitation amounts in the summers of 1977 and 1979 were much closer to normal (Figures 3.18-3.21.). Why, then, was no corn produced in 1977? Plant survival overall was better than in 1978 and tassels did appear in two plots, though the plants were stunted, and no ears formed. Some suggestion as to a part of the cause of failure in 1977 may be seen in the importance of artificial water to sprouting of plants in 1977. Whereas artificial watering played little or no role in sprouting in 1978 or 1979 (Tables 3.3, 3.4), it was very influential in 1977, turning our attention to precipitation in the early part of each of the three years.

All three years deviated from the 1951-1974 total mean annual precipitation (Figure 3.21), but each on a different schedule. The summer of 1977 conformed quite closely to normal patterns, but the year as a whole was more than an inch under normal. Very importantly, both March and April were below normal months and May through August just about normal. In 1979, the one year that can be considered remotely successful, the annual total is well above normal and between April and September only July is below normal, with May and August each over an inch above the mean. It can be suggested, then, that critical deep winter moisture was absent for the 1977 planting, setting the plots at an initial disadvantage and rendering them dependent on artificial watering to germinate. Some of those plants that survived during June were then able to benefit from the July rains, though they never reached productivity, perhaps because the remainder of the summer was only normal in this marginal precipitation regime. It was noted that even after the July rains began, some plants seemed to be severely stressed, probably because soil moisture was depleted throughout the root zone by that time. Franke and Watson (1936:21) attribute one of the two Mesa Verde failures to abnormal dryness during the "critical spring months."

While the annual rainfall total for 1978 was 5 in above normal, the summer months were all subnormal. Much of the above normal precipitation in 1978 occurred in the least agriculturally relevant last third of the year, but the first five months (especially May) were all above normal as well. No artificial water was necessary for germination at either planting in 1978. Soil moisture remained good well into June, but by mid-August little moisture could be detected at 65-70 cm below the surface.

Conclusions

These experiments have graphically illustrated several points:

1) Chaco, under modern conditions, is indeed marginal as a corn growing environment. Navajo successes at growing crops in and near Chaco Canyon have been documented by Judd (1954:52-59, Plates 12 and 13) and Pepper unpublished photographs taken in 1898; Cully et al. 1982). Our results and the precipitation record in general indicate that precipitation con-

ditions must be normal, or perhaps above normal, and that adequate moisture must arrive from at least March through August. The years 1977, 1978, 1979 provide a good example of the variablity in amount and scheduling of precipitation: a subnormal year with dry spring, an above normal year with no summer moisture, and an above normal year with good spring and summer moisture. The longer record indicates that above normal years are very often separated by several subnormal years (Judd 1954:59, 68; Vivian 1974:105; Vivian and Mathews 1965:8), and our short record shows that merely being above normal is not enough. Huntington (1914:81) also documents such cycling at the turn of the century:

> There are now in the [Chaco] Canyon two Indians who are reasonably sure of a good crop of corn each year. I saw their farms, unbelievably dreary wastes of drifting sand in the bottom of the canyon where two large tributaries join [the Escavada and the Chaco, just below Penasco Blanco?] and where the level of ground water is consequently higher than anywhere else.... In spite of these advantages neither of the two Indian farmers has obtained a good crop every year in recent times.... Various other Indians cultivate parts of the valley floor, but with the most meager success. In good years corn is said to grow to a height of 6 to 7 feet; in other years it is only 2 or 3 feet high, and often fails completely.
>
> "In the last sixteen years, according to Mrs. Wetherill... there have been only two good crops. In three years, 1902, 1903, and 1904, the Navajos planted corn as usual, but, with the exception of the two fortunate men already mentioned, got no returns. In the remaining years the crop varied all the way from almost nothing to fair. The reason for its failure in the dry years does not appear to be that the method of cultivation is poorer than in the past, but simply that the summer rains, upon which corn and beans...entirely depend, never fell at all or else did not fall until so late that the frost came before the crops could ripen.

Even in proven locations, then, farming in Chaco is risky, and regular failures are a good possibility on a regular basis. This critical factor in a number of interpretations of cultural developments in the Chaco region (e.g., Judge 1979; Vivian 1983) is well illustrated by these experiments.

2) Under these exacting conditions the necessity for the research on irrigation systems becomes clearer (Vivian 1974). Even such systems, however, probably would not have produced a crop in a year similar to 1978, since the only time our version of that system at the Penasco Blanco plot supplied any water was three days before the killing frosts of September 19 and 20.

3) The one plot that yielded a usable crop was located on the south side of the canyon in a "non-intensified" location. This result directs attention to the greater density of sites on the south side, spanning a longer period of time than is evident on the north side of the canyon. There is at least a suggestion, then, that the horticultural methods

presumed to have been operative on the south side were more reliable on a long-term basis than the attempts to utilize the north side catchments.

4) Those who did manage to grow crops in Chaco, whether or not they used the irrigation systems, clearly had to pay extremely close attention to their crops and were experts--even specialists (but then every Hopi farmer is a specialist). Given the dryness of a normal year's June and early July and the presence of bordered gardens it is reasonable to suggest some form of pot and well irrigation was necessary (Kirkby 1973:41-41, Plates 8-10; Cully et al. 1982:145, 164-165). The quantity of water supplied in this way would have had to exceed that which we provided. Kirkby reports 4,500 liters per day for a 360 m^2 field, or 1.25 cm <u>per day</u>, though the Navajos in the Chaco area apparently hauled less water. In view of the present low productivity of at least part of the Chetro Ketl Fields, it is interesting that Kirkby (1973:42) notes that pot irrigated fields are susceptible to salinization. At present no Anasazi wells are known in Chaco, but shallow hand-dug wells are known to have existed in the canyon historically.

5) It is noteworthy that almost every experimental plot, even in lusher environments such as Mesa Verde, is attended by reports of pest problems, especially rabbits and rodents (see Appendix). Pests were a major problem in the Chaco plots, especially when the plants were small and again when they were bearing ears. The importance of field houses and constant attention is suggested.

6) Because a failure is at least as significant as a success, we encourage others to report the results of similar experiments, whether or not they "succeed." We fully recognize that some of our procedures were faulty, but we have had to work them out as we went along and hope that their evolution may be of use to others.

We can only agree with Don Talayesva:

> "At harvest I was disappointed with my corn crop, realized that I was a poor farmer, and wondered whether I would ever be able to support a family" (Simmons 1942:255).

Acknowledgments

We would like to thank Chaco Canyon National Monument for allowing us to conduct these experiments, Gwinn Vivian for consulting with us on 1978 plot locations, and Gary Nabhan and Charlie Miksicek for supplying us with seed. Though Marcia Newren bore the brunt of tending and recording the plots through the years, several other people helped; among those who toted and tallied, Steve Lekson and Peter McKenna deserve especial note. Jerry Livingston helped with the figures.

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Appendix: Annotated Readings on Archeological Corn Experiments

The following summaries of other Southwestern corn plot experiments are included for comparison. The list is no doubt incomplete.

Colton, Harold S.
1965 Experiments in Raising Corn in the Sunset Crater Ashfall Area East of Flagstaff, Arizon. *Plateau* 37(3):77-79.

This is a brief report of three summers' planting, 1931-1933. Experiments were conducted primarily to evaluate the effects of Sunset Crater ash. Differential success at elevations from 4,900 to 7,000 ft and under different ash and rain conditions are reported. Pests were a problem; no yields are mentioned.

Ford, Dabney
1976 Experimental Farming. In *Reclamation of a Vandalized Prehistoric Settlement Site: Berrenda Creek Project 1976*, edited by A.R. Gomolak and D. Ford, pp. 37-40. Xeroxed NSF report for Grant #SM176-08025.

Beans, onions, and sweet corn were planted in three locations near the classic Mimbres site LA 12992 in Sierra County, southwestern New Mexico. No water was provided and only in a side drainage bottom was there any corn growth. The corn reached a maximum height of 20 cm (8 in) and there is no mention of tassel or silk formation. Ants and grasshoppers are both noted as detrimental. It is concluded that finer soils with good water retention and artificial water supply are probably necessary to successful agriculture in this location.

Franke, Paul R., and Don Watson
1936 An Experimental Corn Field in Mesa Verde National Park. In *Symposium on Prehistoric Agriculture*, University of New Mexico Bulletin 296, Anthropological Series 1 (5), edited D.D. Brand, pp. 19-37. Albuquerque.

A mesa top location in a small drainage was planted with native corn for 17 seasons (and continued after 1936). The experiment was conducted primarily to demonstrate the feasibility of growing corn in the apparently arid conditions of Mesa Verde. Moisture was found to be the most important factor--crops failed in only two of the 17 years reported, both times in dry years. No artificial water was provided; the only care given the field was occasional hoeing; animal predation was significant. Yields were variable, but deemed sufficient to support the postulated prehistoric population.

Howard, Richard M.
1958 Results of an Experimental Plot of Indian Maize. Ms. on file, Gran Quivira National Monument, Gran Quivira, New Mexico.

The results of a single season of planting at Gran Quivira National Monument are given. As at Mesa Verde, the primary purpose of this plot was to demonstrate the possibility of growing corn to visitors to the monument. Two germinations occurred from natural moisture. The earlier, in May, produced mature ears; the later, in July, produced ears that had not matured by the killing frost in October. The summer was substantially normal for moisture (9.7 in or 24.6 cm, May to October); no irrigation was practiced.

Human Systems Research
1973 A Preliminary Experiment with Chapalote Corn in the Tularosa Basin, New Mexico. In Human Systems Research Technical Manual, pp. 445-457. Three Rivers, New Mexico.

This is a report on a single season experiment involving two plots at elevations of 4,820 and 7,000 ft, planted to observe the performance of primitive maize under the different conditions provided by the elevational difference. Hail, cows, and freezing temperatures all rendered the more variable high elevation crop inconclusive and poor; the lower plot produced mature cobs with some plants reaching heights of over 2 m. The higher plot was fenced, and the lower plot was regularly and abundantly irrigated. Plots were in the care of local farmers.

Jeter, Marvin D.
1977 Archaeology in Copper Basin, Yavapai County Arizona: Model Building for the Prehistory of the Prescott Region. Arizona State University Anthropological Research Paper no. 11, pp. 161-162. Tempe.

Dry farming around 1900 is reported, but tree rings suggest that the early 1900s were abornmally wet. An experimental plot in 1976 died out during a "40-day drought" of late May through June. Some cattle and wild animal trampling were experienced, but the loss of the plot is attributed to the drought. "Abnormal varieties" of corn were used.

Litzinger, William J.
1976 The Experimental Garden Project, 1975. In Hovenweep 1975 Archeological Report no. 2, edited by J.C. Winter, pp. 177-190. San Jose State University, Department of Anthropology, California.

Three plots were placed in varying locations in Hovenweep National Monument (Colorado-Utah) and one at Lowry Ruin in 1975. Shallow soil, rodents, and dryness rapidly eliminated plots in check dam and floodplain locations. A larger plot was maintained testing different watering levels administered every two days. The relationship of plant size to quantity of water supplied was direct, but size groups were apparent for the following water amounts: 0-200 ml, 400-1,200 ml, and 2,000-2,500 ml per watering. Unchecked weeds were found to reduce growth by about half in the dry-farmed Lowry plot; with weeding good growth and yield were obtained by dry farming in the Lowry plot in preceding years. Observations and care were stopped before the Hovenweep field matured, so yields were not measured. The plots were quickly and severely reduced by predation when abandoned. In 1976, three of the 1975 gardens were continued; again harvest size was poor, but fallow, weed, and herbivore data were collected (Winter 1977:8-9).

Maule, Stuart H.
1963 Corn Growing at Wupatki. Plateau 36 1:29-32.

This article reports on a single season experiment. Corn was planted in mid-July. The primary objective was to test the effects of Sunset Crater ash as mulch. No artificial water was applied; rodents were found to be a problem especially in dry periods. Germination was very slow and no ears were produced. One inch of ash mulch was found to be optimal, and it was concluded that the mulch was necessary for corn growth.

Shuster, Rita A., and Robert A. Bye
1984 Preliminary Results from the Dolores Archaeological Program Gardens. In Dolores Archaeological Program: Synthetic Report 1978-1981, pp. 94-99. U.S. Department of Interior, Bureau of Reclamation, Engineering and Research Center, Denver.

This report summarizes one of the most extensive and best controlled agricultural experiments connected with an archeological project. A riverine garden and an upland location were planted for two years, 1979 and 1980; a variety of cultivars, including eight strains of maize, were planted. Frost-free days were found to be the major limitation in this experiment though moisture, weeds, and pests were also factors. Mature ears were obtained, with productivity better in the warmer upland plot. One of the best prehistoric controls for these problems is seen to be plot location. Variability in precipitation among adjacent stations is noted; the summers of 1979 and 1980 are termed "particularly short and dry," with between 1.58 in and 5.24 in. (Note that 1979 was relatively wet for Chaco, with 5.44 in; see Gillespie, this volume.)

References Cited

Colton, Harold S. (see Appendix).

Cully, Anne C., Marcia L. Donaldson, Mollie S. Toll, and Klara B. Kelley
1982 Agriculture in the Bis sa'ani Community. In *Bis sa'ani: a Late Bonito Phase Community on Escavada Wash*, vol. 1, edited by C.D. Breternitz, D.E. Doyel, and M.P. Marshall, pp. 115-166. Navajo Nation Papers in Anthropology no. 14. Window Rock, Arizona.

Blaney, Harry F., and Elden G. Hanson
1965 Consumptive Use and Water Requirements in New Mexico. *New Mexico State Engineer Technical Report* 32. Santa Fe.

Franke, Paul R., and Don Watson (see Appendix)

Hack, John T.
1942 The Changing Physical Environment of the Hopi Indians of Arizona. *Reports of the Awatovi Expedition*, no. 1. Papers of the Peabody Museum of American Archaeology 35, no. 1. Harvard University, Cambridge.

Howard, Richard M. (see Appendix).

Human Systems Research (see Appendix).

Huntington, Ellsworth
1914 *The Climatic Factor as Illustrated in Arid America.* Carnegie Institute of Washington, Publication 192. Washington.

Judd, Neil M.
1954 *The Material Culture of Pueblo Bonito*. Smithsonian Miscellaneous Collections, vol. 124. Washington.

Judge, W. James
1979 The Development of a Complex Cultural Ecosystem in the Chaco Basin, New Mexico. In Proceedings of the First Conference on Scientific Research in the National Parks vol. 2:901-906, edited by R.M. Linn. *National Park Service Transactions and Proceedings Series* 5.

Kirkby, Anne V.T.
1973 *The Use of Land and Water Resources in the Past and Present Valley of Oaxaca, Mexico.* Memoirs of the Museum of Anthropology no. 5. University of Michigan. Ann Arbor.

Lagasse, Peter F., William B. Gillespie, and Kenneth G. Eggert
1984 Hydraulic Engineering Analysis of Prehistoric Water-Control Systems at Chaco Canyon. In *Recent Research on Chaco Prehistory*, edited by W.J. Judge and J.D. Schelberg, pp. 187-212. Reports of the Chaco Center no. 8. Division of Cultural Research, National Park Service, Albuquerque.

Litzinger, William J. (see Appendix)

Love, David
1980 Summary of Interpretations of Late Quaternary Geomorphic Conditions in Chaco Canyon. Ms. on file, Division of Cultural Research, Albuquerque.

Loose, Richard W., and Thomas R. Lyons
1976 The Chetro Ketl Field: A Planned Water Control System in Chaco Canyon. In Remote Sensing Experiments in Cultural Resource Management, edited by T.R. Lyons, pp. 133-156. Reports of the Chaco Center no. 1. National Park Service, Albuquerque.

Maule, Stuart H. (see Appendix)

Pepper, George
1898 Unpublished Photos in Archive Nos. 722, 730, 732, 736, 739. Division of Cultural Research, National Park Service, Albuquerque.

Robins, J.S., and C.E. Domingo
1953 Some Effects of Severe Soil Moisture Deficits at Specific Growth Stages in Corn. Agronomy Journal 45:618-621.

Simmons, Leo W. (editor)
1942 Sun Chief: the Autobiography of a Hopi Indian. Yale University Press, New Haven.

Titiev, Mischa
1938 Dates of Planting at the Hopi Indian Pueblo of Oraibi. Museum Notes 11(5):49-42. Museum of Northern Arizona, Flagstaff.

Vivian, R. Gwinn
1970 Aspects of Prehistoric Society in Chaco Canyon, New Mexico. Unpublished Ph.D. Dissertation, University of Arizona, Tucson.

1974 Conservation and Diversion. Water-Control Systems in the Anasazi Southwest. Chapter 9 in Irrigation's Impact on Society, edited by T.E. Downing and M.C. Gibson, pp. 95-112. Anthropological Papers of the University of Arizona no. 25. Tucson.

1983 Identifying and Interpreting Chacoan Roads: An Historical Perspective. In Chaco Roads Project Phase I, edited by C. Kincaid, pp. 3:1-3:20. Bureau of Land Management, Albuquerque.

Vivian, R. Gordon, and Tom W. Mathews
1965 Kin Kletso: a Pueblo III Community in Chaco Canyon, New Mexico. Southwestern Parks and Monuments Technical Series No. 6, Part I. Globe, Arizona.

Windes, Thomas C.
1978 *The Stone Circles of Chaco Canyon, Northwestern New Mexico.* Reports of the Chaco Center No. 5. National Park Service, Albuquerque.

Winter, Joseph C.
1977 *Hovenweep 1976.* Archaeological Report no. 3. Anthropology Department, San Jose State University, San Jose, California.

Chapter Four

Pollen Evidence of Past Subsistence and Environment at Chaco Canyon, New Mexico

by

Anne C. Cully

Introduction

Over the years, archeological excavations at Chaco Canyon have disclosed structures which vary greatly in size and construction. Large, complex sites like Pueblo Bonito and Pueblo Alto were built on a massive scale. They are described variously as towns, greathouses, and more recently, as simply large structures (Lekson 1984). Small sites, described by Truell (1982) as modestly constructed single-story houses, are strikingly different from the large structures in plan and scale. Based on tree-ring and ceramic evidence, Hawley (in Brand 1937) reported that sites of these two differing types were occupied contemporaneously. Conjecture about the differing functions of the smaller and larger sites with regard to social organization and subsistence patterns has continued to the present day (Kluckhohn et al. 1939; Truell 1982; Vivian and Mathews 1964; Windes 1978, 1980).

In order to broaden the knowledge of the subsistence base and to explore possible differences in site function related to the gathering, storage, and processing of plant resources, botanical analyses were undertaken at recently excavated sites. Pollen samples (184) from two small sites and one large structure were processed and analyzed. Excavation began in 1974 at the first small village site, Site 29SJ 627, located in a rincon southwest of Chaco Wash (Figure 4.1). The second village location, Site 29SJ 629, another village site about 60 m to the east in the same rincon, was excavated during 1975 and 1976. Both sites are similar in overall plan (see following sections). In the early stages of occupation, domestic functions were carried out in the pithouses. The aboveground structures probably functioned as storage rooms. Later, domestic or living functions were shifted to the aboveground rooms as various additions were made, and subterranean rooms were then used for ceremonial activities. Initial occupation of both sites occurred in the A.D. 800s. Site 29SJ 629 was abandoned by A.D. 1050, and 29SJ 627 by the early 1100s. Pueblo Alto is a large, complex structure located northeast of the Chaco Canyon rim above Pueblo Alto on a mesa top (Figure 4.1); excavation began there in 1974 and continued through 1979. Occupation of the site has been dated by various methods, and ranges from A.D. 1020 to 1150-1200 (Windes 1980). Preliminary reports on architectural development by Windes (1980) describe the relationship of the architectural components of the site and the tentative building sequence.

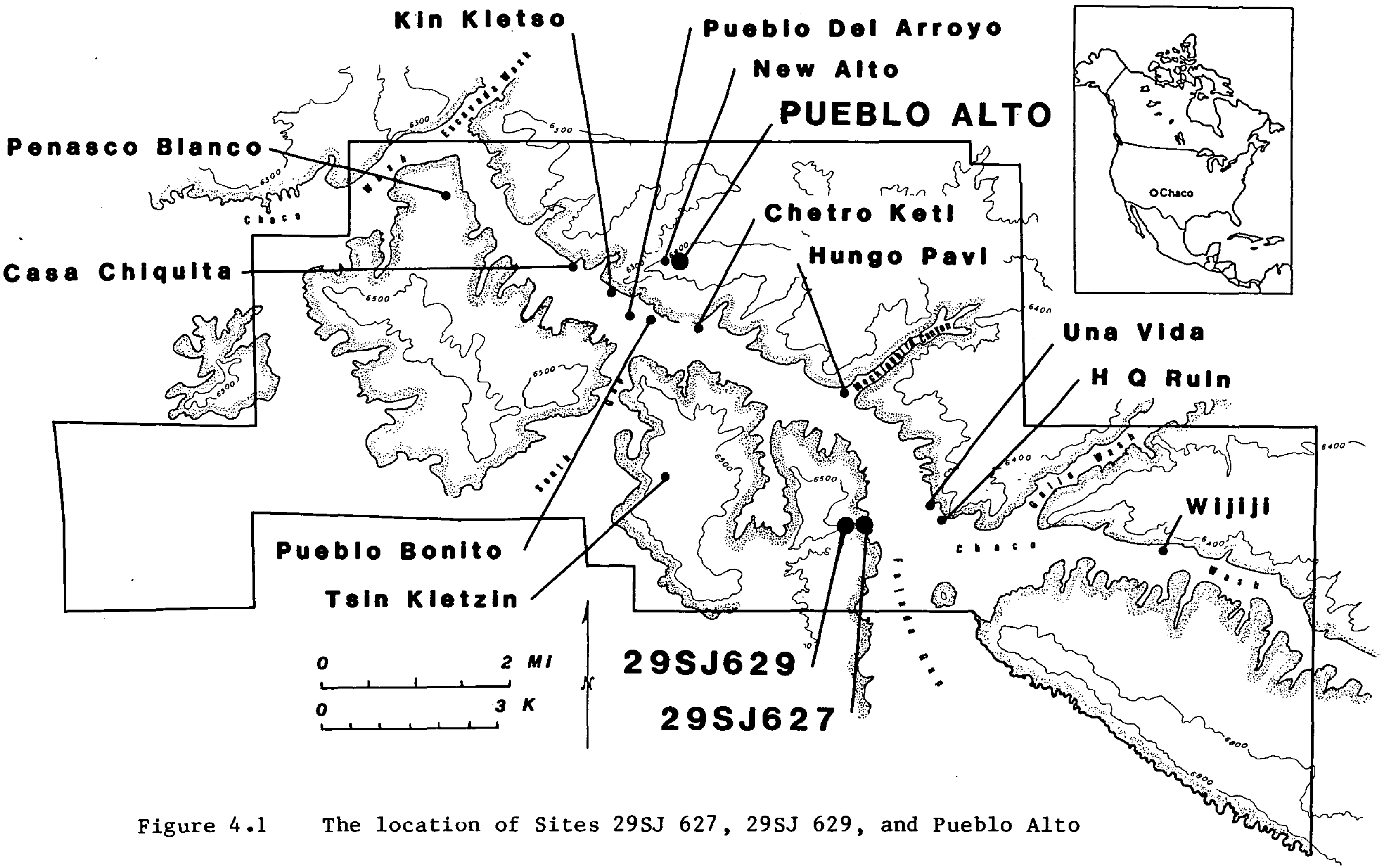

Figure 4.1 The location of Sites 29SJ 627, 29SJ 629, and Pueblo Alto

Pollen analysis is an important form of botanical study that can be used to find evidence of prehistoric plant utilization (Bohrer 1972; Dimbleby 1978; Hill and Hevly 1968). Pollen evidence of storage and preparation of domesticated and wild plant foods has been recovered from many sites in the Southwest (Adams 1980; Bohrer 1972, 1981; Hill and Hevly 1968; Scott 1978a; Weir 1976). In addition to this evidence, Hill and Hevly (1968) at Broken-K Pueblo determined how room function may have affected percentages of pollen grains from economic, or ethnobotanically important taxa, from domestic and wild plants. Pollen analysis has been used to reconstruct the past environment, using pollen samples from dated archeological sites (Bohrer 1972; Hevly 1964; Schoenwetter 1962, 1974; Schoenwetter and Eddy 1964). Recently, reports regarding the inherent problems in sampling from archeological sites have appeared (Cully 1979; Hall 1981a; Hevly 1981; Pippin 1979). Variability in results, differential preservation, and the possibility of changes in local pollen rain due to man's activities have been noted, as well as how these factors may affect the interpretation of the data in environmental reconstruction.

Recent pollen analysis at Chaco Canyon has focused on methodological and ethnobotanical considerations. Careful consideration has been given to sampling techniques. The floor contact level was heavily sampled to detect pollen evidence of plants which may have been brought into the site for subsistence, either for consumption as food or for raw material for construction, fuel, manufacturing, or ceremonial purposes. The development of a sampling methodology facilitated the identification of rooms where activities of plant preparation and storage may have taken place, and permitted comparisons of ethnobotanic information between different sites.

Methodology

Sampling

For sampling in rooms, a grid system was developed that was adaptable to the quadrant system used for excavation by the National Park Service. In each room, alternate lettered grids were sampled (Figure 4.2). The grid could be used in rooms of any size, and at any level of excavation--floor fill, floor contact, and floor levels. The same lettered grids were sampled at all levels. About 100 g of sediment were taken from each grid square. After processing, the results from the individual grid samples could be considered singly, and then compared in order to assess the differences between samples and to determine if any particular locations in a room were utilized for storage or preparation of plants. The results from individual grid samples from a room could also be combined, if necessary, to make comparisons between floors or between rooms within the site. All features were also sampled. Sampling in this way provided the opportunity to assess the variability within rooms, and ensured comparability between rooms, and later, between sites. This basic sampling plan was initiated during the second year of excavation at Site 29SJ 627. With some modifications, this plan was also used at Site 29SJ 629. At Pueblo Alto, the grid was modified to allow for a greater number of grid squares in some of the rooms that were much larger than any at the small sites. Each grid of

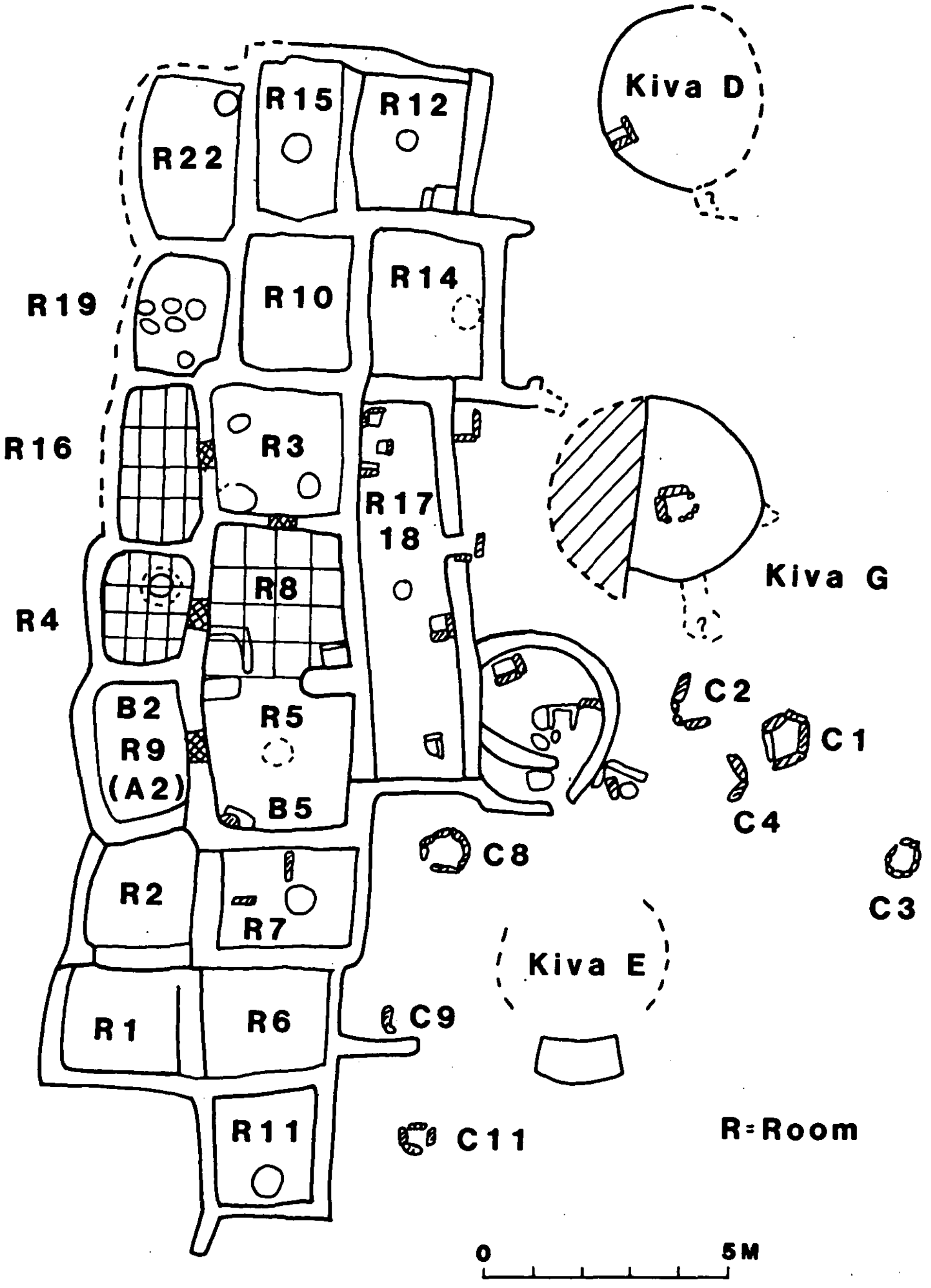

Figure 4.2 Site 29SJ 627 and Sampling Grid

approximately 1 square meter was numbered; a sample was taken from every other grid square (see section on Pueblo Alto). Modifying the sampling plan in this way allowed greater accuracy in locating areas that may have served special purposes involving the use of plants during storage, processing, or ceremonial activities. The increased number of samples (and the consequent increase in time and expense required for analysis) made it necessary to make composite samples from some rooms. Rooms 139, 142, 143, 145 and 147 from the North Roomblock and 229, 112, and Plaza Feature 1 were, depending on size, divided into 2 or 3 sections. A portion of the sediments was taken from each individual sample from the grid squares, and these portions were combined into one pollen sample for each section. For example, about 15 g of sediment were taken from each bag containing a pollen sample from individual grid squares in the northern third of Room 112 and combined into one sample, called Room 112 (North Composite). The resulting composite sample was thoroughly mixed in a clean plastic bag before processing. The grid samples from rooms 110, 103, Kiva 15, and Plaza 2 were processed individually. Initial work at 29SJ 627 indicated that the floor contact level (from the floor to about a centimeter above the floor surface) gave the best results; this level contained pollen dispersed from activities of domestic and wild plant preparation and storage. Pollen from the floors themselves was poorly preserved and difficult to identify. Careful attention was given to the origin of the fill above the floors, as contamination from trash dumping could occur in sediments from the floor contact level and lead to erroneous conclusions about room function (Cully 1977a). Samples from this level were processed and analyzed for 29SJ 627, 29SJ 629 and Pueblo Alto, as well as from selected samples from features associated with the floors, such as mealing bins, storage pits, and firepits.

Processing

Samples from the three sites were processed by the settling tube method, based on separation of particle sizes in a dispersing solution. Ten grams of sediment were taken from the bag, weighed, ground with a mortar and pestle, and washed through 100-mesh screen into clean beakers. Fiveten milliters of 20% hydrochloric acid (HCl) were added to the beakers and stirred several times. When the bubbling action stopped, the sample in solution was transferred to test tubes, centrifuged, decanted, and rinsed. A dispersing agent was used to rinse samples back into beakers. The sample was mixed thoroughly with the aid of a magnetic mixer and poured into settling tubes filled with dispersing agent. After two minutes, the large heavy sand grains had settled in the flexible tubing and a clamp was placed above that part of the tube. After 19 hours, the flexible tubing was removed and the sediment grain sizes above the clamp associated with the pollen were removed into a test tube. Large sand grain sizes and small clay and silt particles were left in the tube. The pollen bearing portion of the sediment was treated with 40% hydroflouric acid (HF) in a hot water bath. Spot checks of the large sand grain portion and the silt and clay portion of the samples were made to make sure they did not contain pollen. The samples were placed in an acetolysis solution and placed in a hot water bath. After this, the remaining portions of the samples were rinsed, placed in glass vials and slides were prepared using a glycerin mounting medium. Pollen extraction was done in the Micropaleontology Laboratory (Geology Department and the Castetter Laboratory for Ethnobotanical Studies, Biology Department, University of New Mexico).

Following Barkley (1934) I attempted to count 200 pollen grains for each sample, to reach the maximum number of taxa and ensure comparability between samples.

The terminology used follows Fieldguide to the Native Vegetation of the Southwest Region (USDA 1978) and A Flora of New Mexico (Martin and Hutchins 1980). Pollen identifications were made using How to Know the Pollen and Spores (Kapp 1969) and reference collections maintained by the Castetter Laboratory for Ethnobotanical Studies.

Site 29SJ 627

Description

Site 29SJ 627 is a small village located in a rincon on the southwest side of Chaco Wash. Construction episodes at 29SJ 627 are outlined by Truell (1981). The first building period consisted of two units of storage rooms and a pithouse; later episodes increased the number of aboveground rooms and subterranean structures. The ramada area was enclosed and made into regular rooms. Room function was determined on the basis of their position within the roomblock and the numbers and kinds of features associated with them. Storage rooms were located along the west side of the roomblock and were generally featureless, although large, bell-shaped storage cists and small, slightly burned, circular firepits were found in some storage rooms. Evidence of low-intensity burning suggests that the firepits were only used occasionally or that they contained materials that were heated elsewhere and then transferred to the pits. In spite of these features, the similarities in room shape and location indicate a function similar to that of other storage rooms. These rooms retain their positions within the roomblock through the reconstruction episodes, as do living and work areas, with well-used hearths and other evidence of living activities (Truell 1981).

Three rooms were chosen for intensive sampling. Rooms 4 and 16 (Figure 4.2) were part of the original construction and had been used throughout the occupation of the site. Room 8 initially served as part of the ramada area that was later completely enclosed during the final construction episode. In each room, several floors or use surfaces were uncovered during excavation (Figures 4.3-4.8). (Floor 1 was removed in 1974; since the sampling plan developed at this site was not put into effect until 1975, only Floor 2 and later floors are discussed here.) Various features, including firepits, were found associated with the floors; rather than a single function of the room being clearly defined by the architecture and presence or absence of features, rooms 16 and 4 seem to have included both storage and living functions at one time or another. As indicated by the presence of deep, well-burned firepits and other features, Room 8 may have been a locus for food processing and other living activities.

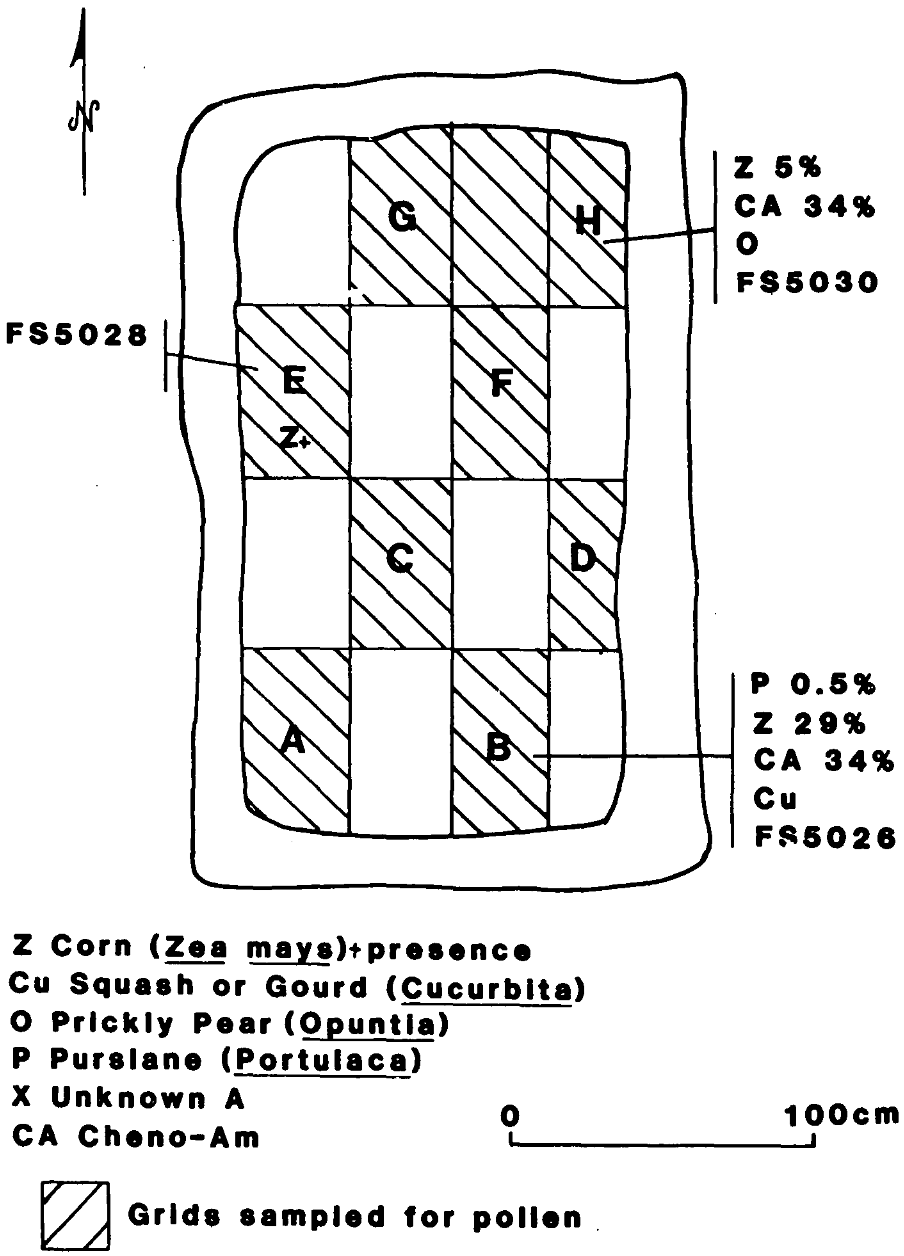

Figure 4.3 Room 16, Floor 2, Site 29SJ 627

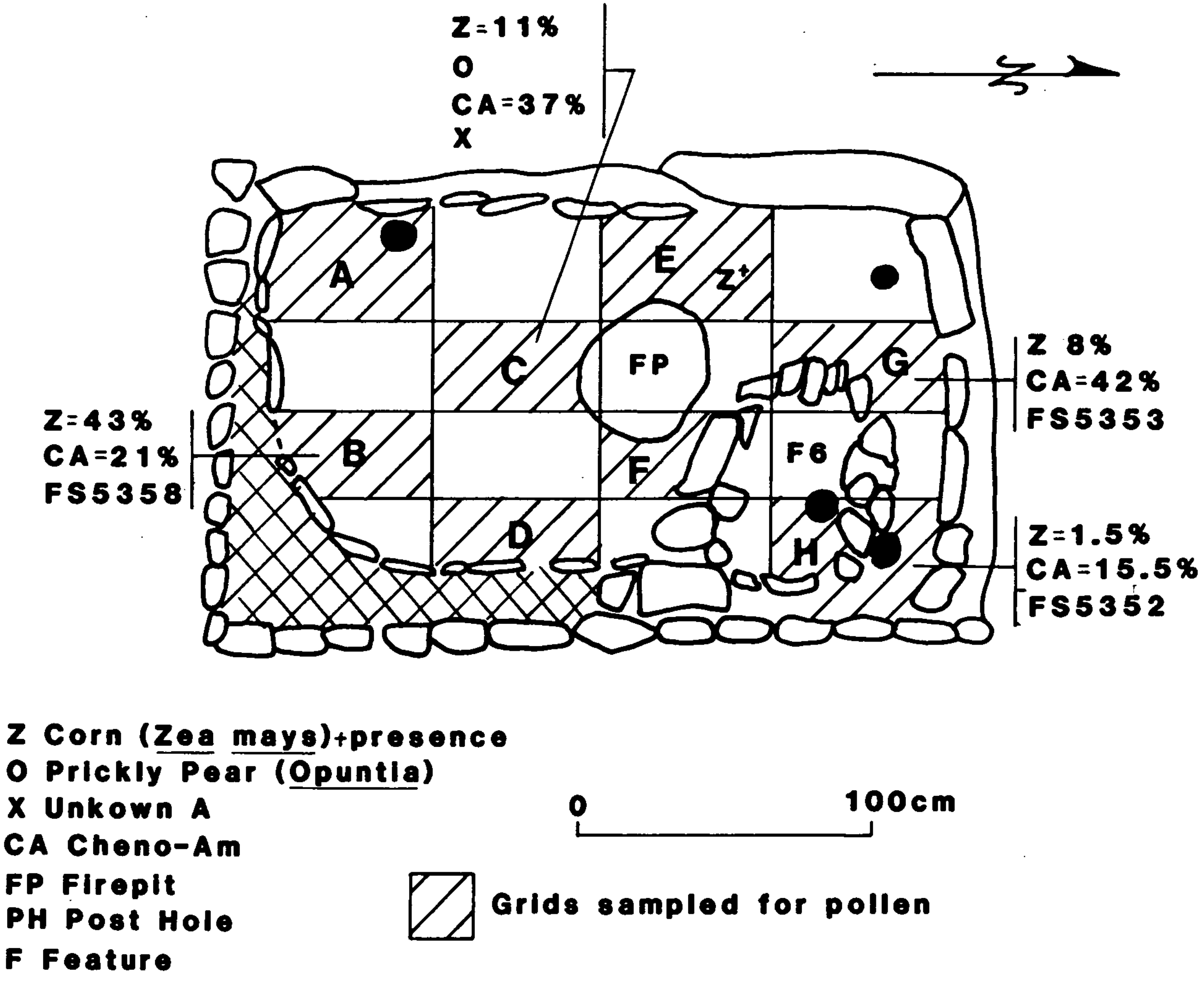

Figure 4.4 Room 16, Floor 3, Site 29SJ 627

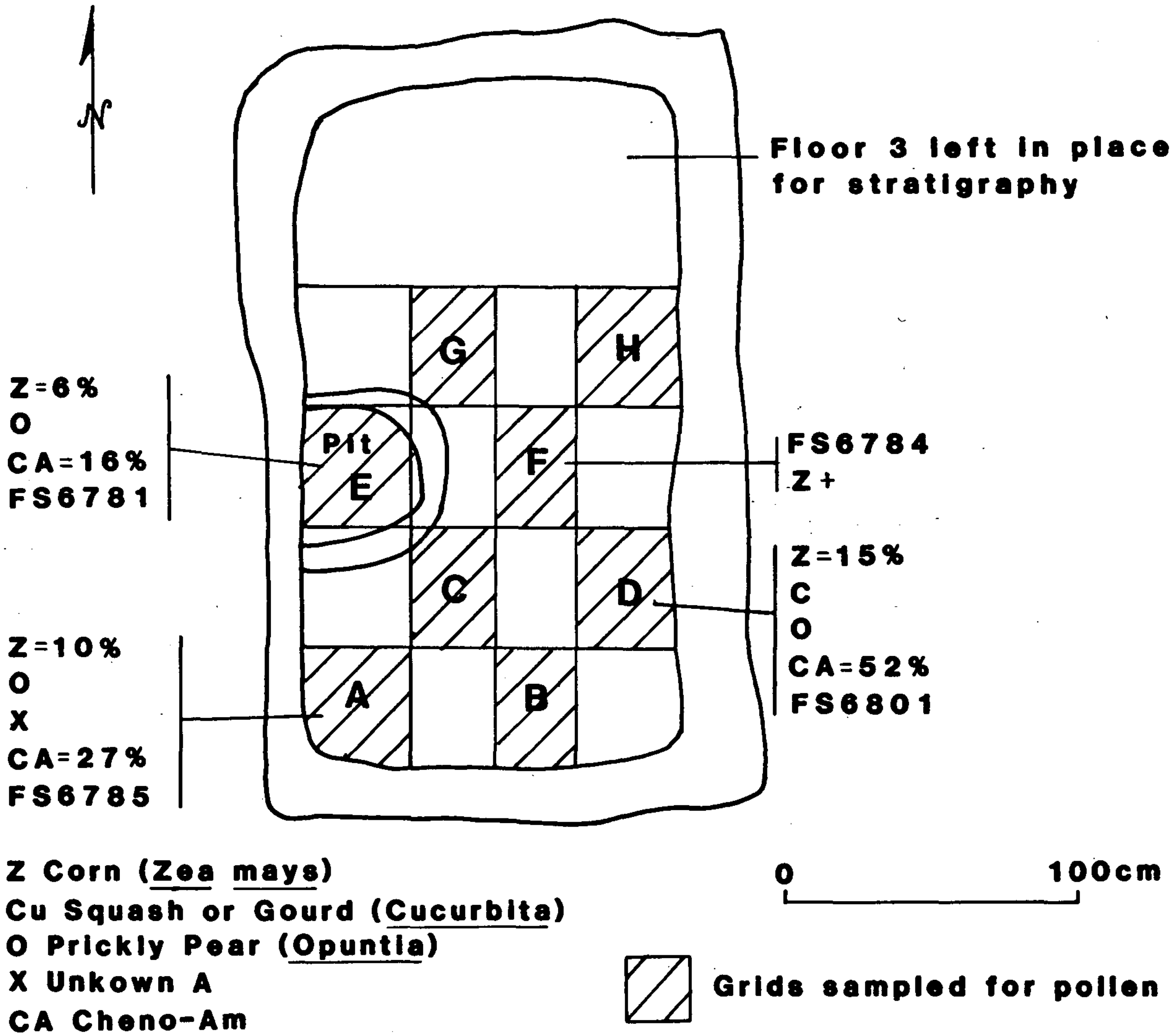

Figure 4.5 Room 16, Floor 4, Site 29SJ 627

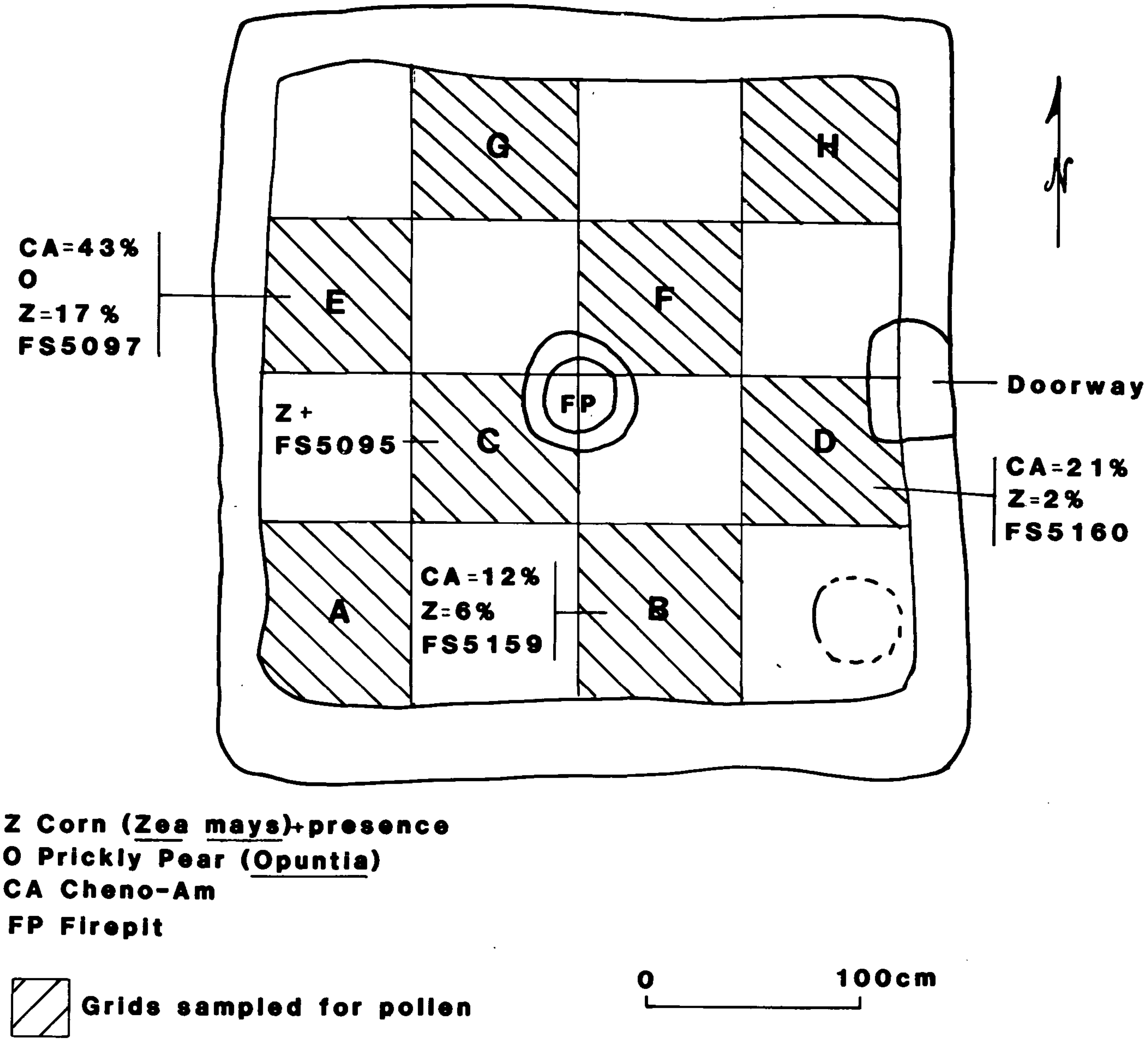

Figure 4.6 Room 4, Floor 2, Site 29SJ 627

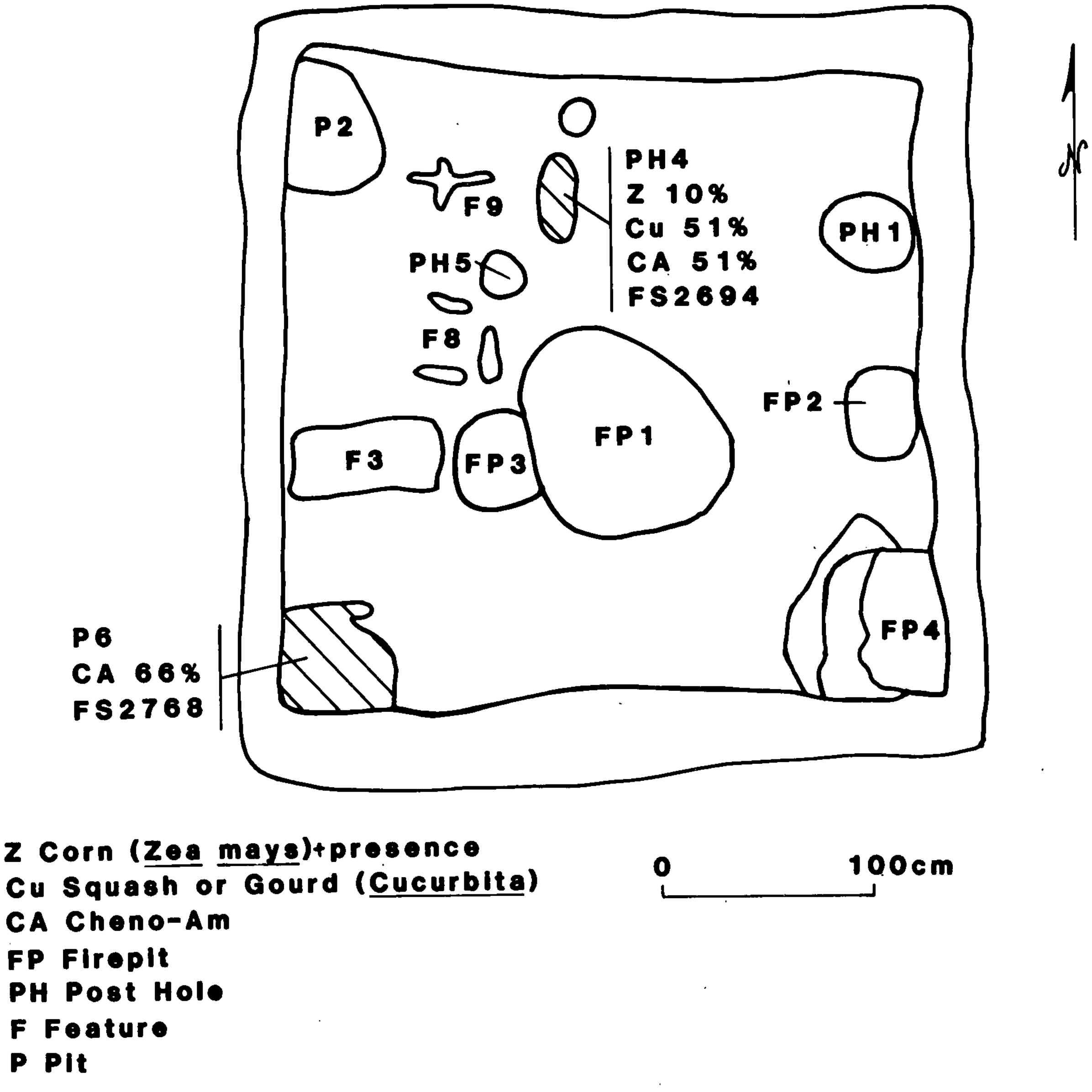

Figure 4.7 Room 8, Floor 2, Site 29SJ 627

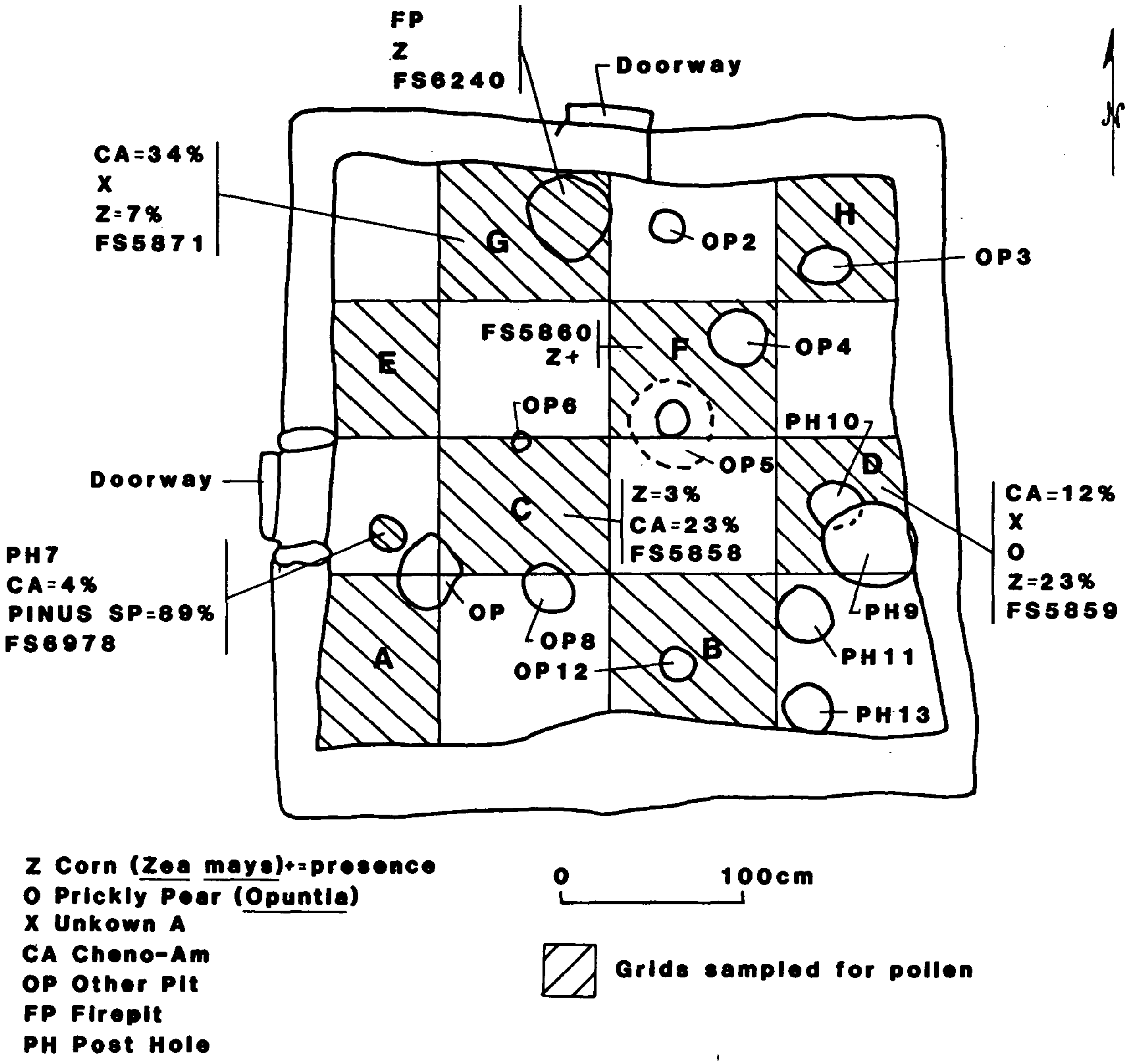

Figure 4.8 Room 8, Floor 3, Site 29SJ 627

Results of Analysis

Room 16

Floor 2. Room 16 was semisubterranean and oval in shape (Figures 4.3–4.5). The floor consisted of a layer of compacted earth with an adobe plug over the north part of the room. Floor 2 may have been a replastering or plugging of Floor 3 just below, in order to construct Floor 1. Truell (1981), however, believes that Floor 2 was formed during the second construction episode and was actually a use surface. No firepits or other features were associated with this floor. High concentrations of corn pollen and two cucurbit pollen grains were located in grid section B (Table 4.1; Figure 4.3). This may be the result of storage of corn and squash.

Corn is wind pollinated; however, it is rarely dispersed away from the fields in which it grows (Raynor et al. 1972). Corn pollen could have been introduced into the site in several ways, as the result of storage after harvesting, processing (shelling, grinding, cooking), or use for ceremonial purposes. Ethnographic descriptions of harvesting and storage at Zuni (Cushing 1920) and Hopi (Whiting 1939) relate that corn was picked, taken from the field, husked and stored. The Keres people roasted, dried, and stored corn ears with the husks on (White 1938). The Navajos pulled six complete corn stalks from the field prior to harvesting, and placed one in each of the six directions on the spot where the ears were to be stored (Hill 1938). Bohrer (1972) has shown that such harvesting, storing, and processing activities could result in dispersal of pollen into dwellings. There is also ethnographic documentation for the ceremonial use of corn pollen. The Cochiti people gather corn pollen from green corn plants and store it in jars (Lange 1959). Hill (1938) describes the Navajos gathering corn pollen when it first appears on the corn, to save for ceremonial use. The Zunis and Hopis use corn pollen in various ceremonies and blessings (Cushing 1920; Stephen 1936; Stevenson 1915). Cushing (1920) and Stevenson (1904) described the Zunis ritually blessing seed corn with corn pollen and making corn meal and pollen paintings on the floors of certain rooms during ceremonies as well as in rooms used for storing ceremonial objects. Stephen (1936) cites numerous examples at Hopi of the use of corn pollen in ceremonies in kivas, and in food packets attached to prayersticks. Corn pollen was used in blessing objects; a little was included with tobacco in cane cigarettes.

Pollen from the genus Cucurbita is large and spiny. Squash and gourds are insect pollinated and cucurbit pollen is unlikely to be part of the normal pollen rain. The presence of this taxon in an archeological site is likely due to introduction with the floral parts or with the fruits. The roots, fruits, and leaves of the buffalo gourd (C. foetidissima) a wild member of this genus, were used medicinally and as food (Jones 1930; Robbins et al. 1916; Swank 1932). Cushing (1920) reports that flowers were gathered from domestic squash plants in the late summer at Zuni, when the blossoms have little chance of producing mature fruit. The flowers were dried and stored for winter kitchen use. Beaglehole

Table 4.1 Pollen Results in Percentages from Floor Contact Samples, Site 29SJ 627

	ROOM 16								
	Floor 2				Floor 3				
	Grid Section B FS 2026	Grid Section E FS 5028	Grid Section H FS 5030	Floor Total	Grid Section B FS 5358	Grid Section C FS 5356	Grid Section G FS 5353	Grid Section H FS 5352	Floor Total
Abies (fir)	2			1					
Acer (maple)									
Juniperus (juniper)	1			1			1	1	0.2
Pinus (pine)	20		44	31	14	40	29	61	38
Populus (cottonwood)					3				0.2
Quercus (oak)									
Salix (willow)									
Cheno-Ams (Chenopodiaceae-Amaranthaceae)	34		34	34	21	37	42	16	30
Sarcobatus (greasewood)							1		0.2
Gramineae (grass family)	6		6	6	12	4	12	15	11
Compositae (sunflower family)	2		8	5	2	4	2	7	4
Artemisia (sagebrush)	2		1	1			1		0.2
Ephedra (Mormon tea)	1		2	1			1	1	1
Celtis (hackberry)									
Leguminosae (pea family)									
Liliaceae (lily family)					2		2	1	1
Malvaceae (globemallow family)			1	1	3	1			1
Opuntia (prickly pear family)			1	1		1			0.2
Portulaca (purslane)	1			1					
Scirpus (bulrush)									
Typha/Sparaganium (cattail/burreed)	1			1					
Type A-Cactaceae						1			1
Cucurbita (squash or gourd)	1			1					
Zea mays (corn)	29	+**	5	17	43	11	8	2	13
Other*	1		1	1		1	3	0.2	0.1
Total Count	209		193	402	121	141	210	200	672

Table 4.1 continued

	ROOM 16 Floor 4				Room 8 Floor 3				
	Grid Section A FS 6785	Grid Section D FS 6801	Grid Section E FS 6789	Floor Total	Grid Section C FS 5858	Grid Section D FS 5859	Grid Section G FS 5871	Grid Section F FS 5860	Floor Total
Abies (fir)									
Acer (maple)	1			0.2					
Juniperus (juniper)							2		1
Pinus (pine)	45	23	59	37	69	25	40		40
Populus (cottonwood)									
Quercus (oak)									
Salix (willow)									
Cheno-Ams (Chenopodiaceae-Amaranthaceae)	28	52	16	37	23	12	34		21
Sarcobatus (greasewood)									
Gramineae (grass family)	11	2	9	6	1	35	9		20
Compositae (sunflower family)	3	2	3	2	1	1	3		2
Artemisia (sagebrush)		2	5	2		1	1		1
Ephedra (Mormon tea)		1		1			1		1
Celtis (hackberry)					1				0.2
Leguminosae (pea family)		1		0.2		1	1		1
Liliaceae (lily family)		1		0.2					
Malvaceae (globemallow family)									
Opuntia (prickly pear cactus)	1	1	1	1		1			1
Portulaca (purslane)					1				0.2
Scirpus (bulrush)									
Typha/Sparaganium (cattail/burreed)		1	1	1			1		0.2
Type A-Cactaceae	2		1	1		1	1		1
Cucurbita (squash or gourd)		1		1					
Zea mays (corn)	10	15	6	12	3	23	7	+	13
Other*		1		0.2	1				0.2
Total Count 145	228	228	102	475	107	211	128		446

Table 4.1 continued

	ROOM 4 Floor 2					Room Totals		
	Grid Section B FS 5159	Grid Section E FS 5097	Grid Section C FS 5095	Grid Section D FS 5160	Floor Total	Room 16	Room 8	Room 4
Abies (fir)						0.3		
Acer (maple)	1				0.2	0.1		0.2
Juniperus (juniper)		1			1	0.4	1	
Pinus (pine)	65	23		58	46	42	40	46
Populus (cottonwood)						0.3		
Quercus (oak)								
Salix (willow)								
Cheno-Ams (Chenopodiaceae-Amaranthaceae)	12	43		21	28	39	21	28
Sarcobatus (greasewood)	3				1	0.1		1
Gramineae (grass family)	9	4		9	7	10	20	7
Compositae (sunflower family)	3	8		5	6	4	2	6
Artemisia (sagebrush)	1	2			1	1	1	1
Ephedra (Mormon tea)		1			1	1	1	1
Celtis (hackberry)							0.2	
Leguminosae (pea family)				1	0.2	0.1	1	0.2
Liliaceae (lily family)						1		0.2
Malvaceae (globemallow family)		1		2	1	1		1
Opuntia (prickly pear cactus)				1	1	1	1	1
Portulaca (purslane)						0.1	0.2	
Scirpus (bulrush)								
Typha/Sparaganium (cattail/burreed)						0.1	0.2	
Type A-Cactaceae				1	0.2	0.3	1	0.2
Cucurbita (squash or gourd)						0.3		
Zea mays (corn)	6	17	+	2	9	14	13	9
Other*		1		1	1	1	0.2	
Total Count	100	213		225	538	1549	446	538

*Other taxa, including *Rhus*, *Ribes*, Caprifoliaceae, Onagraceae, *Rhamnus*, Labiatae.
**When total pollen counts less than 100, + indicates pollen type noted.

(1937) reports that the Hopis served squash blossoms boiled with salt and grease.

Purslane (Portulaca) pollen also occurred in grid section B (Table 4.1; Figure 4.3). The pollen grains are large (greater than or equal to 60 microns), with minute spines (Kapp 1969). These characteristics indicate that the plants are insect pollinated. Purslane pollen is not commonly found in soil samples. When it does occur in an archeological site, it may be because purslane plants were brought in by man. Castetter (1935) reports the gathering, drying, and storing of purslane plants for the winter at Isleta, and the use of this plant for food by most of the modern Pueblo Indians. Medicinal uses for the seed are also reported for the Navajos by Elmore (1943). At Zuni, Cushing (1920) described purslane plants being pulled before the seeds were ripe. The entire plant was dried and the seeds were threshed by agitation or pounding. The seeds must have been highly valued; if the ripening had proceeded too far and the seeds had fallen to the ground, the Zunis swept the surface and winnowed the seed from the dirt.

Floor 3. This floor, made during the first construction episode, appears to be a resurfacing of Floor 4. The periphery of the room at the joining of the walls and floors was lined with upright stone slabs, which were covered with plaster (Figure 4.4; Truell 1981). A large circular cist (Feature 6), lined with ground stone artifacts, was located in the northeast portion of the floor. The floor contained a central firepit and postholes. Eggshells were found concentrated in the north half of the room. High percentages of corn pollen were found in grid section B (Table 4.1, Figure 4.4). Two prickly pear (Opuntia, platyopuntia type) and one Unknown A (Type A-Cactaceae) were found in Section C. Most cacti are insect pollinated and produce highly ornamented and complex pollen grains which are uncommon in the normal pollen rain. The presence of this taxon in an archeological site may reflect the use of the fruits and stems. Plains prickly pear (Opuntia polyacantha) was important to the Hopi when crops failed. The stems and the fruit were eaten. The fruits were sometimes dried for winter use, ground, and mixed with corn meal (Whiting 1939). Cushing (1920) reports that, at Zuni, cactus was gathered, dried, ground on a mealing slab, formed into cakes and stored. Plains prickly pear is common at Chaco Canyon today (Cully 1977b).

Cheno-Am percentages approach 50% in Section G. The Cheno-Am taxon is composed of pollen from the goosefoot family (Chenopodiaceae) and the pigweed family (Amaranthaceae), genus Amaranthus, which is generally indistinguishable to species with the light microscope. Members of these families are generally wind-pollinated, and include many weedy, annual species that are encouraged by soil disturbance. This pollen taxon is ubiquitous in sediment samples from the Southwest, which makes it difficult to determine whether plants of this group were being used in archeological sites. As with other wind pollinated plants, exceptionally high percentages suggest introduction by man. Bohrer (1972) reports that Cheno-Am percentages greater than 50% occur naturally only in surface soil samples from dense thickets of Chenopodiaceous shrubs. The use of seeds and green parts of goosefoot (Chenopodium) are documented among historic

Indian groups (Castetter 1935; Ford 1968; Jones 1930). The seeds of C. leptophyllum were an important food plant for the Zunis (Stevenson 1915). Castetter (1935) reports the greens of this species were used like Spinach by Navajo and Pueblo Indians. C. fremontii seeds were used ground in a meal by the Kayenta Navajo (Wyman and Harris 1951). Annual Atriplex species are also documented as being used for seed (ground and mixed with corn in a mush; Stevenson 1915) and as greens by the Navajo (Wyman and Harris 1951). Castetter (1935) reports the leaves of A. argentea are boiled and eaten as greens by Pueblo Indians of the Rio Grande Valley. The leaves of A. argenteum (argentea?) were boiled with fat and eaten, and this species is supposedly the earliest spring plant used for food. These species occur in Chaco Canyon today, some years in the great abundance typical of weedy annuals in response to favorable conditions (Cully 1977b).

In the family Amaranthaceae, members of the genus Amaranthus are documented as being useful to Pueblo and Navajo Indians. A. graecizans is reported by Castetter (1935) to have been used by the Cochiti as greens, and by the Navajos for ceremonial uses (Elmore 1943). A. hybridus was used at Acoma and Laguna as greens, and sometimes dried for winter use (Castetter 1935). These two species both occur at Chaco Canyon (Cully 1977b). Stevenson (1915) reports the use of A. blitoides at Zuni: the seeds were ground with corn meal, mixed with water, and made into cakes and steamed. A. cruentus (A. hybridus paniculatus, an introduced plant) was used in coloring he' we' or wafer bread made from corn meal. These plants were cultivated in irrigated gardens. Bohrer (1960) reports the continuation of this practice during her fieldwork at Zuni.

Floor 4. This floor was also associated with the first construction period. A single adobe-lined firepit, slightly burned, was found along the west wall (Figure 4.5). The fill contained 21 or more pieces of charcoal. The firepit had been plugged, but the floor may have continued to be used after the pit was closed. The north portion of the fill was left in place for preservation of stratigraphy (Truell 1981). The highest percentage of corn pollen occurred in Grid Section D, along with two cucurbit and one prickly pear pollen grains. Prickly pear and Unknown A (Type-A Cactaceae) pollen occurred in two other sections (Table 4.1, Figure 4.5).

In Room 16, there is a concentration of corn pollen in and around Grid Section B in the south part of the room throughout the three floors, suggesting that the same location was used for storage purposes during the entire use of Room 16. The presence of the slightly burned firepits supports the conclusion that some work activities were also carried out in Room 16 (Truell 1981), activities that may have been associated with processing or storage of corn, cucurbits, prickly pear cactus, and plants of the Cheno-Am group.

Room 4

Floor 2. Room 4 was constructed similarly to Room 16, but only a few slabs were found at the joining of the walls and Floor 2. The floor, associated with the first building construction, was plastered with gray clay, and was coped in places to meet the room walls. The floor was irregular and in poor condition. A shallow, slightly burned firepit was located in the center of the room, and an oval feature (Pit 2) in the southeast corner (Figure 4.6; Truell 1981). The highest percentage of corn pollen occurs in Grid Section E, along with one prickly pear pollen grain. Cheno-Am percentages were highest in this section. Samples taken from the actual floor yielded sparse, poorly preserved pollen.

Room 8

Room 8 was part of a ramada area in the earlier occupation of the site. Floor 2 (Figure 4.7) was constructed and used during the second building episode, when portions of the ramada area were enclosed and made into rooms (Truell 1981). This floor was not sampled with the grid system. Samples from two pits in this floor are reported in the Features section.

Floor 3. This floor was used during the first construction period, and formed a single, continuous surface under the walls of the later-constructed rooms 8 and 3 (Figures 4.2, 4.8). The ramada surface may never have been plastered, and was characteristically uneven and rough. There was a firepit on the north side of the room, and the floor was penetrated by many pits and postholes (Figure 4.8). The use of this area was probably associated with storage rooms 16 (floors 3 and 4) and 4 (Floor 2) (Truell 1981). The highest percentage of corn pollen occurred in Grid D. Prickly pear pollen was also present in this section. Unknown A (Type-A Cactaceae) pollen occurred in sections D and A. Pine pollen percentages were high in Section C (Table 4.1). Posthole 7, located next to Grid Section C contained higher percentages of pine pollen also (Figure 4.8; see Features section).

Features

Samples from 17 pit features were processed from rooms 16, 8, and 3. Six of these features yielded pollen information (Table 4.2). The pollen sample from Pit 2, Room 3, a plugged baking pit 65 cm x 68 cm in the southwest corner of the room, consisted entirely of Cheno-Am pollen. This could be the result of the use of shrubby, chenopodiaceous species (e.g., fourwing saltbush, Atriplex canescens) for fuel. In Room 8, Pit 6 was associated with Floor 2 (Figure 4.8). This shallow basin, approximately 50 cm x 52 cm in diameter and 6 cm in depth, was called a tool storage area (Truell 1981). An extremely high percentage of Cheno-Am pollen was found in the sample from this pit. Rodent disturbance suggests that this high percentage may be associated with storage activities of these animals rather than of humans. Struever (1977), notes that rodents make use of some of the same plant species as man for subsistence. A firepit, Pit 1, associated with Floor 3, contained corn pollen, possibly a result of cooking in the firepit. A pollen sample from Pit 7, a posthole, contained an extremely high percentage of pine pollen. The highest percentage from the floor contact samples from Floor 3 was 69%. The high pine pollen percentage in Pit 7 may be the result of sweeping material which contained pine

Table 4.2 Pollen Results in Percentages from Feature Samples, Site 29SJ 627

	ROOM 16	ROOM 8				ROOM 3
	Floor 3	Floor 2		Floor 3		Floor 1
	FP 4	Pit 4	Pit 6	FP 1	PH 17	Pit 2
	FS 5752	FS 2694	FS 2768	FS 6240	FS 6978	FS 245
Abies (fir)		1				
Acer (maple)						
Juniperus (juniper)			1			
Pinus (pine)		26	28		89	
Populus (cottonwood)						
Quercus (oak)						
Salix (willow)						
Cheno-Ams (Chenopodiaceae-Amaranthaceae)		51	66		4	100
Sarcobatus (greasewood)						
Gramineae (grass family)		2			3	
Compositae (sunflower family)		8	3			
Artemisia (sagebrush)			1		1	
Ephedra (Mormon tea)		1				
Celtis (hackberry)						
Leguminosae (pea family)						
Liliaceae (lily family)						
Malvaceae (globemallow family)			1		2	
Opuntia (prickly pear cactus)					1	
Portulaca (purslane)						
Scirpus (bulrush)						
Typha/Sparganium (cattail/burreed)						
Type A-Cactaceae		1				
Cucurbita (squash or gourd)		1				
Zea mays (corn)	+**	10		+		
Other*		1				
Total Count		217	146		102	200

*Other taxa including *Rhus*, *Ribes*, Caprifoliaceae, Onagraceae, *Rhamnus*, Labiatae.
**Total pollen counts less than 100, pollen type noted.

tree parts from the floor into the pit. The pit was filled with sand and shale and plugged with adobe (Truell 1981).

The comparison of percentages of pollen between all features and all floor contact samples are given in Figure 4.9. Corn pollen is found in higher percentages on floors than in features, and Cheno-Ams in higher percentages in features than on floors.

Variablility Between Grid Samples

Individual pollen samples from grid squares on each floor are different in frequencies of certain pollen taxa (Table 4.1). Figure 4.10 shows the highest and lowest percentages of key pollen types from two grid section samples from each floor. Room 16, Floor 3, sections B and H are widely different in percentages of pine and corn pollen. Room 8, Floor 3, sections C and D vary in percentages of pine, grass, and corn pollen. In Room 4, Floor 2, sections B and E, pine and Cheno-Am pollen percentages are extremely variable. Large differences in the frequencies of economic species could indicate the concentration of storage or processing activities in a particular part of the room. Because of the extreme differences in taxa in samples from grid sections, one sample from one location in a room does not necessarily represent the variability present in the entire floor contact layer. Thus, dependence on one sample from a single location for interpretation of room function, or for environmental information, could lead to mistaken interpretations.

Comparisons Between Rooms

The results of individual grid samples form each floor of rooms 16, 4, and 8 were combined (Table 4.1). The total pollen counts for floors 2, 3, and 4 in room 16, Floor 2 in Room 4 and Floor 3 in Room 8 were compared (Figure 4.9). The combination of results from grid sections gives a less variable sample of each room as a whole. At Site 29SJ 627, the pollen spectra from the three rooms were similar, suggesting that similar activities occurred in each room.

Room and Feature Function

At Broken K Pueblo, Hill and Hevly (1968) attempted to relate room function to the presence of pollen from domestic or wild plant resources and the relative percentages of these taxa. Pollen types of ethnobotanic importance include corn, squash, gourd, cactus, purslane, and others which are documented in ethnographic literature as being important to modern southwestern Indian groups for food, fuel, construction, and manufacturing. There were fewer of the economically important pollen taxa in living rooms (characterized by firepits, heating pits, mealing bins, etc.) than in storage rooms (featureless). The relative percentages of these taxa were also lower in living rooms than in storage rooms at Broken K Pueblo.

Palynological evidence suggests that at least limited living activities occurred in all the rooms sampled. Corn pollen was consistently higher in percentage in the south part of the floors in Room 16, suggest-

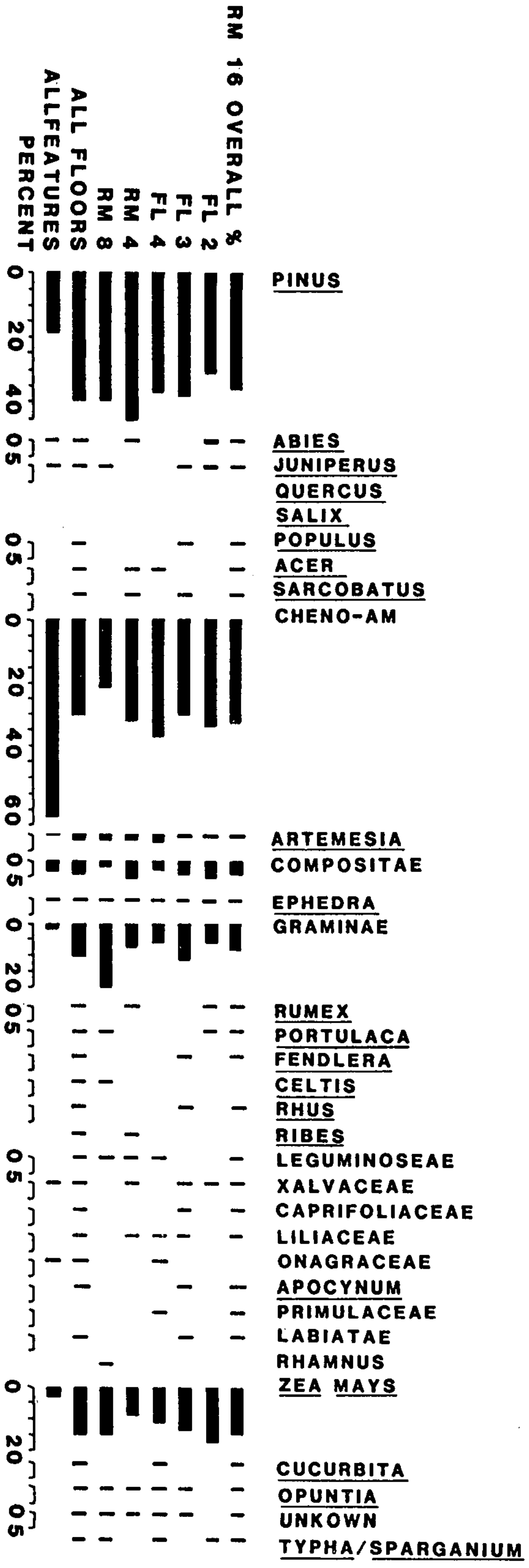

Figure 4.9 Pollen percentages of rooms, floors, combined floors and combined features, Site 29SJ 627

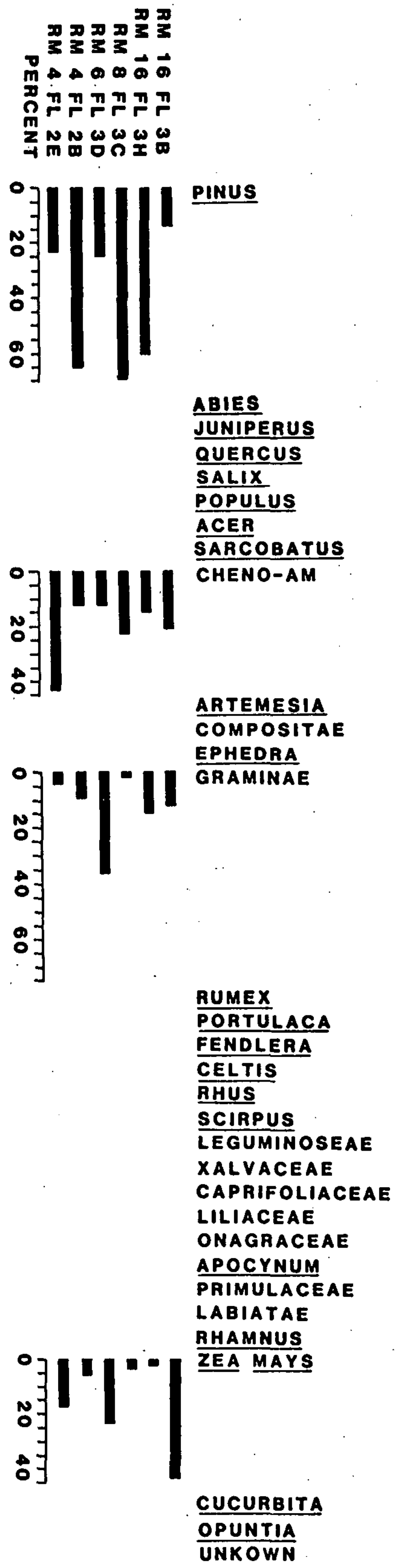

Figure 4.10 Pollen percentages of certain taxa from two grid squares from each room, Site 29SJ 627

ing that storage or processing of corn occurred in this area throughout the use of the room. Pollen samples from features were higher in Cheno-Ams than samples from floors; samples from floors were higher in corn pollen than those from features. The total percentage of Cheno-Am pollen is skewed by the high percentage of this taxon in a single Feature (Table 4.2).

Site 29SJ 629

Description

Site 29SJ 629 is a small village located close to Site 29SJ 627. The site was excavated during the summers of 1975 and 1976. Initial construction at this site produced a pithouse and a row of contiguous aboveground rooms. Between the pithouse and the surface structures was a plaza area with several large, bell-shaped cists or pits in front of the rooms. The presence of postholes indicates that a ramada was constructed over part of the plaza. During later construction, several rooms were added at both ends of the site and two pit structures were built (Figure 4.11; Windes 1978).

Initial work at 29SJ 627 focused on methodological considerations. Several rooms were intensively sampled and the resulting material processed and analyzed. This approach resulted in a better understanding of how sampling methodology can affect the results and interpretation of data from pollen analysis. Excavations at 29SJ 629 provided an opportunity to apply what was learned at 29SJ 627 and focus on questions relating to subsistence and function. Samples from 29SJ 629 were taken from the floor contact levels, and from mealing bins, storage pits, and firepits associated with the floors. The grid pattern was modified at 29SJ 629 to accommodate irregularly shaped rooms (Figure 4.11). Unless otherwise designated, the samples included in this report are from the last occupation (Floor 1) of each room or pithouse.

Results of Analysis

Rooms 5 and 6

Rooms 5 and 6 are adjacent to one another (see Figure 4.11); since they lack firepits, mealing bins, and other features associated with living rooms, they may have served as storage rooms (Figures 4.12 and 4.13; Windes 1978).

Room 5. This room was probably constructed in the A.D. 800s, and may be one of the earliest at the site (Windes 1978). The floor was unplastered. Sampling was limited in this room because of disturbance by an extensive ant colony (Figure 4.12). The south half of the room was represented by several pollen samples, only one of which contained adequate pollen for analysis (FS784, see Table 4.3 for results). This sample is characterized by the highest percentage of willow (Salix) pollen in the site. Willows are considered to be insect pollinated, but their pollen is often blown about by the wind and is present in low percentages in some

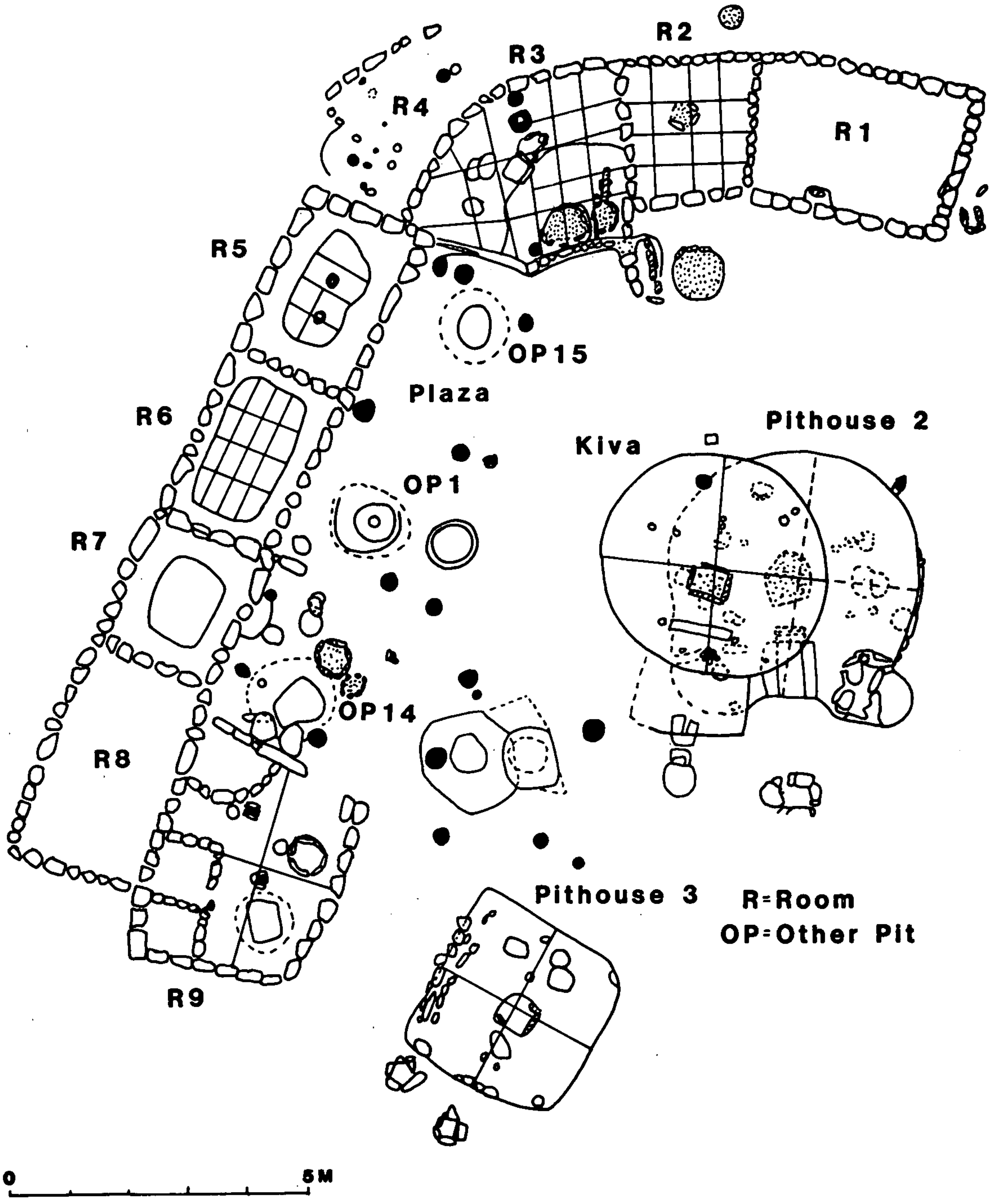

Figure 4.11 Site 29SJ 629 and Floor Sampling Grid

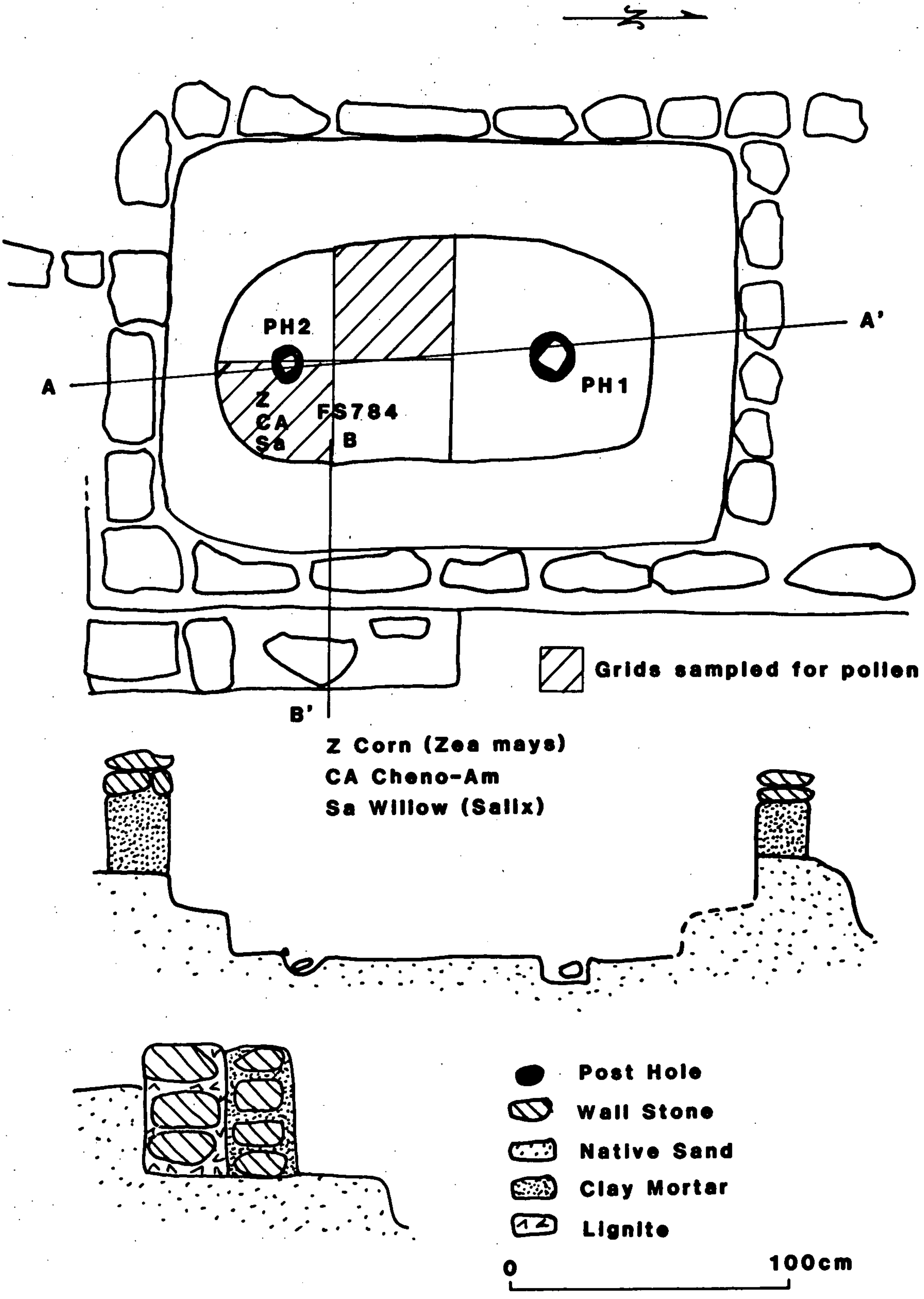

Figure 4.12 Room 5, Site 29SJ 629

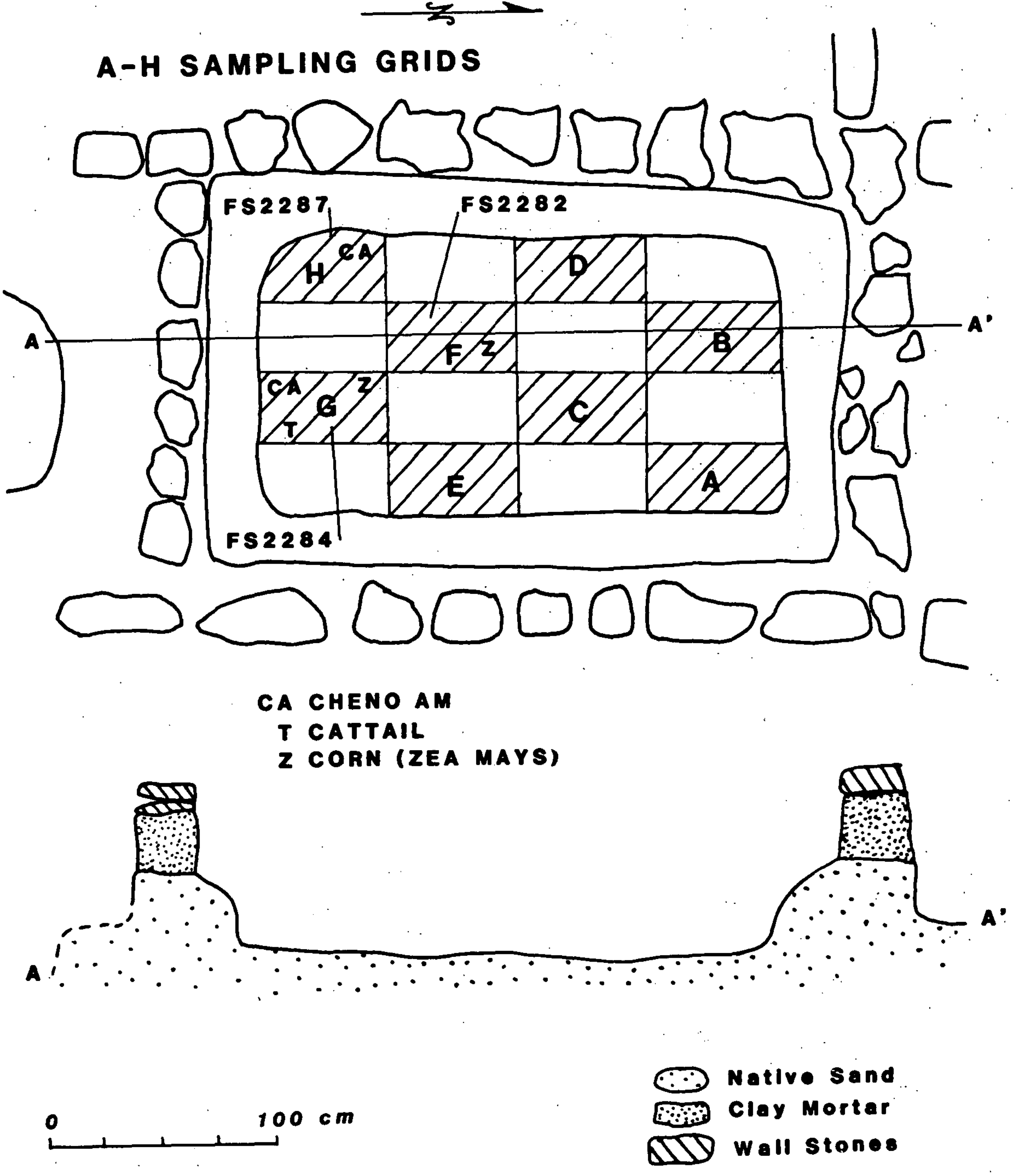

Figure 4.13 Room 6, Site 29SJ 629

Table 4.3 Pollen Results in Percentages from Floor Contact Samples, Rooms 2, 3, 5, 6, and 9, Site 29SJ 629

	ROOM 5	ROOM 6				ROOM 9		
	South half FS 784	SW 1/4 of W 1/4 FS 2287	SW 1/4 of SE 1/4 FS 2284	NE 1/4 of SW 1/4 FS 2282	Room Total	FS 789	FS 790	Room Total
Abies (fir)								
Acer (maple)								
Picea (spruce)		1	3		2			
Juniperus (juniper)	5	1			1			
Pinus (pine)	14	14	21		17	24	11	17
Pseudotsuga (Douglas fir)								
Populus (cottonwood)			2		1			
Quercus (oak)		0.4			0.1			
Salix (willow)	4		0.4		0.1			
Juglans (walnut)								
Oleaceae (olive family)		3			2			
Cheno-Ams (Chenopodiaceae-Amaranthaceae)	58	55	54		55	59	81	70
Sarcobatus (greasewood)	0.4	1	4		3	1		0.2
Gramineae (grass family)	10	7	6		6	3	3	3
Compositae (sunflower family)	1	6	1		4	5	0.4	2
Low-spine Compositae (spines < 2 microns)								
High-spine Compositae (spines > 2 microns)								
Artemisia (sage brush)	1	3	1		2		2	1
Ephedra (Mormon tea)		2	0.4		1	1		0.4
Celtis (hackberry)	0.4							
Cruciferae (mustard family)		0.4			0.1			
Fraxinus (ash)								
Cyperaceae (sedge family)						3		1
Leguminosae (pea family)	2		0.4		0.1	4		2
Liliaceae (lily family)	0.4	1			1			
Yucca (yucca)	0.4							
Malvaceae (globemallow family)	0.4		1		0.3	1	2	1
Sphaeralcea (globemallow)								
Rosaceae (rose family)		1			0.3			
Solanaceae (potato family)								
Lycium (wolfberry)								
Solanum (wild potato)								
Parthenocissus (Virginia creeper)			0.4		0.1			
Scirpus (bulrush)								
Opuntia (prickly pear cactus)								
Portulaca (purslane)	0.4					1		0.2
Typha (cattail)			0.4		0.1			
Type A-Cactaceae								
Cleome (beeweed)								
Cucurbita (squash or gourd)								
Zea mays (corn	2		0.4	+**	0.1	1		0.2
Other*	3	6	5		5		1	0.4
Total	248	278	239		517	220	279	449

Table 4.3 continued

	ROOM 2					ROOM 3					
	Grid A FS 331	Grid B FS 334	Grid E FS 336	Grid F FS 337	Room Total	Grid I FS 1118	Grid K FS 1120	Grid F FS 650	Grid H FS 651	Grid D-2 FS 779	Grid D FS 780
Abies (fir)											
Acer (maple)											
Picea (spruce)											
Juniperus (juniper)	1				0.2						
Pinus (pine)	13	15	0.4	12	10	19	34				
Pseudotsuga (Douglas fir)											
Populus (cottonwood)											
Quercus (oak)											
Salix (willow)	1				0.2						
Juglans (walnut)											
Oleaceae (olive family)											
Cheno-Ams (Chenopodiaceae-Amaranthaceae)	56	73	5	19	42	33	28				
Sarcobatus (greasewood)	2	3			2	1	1				
Gramineae (grass family)	9	6	89	65	35	22	18				
Compositae (sunflower family)		2		1	1	10	2				
Low-spine Compositae (spines < 2 microns)											
High-spine Compositae (spines > 2 microns)											
Artemisia (sage brush)				1	0.1		2				
Ephedra (Mormon tea)	0.3						1				
Celtis (hackberry)											
Cruciferae (mustard family)							1				
Fraxinus (ash)											
Cyperaceae (sedge family)		1			0.1						
Leguminosae (pea family)	1				0.3	1	1				
Liliaceae (lily family)											
Yucca (yucca)											
Malvaceae (globemallow family)	2				1	15	11				
Sphaeralcea (globemallow)											
Rosaceae (rose family)	1				0.2						
Solanaceae (potato family)											
Lycium (wolfberry)											
Solanum (wild potato)											
Parthenocissus (Virginia creeper)											
Scirpus (bulrush)											
Opuntia (prickly pear cactus)	0.2		0.4		0.2						
Portulaca (purslane)	1				0.4				+		
Typha (cattail)											
Type A-Cactaceae	0.2							+			
Cleome (beeweed)											
Cucurbita (squash or gourd)											
Zea mays (corn)	12	2	5	2	7	2	1	+	+	+	+
Other*	0.2				0.1		1				
Total	403	157	228	100	888	93	211				

Table 4.3 continued

	ROOM 3			
	Grid C FS 781	Grid A FS 1116	Grid E FS 1117	Room Total
Abies (fir)	1		1	0.4
Acer (maple)				
Picea (spruce)				
Juniperus (juniper)				
Pinus (pine)	34	31	40	31
Pseudotsuga (Douglas fir)				
Populus (cottonwood)			1	1
Quercus (oak)				
Salix (willow)	2		3	1
Juglans (walnut)				
Oleaceae (olive family)				
Cheno-Ams (Chenopodiaceae-Amaranthaceae)	38	11	27	27
Sarcobatus (greasewood)	2	2		1
Gramineae (grass family)	6	5	7	11
Compositae (sunflower family)	6	6	7	5
Low-spine Compositae (spines < 2 microns)				
High-spine Compositae (spines > 2 microns)				
Artemisia (sage brush)	2	17	4	5
Ephedra (Mormon tea)	1	2	1	1
Celtis (hackberry)				
Cruciferae (mustard family)				0.1
Fraxinus (ash)				
Cyperaceae (sedge family)				
Leguminosae (pea family)	3		1	2
Liliaceae (lily family)	2			1
Yucca (yucca)				
Malvaceae (globemallow family)	1			6
Sphaeralcea (globemallow)		11	3	2
Rosaceae (rose family)		5		1
Solanaceae (potato family)				
Lycium (wolfberry)				
Solanum (wild potato)				
Parthenocissus (Virginia creeper)				
Scirpus (bulrush)				
Opuntia (prickly pear cactus)		3		1
Portulaca (purslane)	1	1		1
Typha (cattail)				
Type A-Cactaceae			1	0.1
Cleome (beeweed)				
Cucurbita (squash or gourd)				
Zea mays (corn)	2	5	4	2
Other*	3	1		2
Total	195	127	75	701

*For other taxa, see Cully (1983).
**When total pollen counts less than 100, + indicates pollen type noted.

surface samples and occasional archeologically derived samples. In Room 5, willow branches may have been used in roofing materials. Willow was used by the Hopis in roof construction (Whiting 1939). Cheno-Am pollen counts were high (57.8%). A small amount of corn (Zea mays) pollen was recovered.

Room 6. The floor of this room was unplastered, but apparently smoothed to reduce irregularities (Windes 1978). Sampling in this room was also restricted to the south half (Figure 4.13). Samples from this room were high in Cheno-Ams. Rooms 5 and 6 were roofed with an unidentified shrubby plant material (Windes 1978). It is possible that this shrubby material may be from plants of the Cheno-Am group, which includes saltbush (Atriplex). Such shrubby material could create an artificially high Cheno-Am count in rooms 5 and 6. One sample, FS2284, contained cattail (Typha) pollen. Cattail pollen occurs in tetrads, or groups of four. Cattail is a wind pollinated plant that produces abundant pollen. Its short dispersal distance (Potter and Rowley 1960) makes it unlikely to find naturally dispersed cattail pollen in a site, unless the site is near a riparian habitat. Ethnographic evidence suggests that this taxon could have been introduced into Site 29SJ 629 on plant parts brought in for use as food, matting, or construction (Castetter 1935; Jones 1930; Swank 1932). Whiting (1939) and Stevenson (1904) also report that cattails are used ceremonially by the Hopis because they are associated with water. Corn pollen was found in two of the three samples processed (Figure 4.11; Table 4.1).

Rooms 2 and 3

According to Windes (1978), rooms 2 and 3 may have been used together as a unit. Room 3 was probably enclosed as an extension of the ramada, in somewhat the same way as remodeling occurred at Site 29SJ 627. Room 3 may have been built in the late A.D. 900s, after rooms 5, 6 and 7, and used until abandonment of the site. Room 2 may postdate Room 3 and was probably used as an adjunct to Room 3 in the A.D. 1000s (Windes 1978). The presence of numerous features, such as firepits, heating pits, and several other pits of uncertain function in Room 3 and a firepit in Room 2, indicates these were rooms of activities of food preparation. The presence of burned remains of domesticated and wild foods in fill and on the floors of these rooms reinforces this, as does the presence of certain types of pollen. Rodent disturbance has occurred in both rooms (Windes 1978), however, making it possible to confuse human and rodent introduction.

Room 2. This room contained a firepit (Figure 4.14). Charred vegetal remains were found in Layer 2 of the floor fill, including twine, corn, beans, cactus pads, and a thick layer of material identified as grasses (Windes 1978). Corn pollen and high percentages of grass pollen occurred in FS336 and FS337 (88.6% and 65.0%). Although some species are self-pollinating, most grasses are wind pollinated. Grass pollen is spherical in shape and has one pore (Wodehouse 1959). Different species of grasses produce pollen which is difficult to distinguish and is often lumped into one taxon, that of the family Gramineae. As with other wind pollinated taxa, high percentages of grass pollen in an archeological site

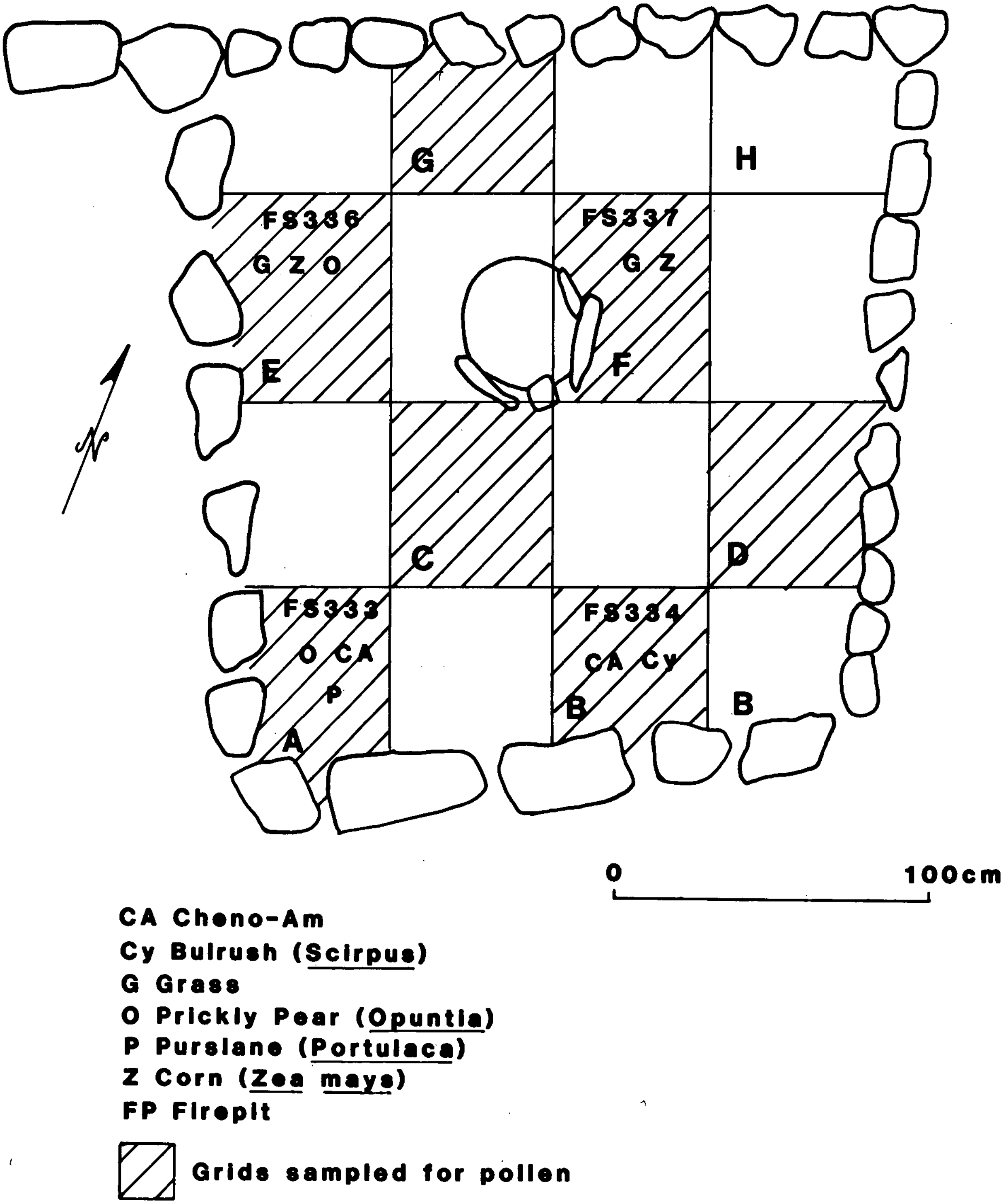

Figure 4.14 Room 2, Site 29SJ 629

suggests the use of seeds or stems. The Hopi collected Indian ricegrass (*Oryzopsis hymenoides*) and dropseeds (*Sporobolus* cryptandrus, *S. airoides*, *S. giganteus*, *S. contractus* and *S. flexuosus*) seeds and ground them into meal (Whiting 1939). Six-weeks fescue (*Festuca octoflora*) was planted with early corn and eaten by the Kayenta Navajos (Wyman and Harris 1951). The stems of blue grama grass (*Bouteloua gracilis*) were used as brushes. The stems of the common reed (*Phragmites communis*) were used for roofing, arrow shafts, popes, weaving rods, and prayer sticks (Elmore 1943; Robbins et al. 1916; Whiting 1939). High percentages of Cheno-Ams were found in sections A and B (Table 4.3; Figure 4.14). Prickly pear cactus (*Opuntia* - platyopuntia type) also was noted in sections A and B. Small percentages of purslane pollen were identified in Section A. Section B contained bulrush (Cyperaceae) pollen.

Room 3. Two firepits, two heating pits, and two slab-lined pits were found in this room. One of these slab-lined pits, Other Pit 1, was sampled and analyzed for pollen (see section on Features; Table 4.4). Other Pit 2 contained corn cob and wood fragments, and squash seeds (Toll 1981a). Corn pollen was present in nearly all the floor contact samples from this room. Several samples contained high percentages of pollen types that are usually present in low numbers; for example, FS1116 and FS1120 contained high percentages of grass pollen and globemallow (family Malvaceae) pollen. The large, echinate (spiny) pollen produced by most members of this family are morphologically adapted to insect pollination. Globemallow pollen (mostly *Sphaeralcea* type) is common in low percentages in surface and archeological samples; however, high percentages of this type in samples from archeological sites suggest introduction of other plant parts. Ethnobotanical accounts of the use of *Spaeralcea* describe medicinal uses. At the Hopi villages, the root is chewed or boiled for broken bones, or taken with cactus roots for bad digestion (Whiting 1939), while at Picuris the root was pounded up, water added and the paste applied over a broken bone that had been set. After drying it formed a cast (Krenetsky 1964). Section A contained a high percentage of sagebrush (*Artemisia*) pollen (Table 4.3). The high percentage of this wind pollinated genus may be due to the use of sagebrush for fuel. The dry bushes are used by the Tewas for fuel (Robbins et al. 1916). Various species of sagebrush are used by the Navajos. Big sagebrush (*A. tridentata*) is taken in an infusion for headache, colds, fevers, and before great physical exertion (Elmore 1943; Wyman and Harris 1951). At Hopi, false tarragon (*A. dracunculoides*) leaves were gathered, baked between hot stones, and dipped in salted water before eating (Whiting 1939). Welsh (1978) reports big sagebrush (*Artemisia tridentata*) remains in the charcoal from Heating Pit 1 (Figure 4.12).

In both rooms 2 and 3, sampling by grids has revealed an interesting array of pollen types from various locations (Figures 4.14 and 4.15). To a certain extent, flotation remains reflect this variety of taxa (although not necessarily the same taxa indicated by pollen analysis) and the same patchiness of distribution. Room 3 contained a diversity of plant items in flotation samples, including winged pigweed (*Cycloloma atriplicifolium*) seeds, a globemallow (*Sphaeralcea*) seed, as well as Cheno-Ams, purslane (*Portulaca*, tansy mustard (*Descurainia*), stickleaf (*Mentzelia*), spurge (*Euphorbia*), and burned corn cupules (FS1112, 1114, 654, 653; Toll 1981a). In Room 2 a wide variety of plant types occurred in flotation also, for

Table 4.4 Pollen Results in Percentages from Plaza Area, Pithouses and Features, Site 29SJ 629

	PLAZA AREA	PITHOUSE 1/KIVA	PITHOUSE 2	PITHOUSE 3			
	Plaza Grid 8 Section F Level 3 FS 1494	FS 2066	SE Quad. FS 337	Central Area FS 2623	SW Quad. FS 2619	SE Quad. FS 2620	Room Total
Abies (fir)		5	2	2		2	1
Acer (maple)							
Picea (spruce)		1					
Juniperus (juniper)	0.4	1	2				
Pinus (pine)	11	20	44	5	16	24	17
Pseudotsuga (Douglas fir)							
Populus (cottonwood)					0.3	0.4	0.3
Quercus (oak)							
Salix (willow)	0.4						
Juglans (walnut)							
Oleaceae (olive family)	0.4		1			0.4	0.1
Cheno-Ams (Chenopodiaceae-Amaranthaceae)	47	51	32	2	3	6	4
Sarcobatus (greasewood)	0.4	8	2		9	0.4	4
Gramineae (grass family)	10	1	4	6	4	3	4
Compositae (sunflower family)	1	1	2	1	1		1
Low-spine Compositae (spines < 2 microns)							
High-spine Compositae (spines > 2 microns)							
Artemisia (sage brush)	3	4	1	2	3		2
Ephedra (Mormon tea)	3	2	2				
Celtis (hackberry)					0.3	0.4	0.3
Cruciferae (mustard family)		1	1				
Fraxinus (ash)							
Cyperaceae (sedge family)							
Leguminosae (pea family)	2	1	1		1		1
Liliaceae (lily family)	0.4						
Yucca (yucca)							
Malvaceae (globemallow family)	0.4						
Sphaeralcea (globemallow)					0.3	1	1
Rosaceae (rose family)							
Solanaceae (potato family)							
Lycium (wolfberry)							
Solanum (wild potato)							
Parthenocissus (Virginia creeper)	0.4						
Scirpus (bulrush)							
Opuntia (prickly pear cactus)			2	7	1	4	4
Portulaca (purslane)							
Typha (cattail)	0.4	2			1		1
Type A-Cactaceae			1	3			1
Cleome (beeweed)							
Cucurbita (squash or gourd)							
Zea mays (corn)	17	2	1	73	56	55	59
Other*	3	1		5	1	1	1
Total	258	223	188	118	263	225	606

Table 4.4 continued.

	FEATURES			
	OP1, F1.12 FS 2094	OP14, L7 FS 2066	Room 3 Pit 6 FS 1237	Feature Totals
Abies (fir)	5	2		2
Acer (maple)				
Picea (spruce)		1		0.1
Juniperus (juniper)	1	1		1
Pinus (pine)	11	3	7	8
Pseudotsuga (Douglas fir)				
Populus (cottonwood)	2			1
Quercus (oak)				
Salix (willow)				
Juglans (walnut)				
Oleaceae (olive family)				
Cheno-Ams (Chenopodiaceae-Amaranthaceae)	37	14	7	19
Sarcobatus (greasewood)	1			0.3
Gramineae (grass family)	9	1	75	34
Compositae (sunflower family)	2	2	1	1
Low-spine Compositae (spines 2 < microns)				
High-spine Compositae (spines 2 > microns)				
Artemisia (sage brush)	4	4		2
Ephedra (Mormon tea)				
Celtis (hackberry)				
Cruciferae (mustard family)				
Fraxinus (ash)				
Cyperaceae (sedge family)				
Leguminosae (pea family)	2			1
Liliacea (lily family)				
Yucca (yucca)				
Malvaceae (globemallow family)				
Sphaeralcea (globemallow)				
Rosacea (rose family)				
Solanaceae (potato family)				
Lycium (wolfberry)				
Solanum (wild potato)				
Parthenocissus (Virginia creeper)	1		0.3	0.3
Scirpus (bulrush)				
Opuntia (prickly pear cactus)	2	2	0.2	
Portulaca (purslane)				
Typha (cattail)				
Type A-Cactaceae	1			1
Cleome (beeweed)				
Cucurbita (squash or gourd)	2			1
Zea mays (corn)	19	70	11	26
Other*	5	1	1	2
Total	205	113	222	540

*For other pollen taxa, see Cully, (1983).

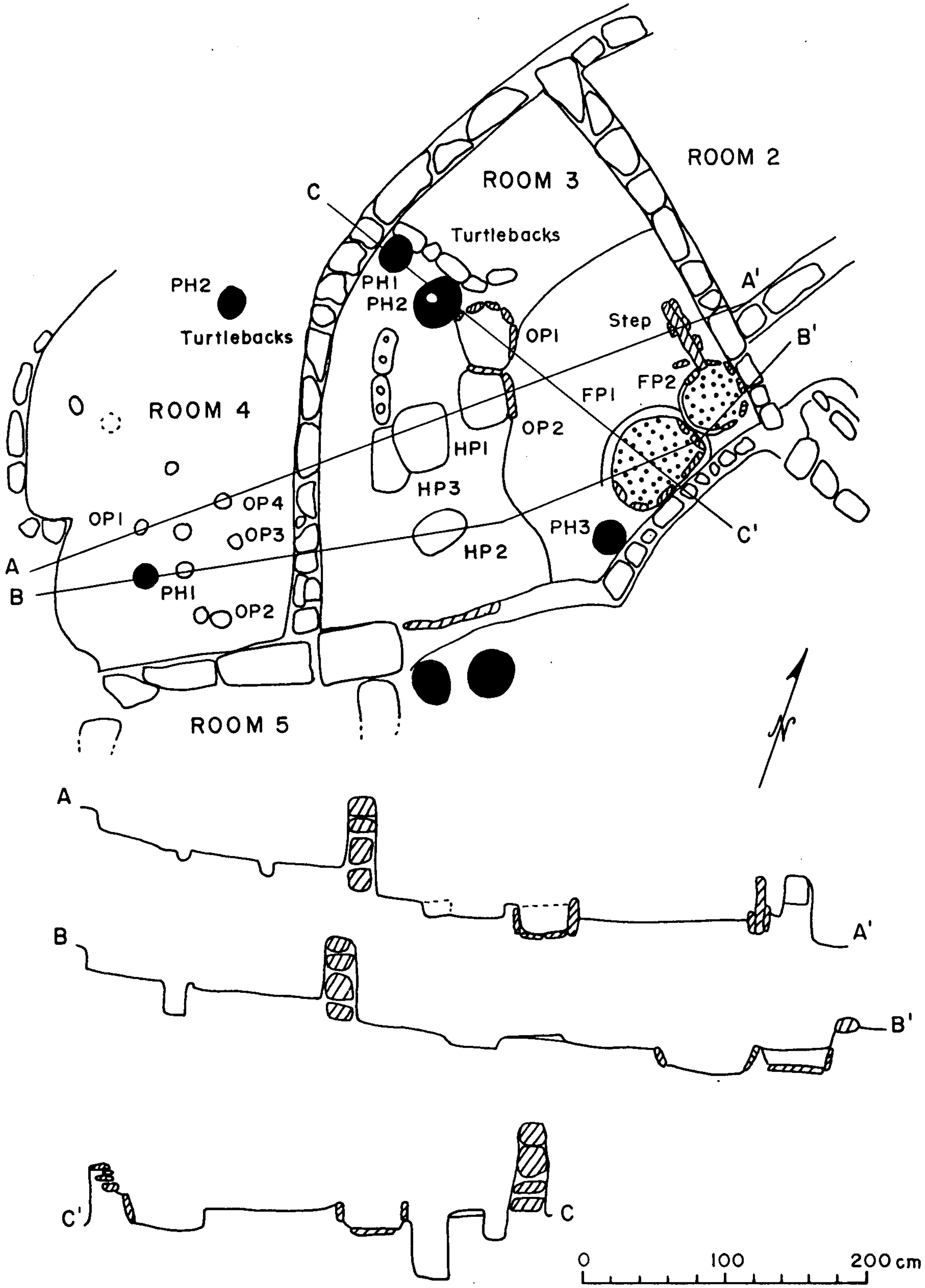

Figure 4.15 Room 3, Site 29SJ 629

example, sand dropseed (*Sporobolus cryptandrus*), evening primrose (*Oenothera albicaulis*), bulrush (*Scirpus*), and beeweed (*Cleome*). While the possibility of contamination by rodent activity must be considered, the diversity and abundance of cultivated and wild plant taxa found in pollen and flotation samples may be the result of using different areas for temporary storage or preparation of various plant resources.

Room 9

Room 9 was a partially enclosed room, containing three masonry bins, one slab-lined firepit, a heating pit, and another pit (Figure 4.16). There was no evidence that the floor had been prepared. Turkey eggshell fragments were found on the floor. This room, along with Room 8, was probably added at a later date to the central room block (Windes 1978). Room 9 is similar in construction to Room 3.

Pollen analysis of 2 samples from near bins 2 and 3 resulted in a small amount of corn pollen and high amounts of Cheno-Am pollen (Table 4.3; Figure 4.16). Pollen from the family Cyperaceae was found in FS789. This family contains the genus *Scirpus*. The pollen may be associated with the *Scirpus* remains found in the flotation from Feature 2 (Toll 1981a). Ethnographic studies mention only the use of roots and shoots of this species (Swank 1932). Bulrush seeds have also been found at Salmon Ruin (Adams 1980), suggesting that seeds may also have been used in the past. Grass pollen was extremely low in both samples. Corn remains were found in the flotation sample from Bin 2, along with burned saltbush (*Atriplex canescene*, tansy mustard, and bulrush (*Scirpus*) seeds (Toll 1981a). Corn and winged pigweed seeds were found in front of Bin 3 (FS787; Toll 1981a).

Overall, samples from Room 9 exhibit differences in several important taxa compared to those from the other living rooms. For example, percentages of Cheno-Ams from the combined counts of two samples from Room 9 is 79%. Combined counts from Room 2 equalled 42% (although single samples from this room range from 42% to 73%). The Cheno-Am percentage from all samples in Room 3 equalled 27%, with single samples varying from 11% to 33% (see Table 4.3). Gramineae pollen in total for Room 2 is 35%, Room 3, 11%, and Room 9, 3%. The differences in pollen results may be due to differences in utilization of these rooms, although flotation remains from both contain similar items, such as charred corn, purslane, etc.

Plaza Area

The plaza and ramada areas east of rooms 5 and 7 and between rooms 3 and 9 (Figure 4.17) were not remodeled into enclosed rooms as at Site 29SJ 627. However, the plaza contained many features, such as firepits, post holes, and bell-shaped cists. With a ramada roof, part of this area was presumably used for living space, where activities involving processing and storage of plant resources took place.

The pollen sample taken from within Other Pit 14 (one of the bell-shaped cists, Figures 4.14 and 4.20), was extremely high in corn pollen

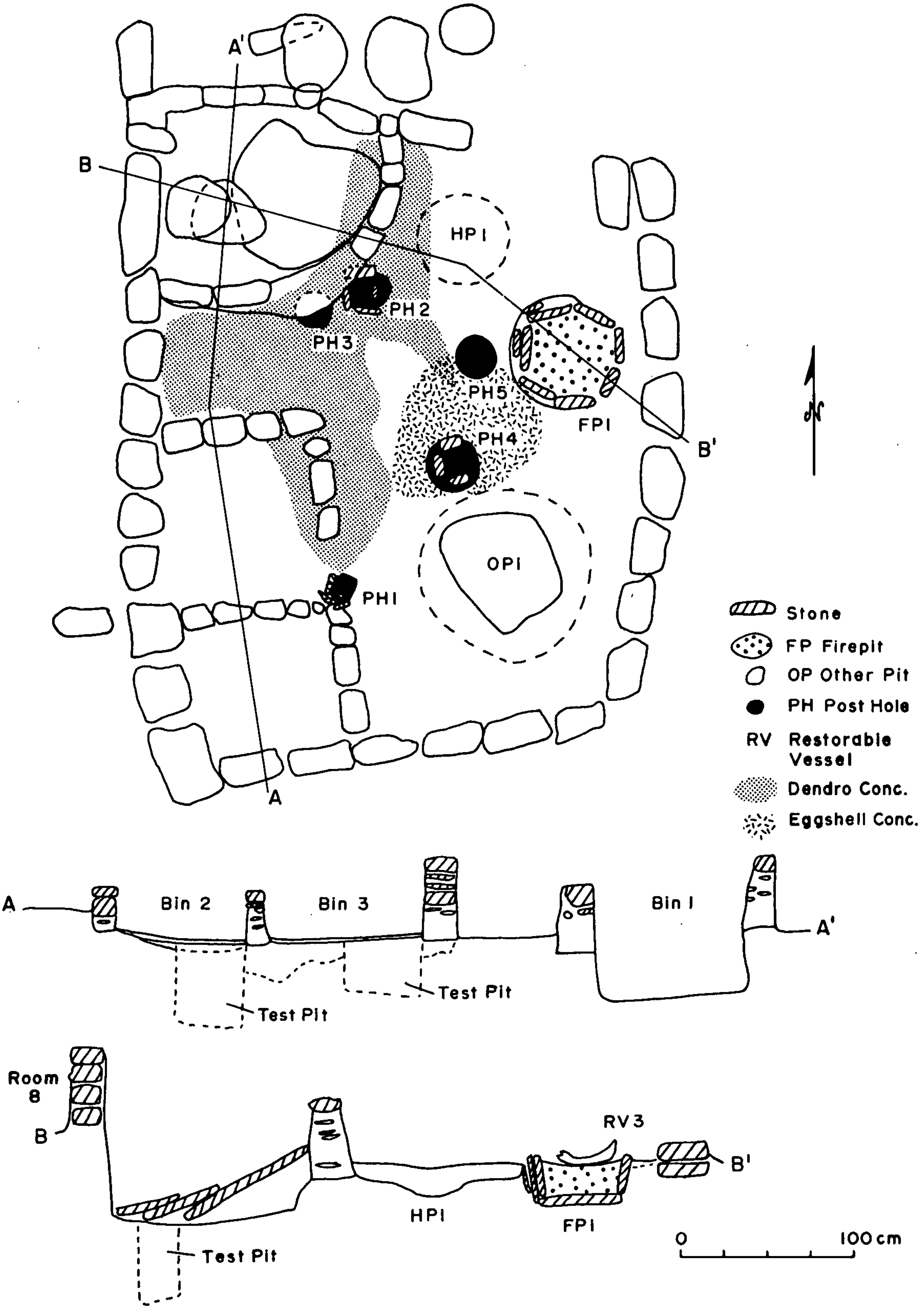

Figure 4.16 Room 9, Site 29SJ 629

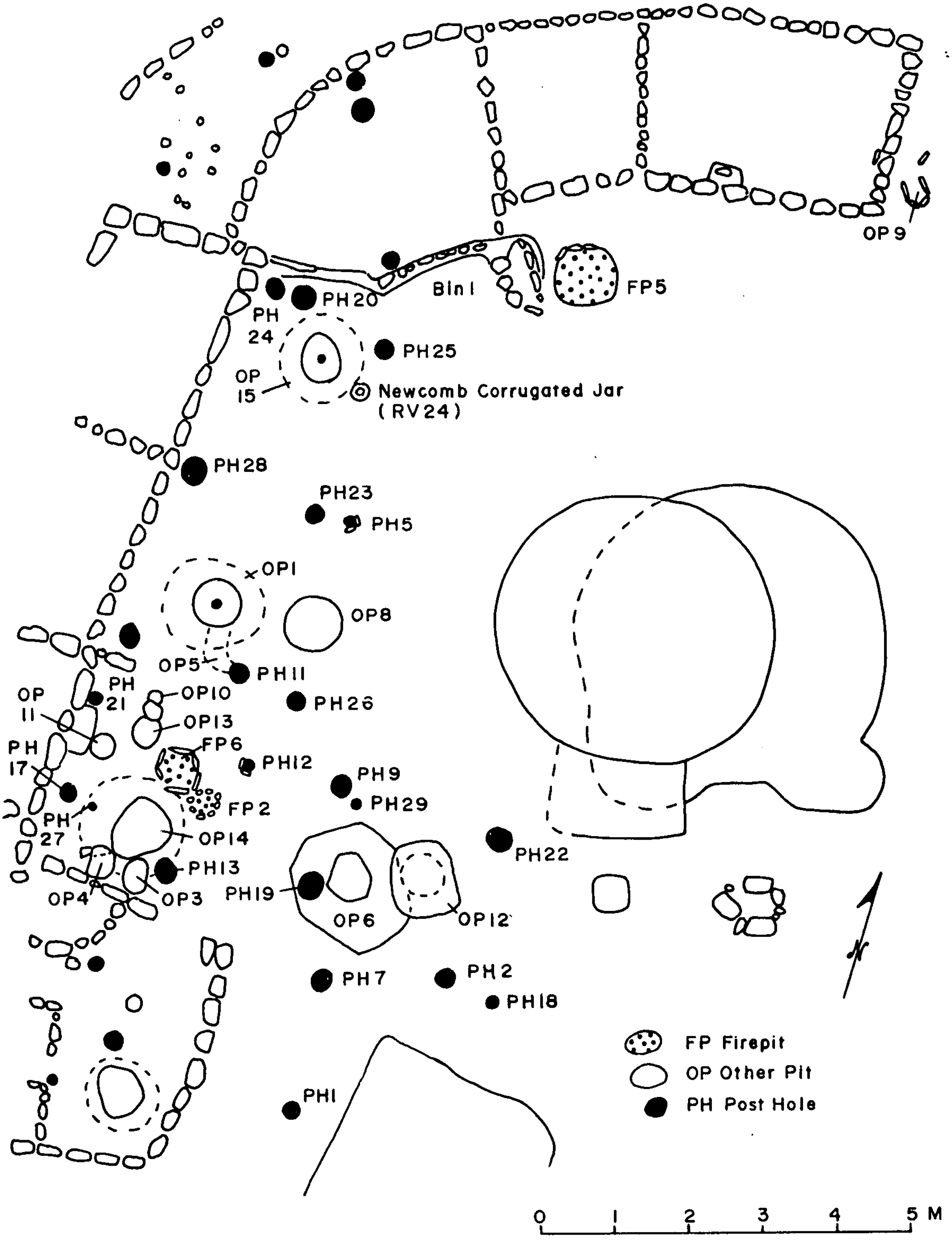

Figure 4.17 Plaza Area, Site 29SJ 629

(Table 4.4). FS1494, taken from between Other Pit 14 and the wall of Room 9 also contained corn pollen. This may result from the proximity of storage pits 3, 4 and 14. FS1494 also contained squash or gourd (Cucurbita) pollen. Pollen from this genus is large and spiny. Squash and gourds are insect pollinated; Cucurbita pollen is unlikely to be part of the normal pollen rain. Its presence indicates the storage or use of squash or gourd in immediate area. Cattail pollen was noted in this sample as well. Corn was found in three flotation samples from nearby Other Pit 14, and cob fragments from the macro-remains (Toll 1981a).

Pithouses

Pithouse 3. This pithouse was constructed around A.D. 925, probably during the second phase of construction at 29SJ 629. This was the most rewarding of the pithouse structures in terms of pollen analysis. Three of the five samples analyzed form this pithouse combined adequate numbers of pollen grains for counting. These three samples, FS2623, FS2619, and FS2620, from the central area and the south half of the pithouse (Figure 4.18), contained extremely high percentages of corn pollen (Table 4.3; Figure 4.18). These are the highest percentages of corn pollen found at 29SJ 629 (with the exception of Other Pit 14 in the plaza area). In addition to their great numbers, the pollen grains occurred at times in clumps. High relative percentages of corn pollen in archeological sites have been interpreted as the result of introduction with corn which was being processed or stored (Fish 1981; Hill and Hevly 1968), or as the result of medicinal or ceremonial use of pollen (Bohrer 1980). High percentages of greasewood (Sarcobatus) pollen were found in the southwest quadrant of Pithouse 3. Greasewood is one of the few chenopodiaceous shrubs whose pollen can be distinguished from other Cheno-Ams. The woody stems of this shrub may have been used as fuel in Pithouse 3. Such uses for greasewood are described by Whiting (1939) at Hopi. Cattail and prickly pear cactus pollen was also identified in this sample.

The floor of Pithouse 3 was unplastered and contained twelve pits, including a heating pit and a firepit. Heating Pit 1 contained a layer of charred sagebrush remains (Windes 1978).

Pithouse 2. Three floors were found in Pithouse 2; Floor 1 was plastered, and contained a firepit, mealing bins, and other features (Figure 4.19). Floor 2 underlies Floor 1 in a small area of the pithouse. FS337 was taken from Subfloor Layer 1, near the mealing bins in the southwest quadrant, and contained a low frequency of both corn and prickly pear pollen. Corn remains were found in flotation samples from Floor 1, from the mealing bins in Floor 2, and from the central firepit (Toll 1981a). This pithouse was constructed for domestic use in the first phase of building at the site (A.D. 875), may have been used for ceremonial purposes later (Windes 1978).

Pithouse 1/Kiva. The Kiva was built in part over Pithouse 2 (Figures 4.2 and 4.20) sometime around A.D. 1100. Most of the other rooms at 29SJ 629 were abandoned at this time (Windes 1978). Four of the five pollen samples from this room yielded very low counts. However, the sample from

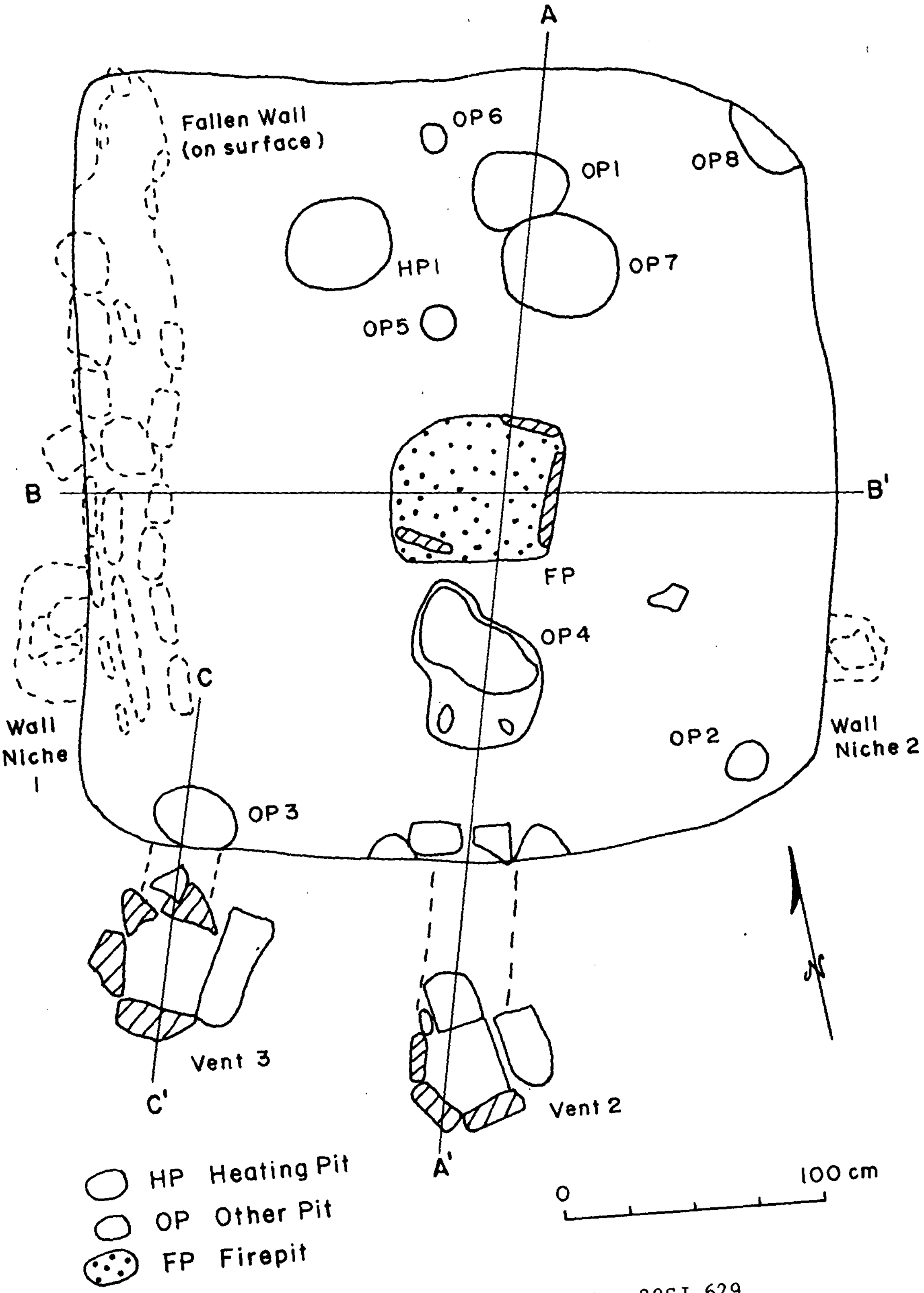

Figure 4.18 Pithouse 3, Site 29SJ 629

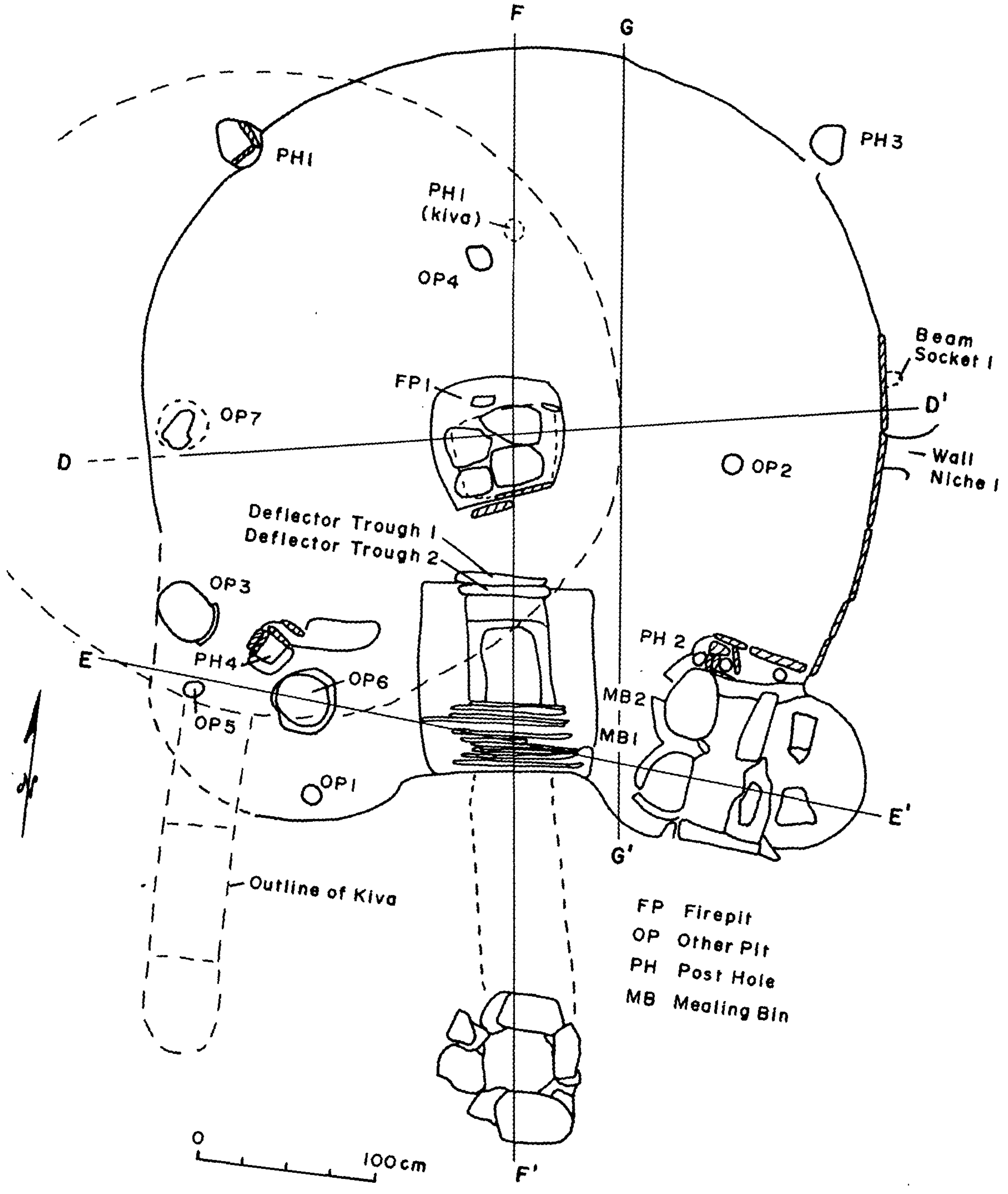

Figure 4.19 Pithouse 2, Site 29SJ 629

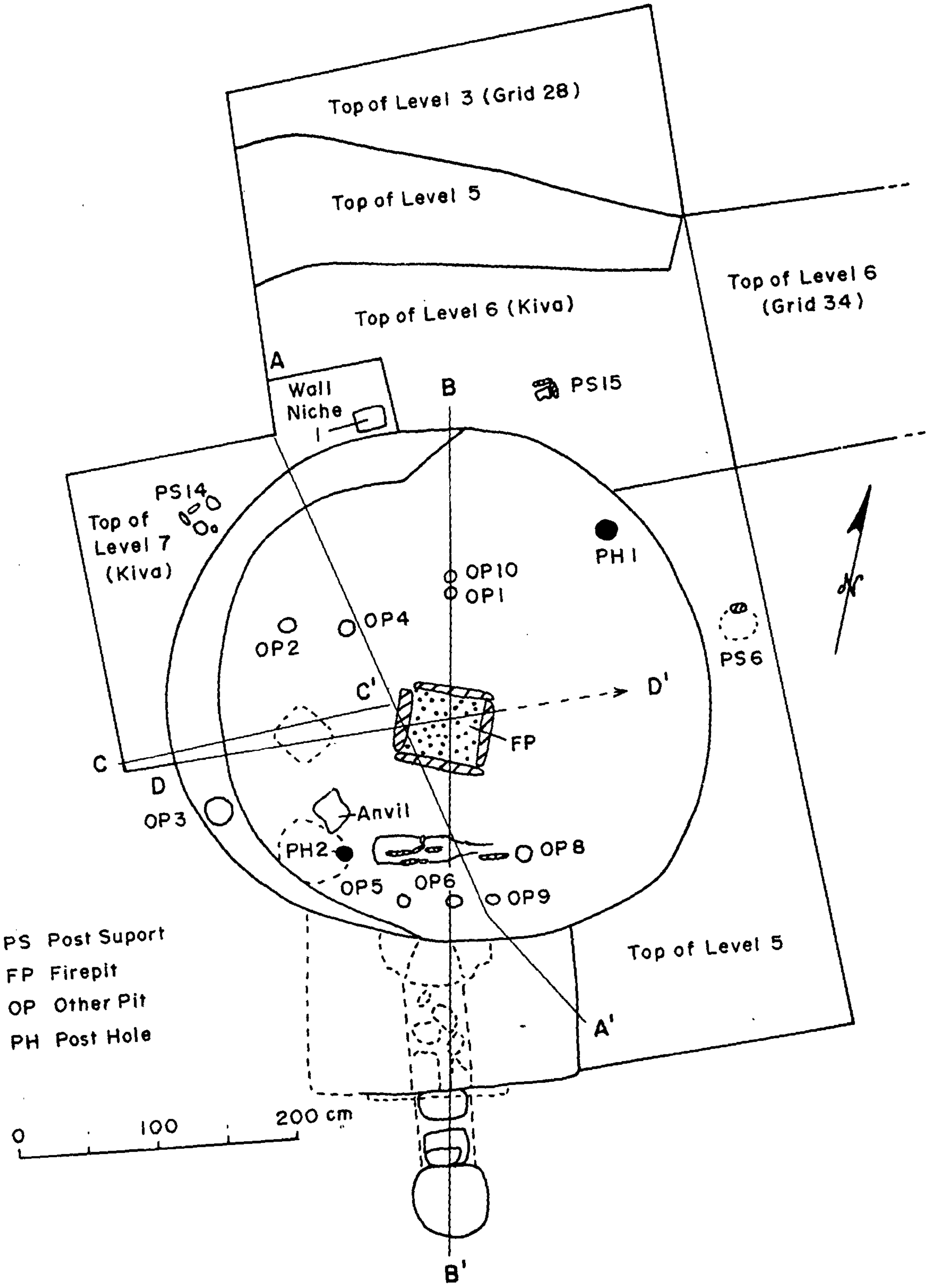

Figure 4.20 Kiva, Site 29SJ 629

the northeast quarter of the room did yield adequate numbers of pollen. In comparison to Pithouse 3, the percent of corn pollen is low (2.0%). A tetrad (a group of four grains) of cattail (Typha) pollen was present. The pollen was probably introduced by man with other cattail plant parts to be used in matting (Castetter 1935) or perhaps ceremonially (Stevenson 1904; Whiting 1939).

Features

Two bell-shaped cists or pits from the ramada area in front of rooms 5 and 6 were sampled (Figure 4.11). These pits were apparently constructed as storage features along with the aboveground rooms 5, 6, and 7. They were filled with trash and sealed about the same time as the abandonment of Pithouse 3 (ca. A.D. 1000; Windes 1978). Presumably, the trash consisted of debris from various tasks carried out on the occupation surface of the plaza area, thus pollen samples might reflect vegetal debris from these activities as well as the storage of plant foods in the cists. Pollen samples from both cists contained 19% and 70% corn pollen respectively (Table 4.4). Cucurbit and prickly pear pollen were found in a sample from Other Pit 1. Toll (1981a) reports corn and cucurbit remains from a flotation sample taken from the floor of Other Pit 1 (FS2008) and corn from all three flotation samples taken from Other Pit 14 (FS2690, FS2770, and FS3099), as well as cob fragments in the macro-remains. Cucurbit remains occurred in flotation sample FS2690.

The pollen sample from Other Pit 1 (Firepit 6; Figure 4.3) in Room 3 contained 11% corn pollen and 75% grass pollen. Toll (1981a) reports corn in flotation remains from this pit, and Windes (1978) reports corn cobs were located in the sub-floor of Room 3.

Room and Feature Functions

During the last stages of occupation at Site 29SJ 629, rooms 5 and 6 were probably used contemporaneously with rooms 2, 3, and 9. Pollen samples processed and analyzed from the last occupied floors of these rooms are roughly comparable in chronological terms. The dichotomy in room function based on presence or absence of features and diversity and abundance of economic pollen types observed by Hill and Hevly (1968) at Broken K Pueblo seems to be present in this portion of the small village site in Chaco Canyon as well. Rooms 5 and 6 were probably used for storage or for non-food related activities; rooms 2 and 3 contained features characteristic of living rooms. Pollen samples from Room 2 did contain the highest numbers of economic pollen taxa and the highest percentage of corn pollen of the four rooms (Table 4.3). Rooms 3 and 9 contained one more economically important taxon than rooms 5 and 6.

In the tub or storage rooms, the high percentage of Cheno-Am pollen may be the result of the use of chenopodiaceous shrubs in roof construction. Cattail and willow may also have been used in construction. The small percentages of corn pollen may be the result of storage for future use; however, activities completely unrelated to plant processing or storage may have been of major importance in these rooms (Windes 1978), with consequent lower numbers and percentages of economic taxa.

The living rooms contained a highly variable array of pollen types in various locations. Corn pollen was present in nearly all the grid samples from rooms 2 and 3 and in the two samples from Room 9. Prickly pear cactus, purslane, and plants of the bulrush family may have been processed and stored. Globemallow may have been brought in to be used for medicinal purposes. High percentages of sagebrush pollen indicates the use of sagebrush for fuel. High percentages of Cheno-Ams suggest the use of chenopodiaceous shrubs for fuel or construction, or the use of shrubby or herbaceous taxa for food.

The plaza area also contained many firepits, storage pits, and other pits of uncertain functions (Windes 1978). Presumbly, many activities involving food storage and processing were carried out in the plaza as well as the living rooms. The single productive pollen sample from Grid 8 contained taxa from several cultivars and wild plant resources (Table 4.3). The presence of corn and cucurbit pollen in this grid may be due to the proximity of the sample location to several pits, which may have been used for storage or which included debris swept in from the surrounding surfaces.

Plaza features Other Pit 1 and 14 were in use from the first building phase until about A.D. 1000, when rooms 2, 3, 8, and 9 were completed and many, if not all of the domestic activities had shifted to aboveground rooms (Windes 1978). As the pits were abandoned, they were filled with trash and debris and plugged, so the high percentages of corn pollen and the presence of cucurbit, grass, and prickly pear cactus pollen may be related to the debris rather than storage of these taxa in the pits themselves. The extremely high percentage of corn pollen in Other Pit 14 (Table 4.4) suggests however, that corn was stored in this pit while it was in use. Both corn and squash may have been stored in Other Pit 1. Flotation analysis provides good corroboration here; flotation samples from these locations contained wild and cultivated plant remains. The flotation evidence suggests both plaza debris (charred, firepit-like assemblages) and original storage functions (unburned cultivars and nonlocal wild economics (Toll 1981a).

Other Pit 1 (Firepit 6) in Room 3 contained high percentages of grass pollen. The introduction of this pollen type may have occurred when grass seeds were being parched over a fire, as described by (Castetter 1935). The grass pollen present in this pit may have been introduced in a similar way.

Pithouse 3 was abandoned at about the same time as the large bell-shaped pits in the plaza were filled and sealed. The pithouse contained a firepit, heating pit, and numerous other pits suggestive of living or domestic activities. Windes (1978) suggests that this pithouse may represent a transition between domestic and ceremonial functions in subterranean rooms and that activities in Pithouse 3 may have actually been of a ceremonial nature. The most remarkable characteristic of the pollen samples from this pithouse is the extremely high percentage of corn pollen (Table 4.3). High relative percentages of corn pollen in features of archeological sites have been interpreted as the result of the processing and storing of corn (Fish 1981; Hill and Hevly 1968). Fish (1981) interprets high percentages from floors or feature samples as evidence of primary introduction of corn, that is, immediately after harvesting. Pithouse 3 may have been used for the initial or primary storage of corn immediately after harvesting. By Hill and Hevly's criterion, Pithouse 3 would be called a living room because of the high percentage of a major economic pollen type, although the extremely high percentage of corn pollen suggests a special function for this room. Alternatively, the high percentages and the clumped or aggregated corn pollen grains suggest a special, possibly ceremonial origin. While samples from most kivas are low in economic type pollen (Cully 1977a; Fish 1981; Hill and Hevly 1968), Bohrer (1980) reports high percentages and aggregated grains of corn pollen from several proveniences in kivas at Salmon Ruin in northwestern New Mexico. Prickly pear cactus may also have been stored or prepared in the pithouse. The presence of cattail pollen suggests the use of cattails for matting, perhaps for ceremonials. The presence of greasewood pollen suggests the use of this shrub as fuel.

Pithouse 2 was in use nearly throughout the entire occupation of the site. In the early stages, the function of the pithouse was probably almost entirely domestic; however, with the addition of aboveground rooms, living or domestic activities shifted to these locations, and Pithouse 2 may have been used for ceremonial purposes (Windes 1978). The single sample from between the later floors at this site suggests at least some domestic activities in this room. The presence of corn and prickly pear cactus pollen may be due to grinding corn and cactus fruits and stems in the mealing bins nearby (Figure 4.19).

Activities involving the storage and preparation of plant foods seems to have centered around rooms 2 and 3 and probably Room 9 as well. Many of these activities were also carried out in the plaza area. The storage or tub rooms (5 and 6) may have been the center of other, non-plant related activities. Pithouse 3 and the large bell-shaped cists in the plaza may have been the sites of the initial or primary storage of corn immediately after harvesting. The abandonment of both the bell-shaped pits and Pithouse 3 at about the same time may be coincidental or related to some other changes going on in the site; however, it does suggest that these two proveniences shared a storage function. Alternatively, Pithouse 3 may have served primarily as a ceremonial room. The storage pits in the plaza may have been sealed as more aboveground rooms were available for these purposes. The ceremonial functions in Pithouse 3 could have shifted to Pithouse 2 as the aboveground rooms became more frequently used for living activities; however, the samples from the last occupation of rooms 2, 3, 5, 6 and 9, Pithouse 2, and the Kiva did not contain similarly high corn pollen percentages. This may be due to sampling error; only a few samples with adequate pollen counts were available from Room 9, Pithouse 2, and the Kiva. It also suggests that there may have been a change in the nature of occupation of the site as a whole (perhaps from seasonal to year-round). High relative percentages of corn pollen in the rooms occupied until abandonment may have been lowered by influxes of pollen from other economically important taxa that were brought into the site and used immediately or stored to be used year-round.

Pueblo Alto

Description

Pueblo Alto, a large, complex structure (Figure 4.21), was occupied at the same time as many of the smaller village sites located in Chaco Canyon. Several of the excavated sites, 29SJ 627 (Truell 1981) and 29SJ 629 (Windes 1978) were extensively sampled for pollen, flotation, and macrobotanical remains in an effort to identify plant resources. The excavations at Pueblo Alto have made it possible to compare information on subsistence from the small sites and a large structure to determine whether the inhabitants of these two different site types were utilizing different resources. Human coprolites were also found at Pueble Alto, and their study (Clary 1981) allowed a comparison on coprolite pollen with pollen from soil samples at the same site.

Results of Analysis

West Roomblock

The upper floors of two of the excavated rooms in this block contained mealing bins, heating pits, firepits, and burned areas on the floor surfaces (Figures 4.22-4.26). Room 110 contained mealing bins, firepits, postholes, and other pits (Figure 4.23). The first floor consisted of eight or nine different surfaces, none of which extended throughout the room. The floor contact samples described here represent last use of the room.

Windes (1980) believes that Room 110 was originally paired with Room 112 (Figure 4.22) and the rooms were used as a unit. Archeomagnetic dates taken from Floor 1 in both rooms yielded dates which indicated contemporary occupation of the two rooms (Windes 1980).

The relationship of Room 229 to its neighbors (rooms 110 and 112) is not clear. Rooms 110 and 112 were originally paired by a connecting doorway; the door between rooms 229 and 112 appears to be a later addition (Windes 1980). Ceramic and absolute dates suggest contemporaneity of the floors from these rooms, making it possible to compare pollen results from a functional point of view.

Several major differences are evident in the plan views of rooms 110, 112, and 229. Room 110 contains a formal firepit and many other features, while rooms 112 and 229 do not. These latter two do have, however, numerous burned areas on the floor surfaces. Mealing bins are present in Room 110, but not in 112 or 229. A sealed partition was found in the north part of Room 110. It appears that these rooms were used for different

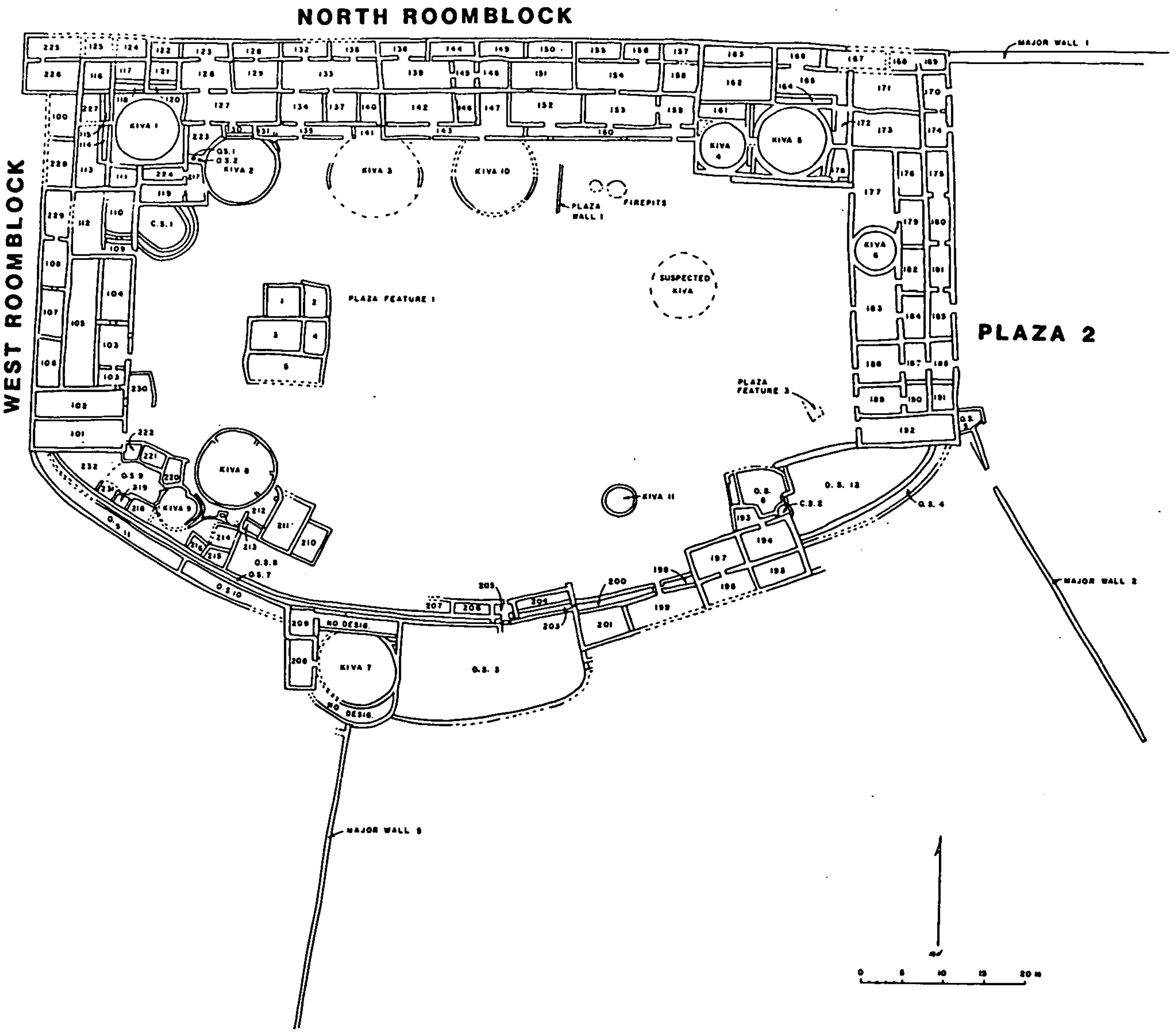

Figure 4.21 Pueblo Alto

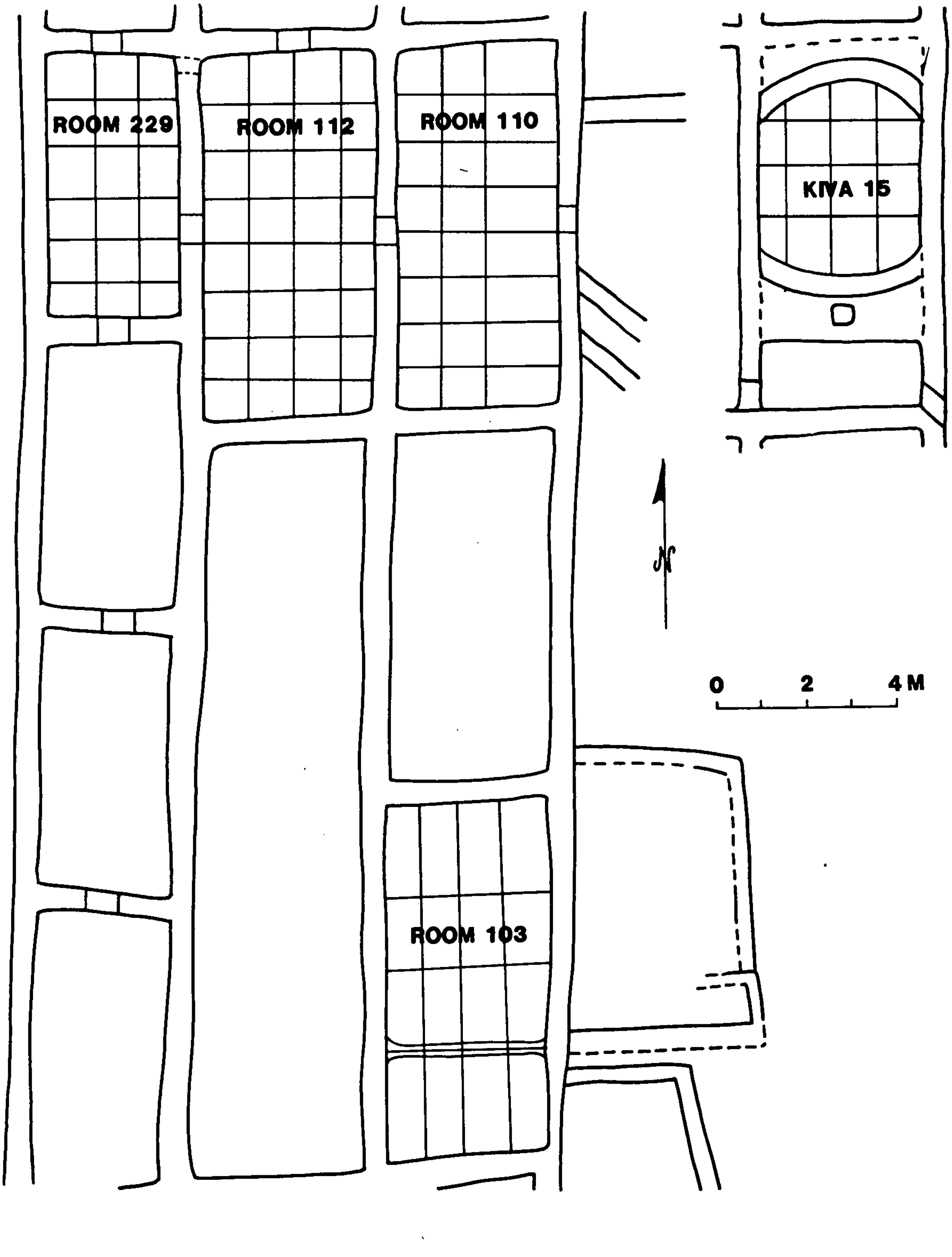

Figure 4.22 West Roomblock and Sample Grids, Pueblo Alto

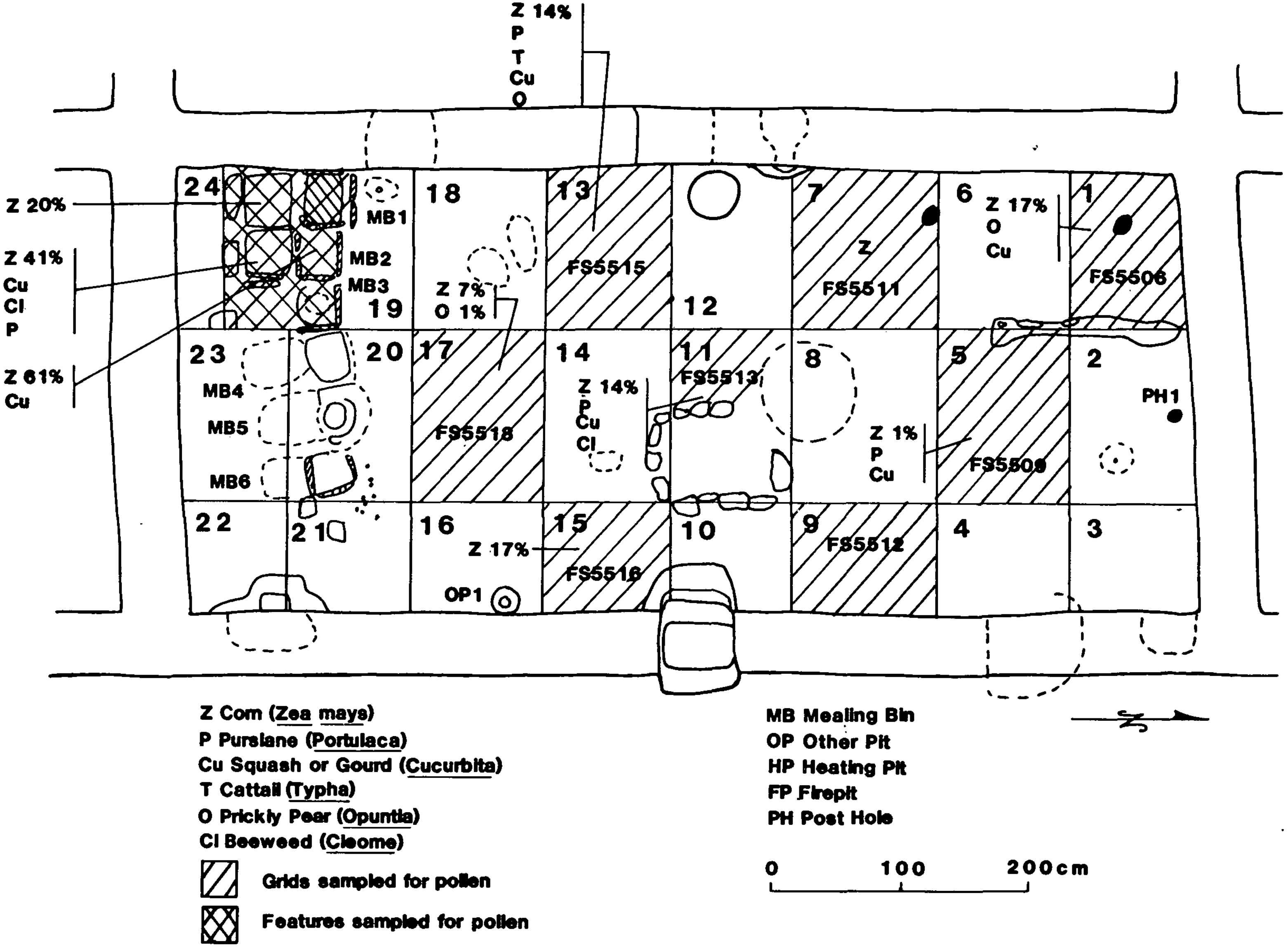

Figure 4.23 Room 110, Pueblo Alto

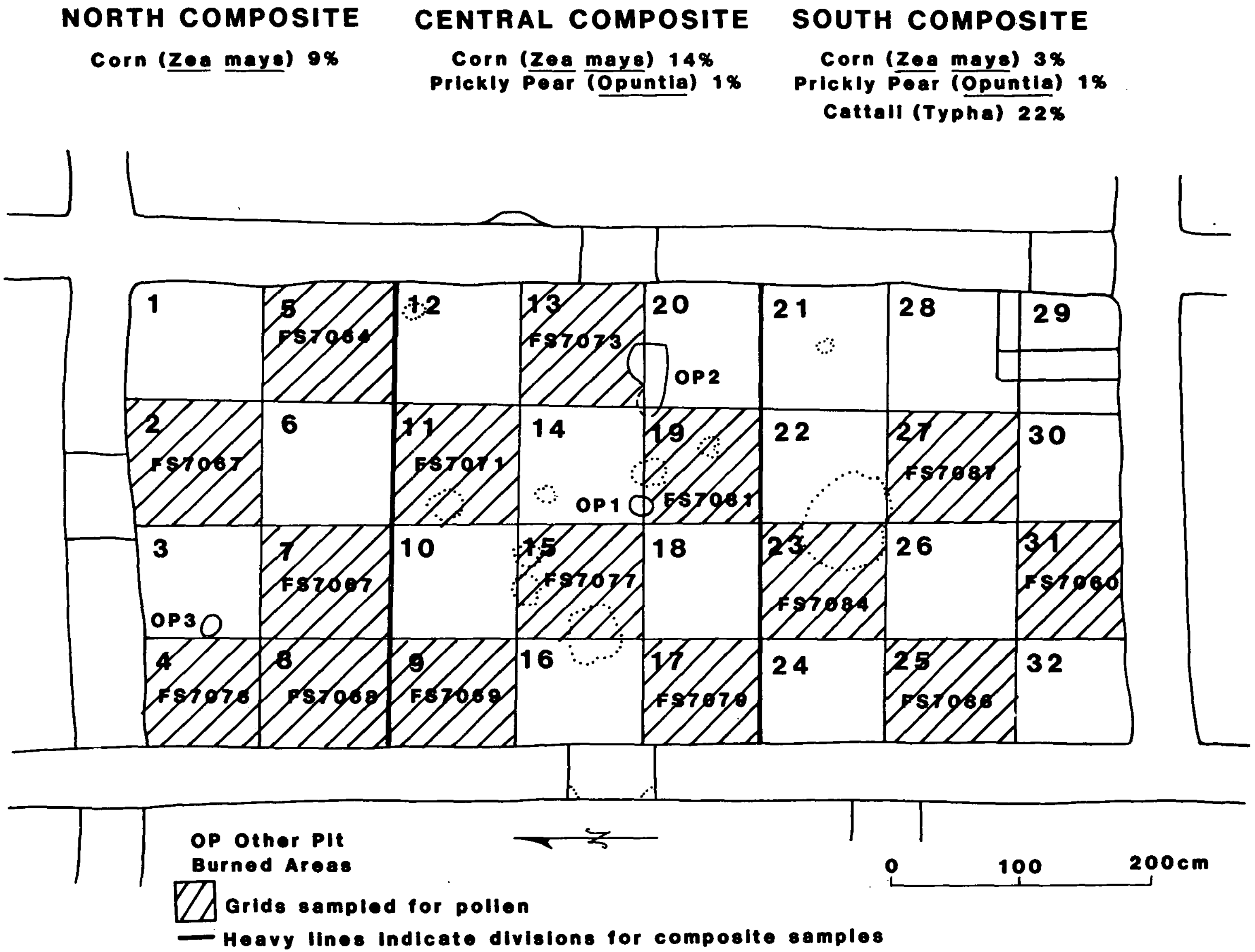

Figure 4.24. Room 115, Pueblo Alto

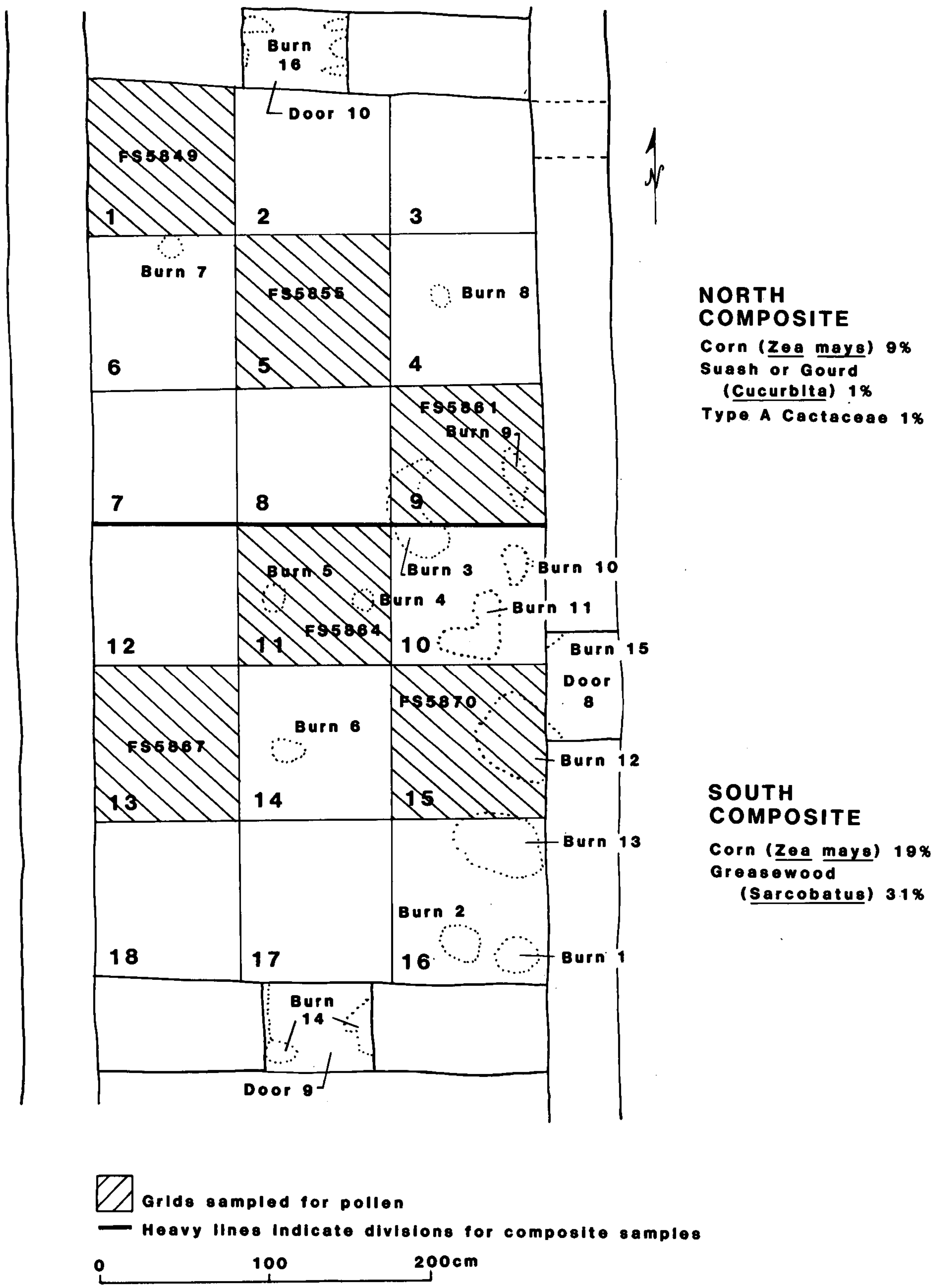

Figure 4.25 Room 229, Floor 1, Plan View, Pueblo Alto

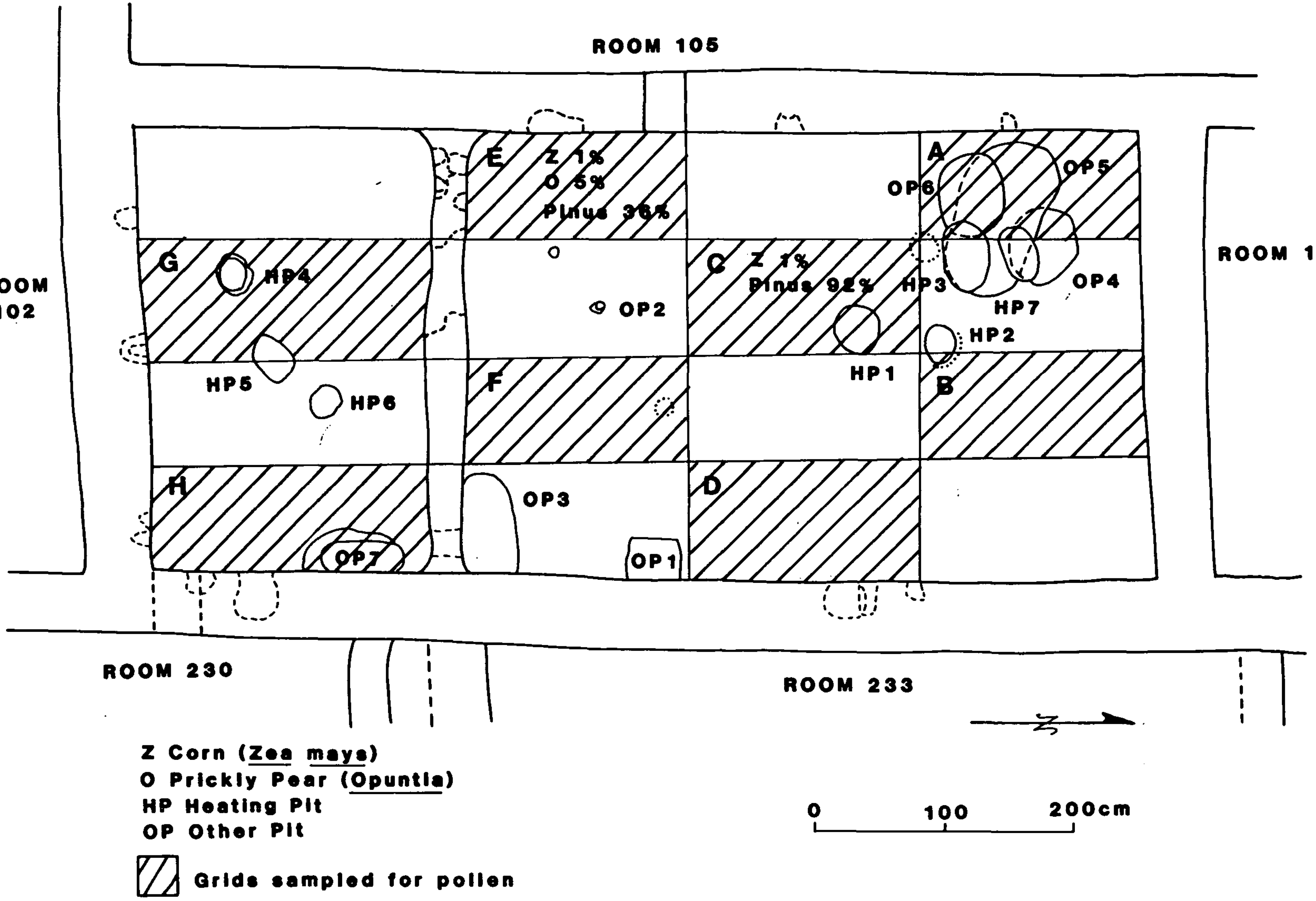

Figure 4.26 Room 103, Pueblo Alto

purposes and results from pollen analysis may be expected to reflect these functional differences.

Room 110. Several taxa of economic importance were found in Room 110. Corn pollen was found in eight of nine grid samples (see Table 4.5). Cucurbit, beeweed, purslane, cattail, and prickly pear pollen grains were also found in various grid samples (Figure 4.23). Grid 11 contained corn, cucurbit, purslane, and beeweed pollen. Another sample from Grid 1, which included the floor behind the sealed partition contained a high percentage of corn pollen.

A row of six mealing bins was found in Room 110 (Figure 4.23). Mealing bins 1, 2, and 3, were chosen for sampling. The bins were constructed during use of the earlier surfaces of Floor 1; they continued in use until the end of the occupation of Floor 1 and are contemporary with floor samples from the last occupation of the room. These bins contained high percentages of corn pollen (Figure 4.23). Corn was associated with cucurbit, beeweed, and purslane pollen were in Bin 2 and with cucurbit pollen in Bin 3.

Room 112. In Room 112, three composite samples were formed from separate grid samples (Figures 4.22 and 4.24). This room lacked the features (firepit, mealing bins, partitions, etc.) present in Room 110, but did contain burned areas on the floor. How or why these areas became burned is not clear. While the burning of shrubby or woody material may have caused the burned spots, there was little pollen evidence for use of such fuel, i.e., the percentage of pine, greasewood, sagebrush, and juniper pollen were low (Table 4.5). All sections of the room contained corn pollen. The south section contained an extremely high percentage of cattail pollen (22%; Table 4.5 and Figure 4.24). The abundance of this normally scarce pollen type may indicate the storage or use of cattail plants for matting or food.

Room 229. Room 229 also lacked floor features and contained many burned areas. Individual samples from this room were made into north and south composite samples (Figures 4.22 and 4.25). Corn pollen was found in both sections of the room. Cucurbit and Type A - Cactaceae pollen occurred in the northern section also. An extremely high percentage of greasewood pollen (31%) was encountered in the southern portion of the room. Since most of the burned areas are in the south portion, it is tempting to speculate that the greasewood pollen is associated with burning of this shrub.

Room 103. Windes (1980) considers Room 103 to be part of another suite of rooms. Only one room of this suite was excavated (Figure 4.22). During the first year of excavation, this room was sampled for pollen and flotation in order to conduct a contamination test. Samples were taken from the same grid section at timed intervals to see if an increase in exposure time caused an increase in contamination from modern pollen rain (Cully 1977a). Grid C (Figure 4.26) was focus of the test. This area of Room 103 was excavated to several centimeters above the floor surface and then covered with a plastic sheet until the contamination study could be-

Table 4.5 Pollen Results in Percentages, West Roomblock, Pueblo Alto

	ROOM 110							
	Grid 1 FS 5506	Grid 5 FS 5509	Grid 7 FS 5511	Grid 11 FS 5513	Grid 13 FS 5515	Grid 15 FS 5516	Grid 17 FS 5518	Room Total
Abies (fir)	1	2		1	5	4	3	3
Acer (maple)						1		0.2
Picea (spruce)								
Juniperus (juniper)		1				1		0.2
Pinus (pine)	40	73		67	42	50	63	55
Pseudotsuga (Douglas fir)								
Populus (cottonwood)					0.5			0.1
Quercus (oak)								
Salix (willow)								
Juglans (walnut)								
Oleaceae (olive family)								
Cheno-Ams (Chenopodiaceae-Amaranthaceae)	7	3		1	9	16	7	7
Sarcobatus (greasewood)	1	1		1	1	1		1
Gramineae (grass family)	10	9		11	5	6	9	8
Compositae (sunflower family)								
Low-spine Compositae (spines < 2 microns)	4			2	2	2	2	2
High-spine Compositae (spines > 2 microns)	3	1		1	1	1		1
Artemisia (sage brush)	1				4	1	2	1
Ephedra (Mormon tea)	6	1		3	2	1	2	2
Celtis (hackberry)								
Cruciferae (mustard family)				0.4				0.1
Fraxinus (ash)								
Cyperaceae (sedge family)								
Leguminoseae (pea family)	10	2		1	12	1	3	5
Liliaceae (lily family)								
Yucca (yucca)								
Malvaceae (globemallow family)								
Sphaeralcea (globemallow)					1			0.2
Rosaceae (rose family)								
Solanaceae (potato family)					1			0.2
Lycium (wolfberry)								
Solanum (wild potato)								
Parthenocissus (Virginia creeper)								
Scirpus (bulrush)								
Opuntia (prickly pear cactus)	1				0.4		1	0.4
Portulaca (purslane)		1		1**	0.4			0.4
Typha (cattail)					2			0.4
Type A-Cactaceae		2						0.3
Cleome (beeweed)				0.4				0.1
Cucurbita (squash or gourd)		1		1	0.4			0.4
Zea mays (corn)	17	6	+	14	14	17	7	12
Other*		1			1	1	1	0.4
Total	91	200		236	263	211	220	1231

Table 4.5 continued

	ROOM 112				ROOM 229			ROOM 103		
	North Composite	Central Composite	South Composite	Room Total	North Composite	South Composite	Room Total	Grid C	Grid E	Room Total
Abies (fir)	1	1	1	1						
Acer (maple)	2	1		1		3	0.2			
Picea (spruce)										
Juniperus (juniper)			0.4	0.1	1	0.3	1			
Pinus (pine)	47	45	21	37	25	22	23	92	37	54
Pseudotsuga (Douglas fir)										
Populus (cottonwood)										
Quercus (oak)										
Salix (willow)			1	0.3		1	1		1	0.3
Juglans (walnut)										
Oleaceae (olive family)						2	1			
Cheno-Ams (Chenopodiaceae-Amaranthaceae)	24	23**	27	24	31	12	17	3	35	25
Sarcobatus (greasewood)		1	1	0.3		31	24			
Gramineae (grass family)	7	7	7	7	16	8	10	3	11	8
Compositae (sunflower family)										
Low-spine Compositae (spines < 2 microns)	3		4	2.5	7		2		5	3
High-spine Compositae (spines > 2 microns)					2		1		1	0.3
Artemisia (sage brush)	1	1	7	3.1	3	3	3	1	1	1
Ephedra (Mormon tea)	1	1		1	1	1	1		1	1
Celtis (hackberry)										
Cruciferae (mustard family)						0.3	0.2			
Fraxinus (ash)										
Cyperaceae (sedge family)										
Leguminosae (pea family)	5	5	3	4	3		1		2	1
Liliaceae (lily family)		1	0.1	0.1		0.3	0.2			
Yucca (yucca)										
Malvaceae (globemallow family)										
Sphaeralcea (globemallow)										
Rosaceae (rose family)										
Solanaceae (potato family)			1	0.3		0.3	0.2			
Lycium (wolfberry)										
Solanum (wild potato)										
Parthenocissus (Virginia creeper)										
Scirpus (bulrush)										
Opuntia (prickly pear cactus)		1	0.4	0.3					5	4
Portulaca (purslane)	1	1	1	1						
Typha (cattail)			22	8						
Type A-Cactaceae					1		0.2			
Cleome (beeweed)										
Cucurbita (squash or gourd)					1					
Zea mays (corn)	7	14	3	8	9	19	16	1	1	1
Other*	1	1	3	1	2	0.3	1		1	1
Total	221	211	245	677	106	320	426	100	222	322

*For other taxa, see Cully (1983b).
**Pollen found in aggregates of clumps.

gin. The first sample from Grid C contained a very high percentage of pine pollen (Table 4.5). It is possible that contamination from the ambient pollen rain had already occurred in spite of the plastic cover. Grid E, which was not part of the contamination test, contained a lower percentage of pine and an unusually high percentage of prickly pear cactus pollen. Both samples contained low percentages of corn pollen. Samples from sections D and F did not contain pollen (see Table 4.5).

The function of Room 103 is difficult to determine. The presence of a large number of heating pits and partition walls indicates that the room was not used for storage. Pollen results are essentially unreliable because of the possibility of contamination of the samples which were processed from this room; therefore, they have not been considered in succeeding discussions of room function.

North Roomblock

In the North Roomblock, Windes (1980) describes suites or units of several rooms (Figure 4.27). Rooms 138 and 139 were part of the first construction; Room 142 and the corridor room (143) were added later, followed by rooms 145 and 146 created from subdivisions of rooms 139 and 142 respectively, and finally, the enclosure of Room 147. The upper floors of these rooms were probably in use at the same time during the early 1100s, and the rooms can be compared functionally, as in the West Roomblock.

Room 139. In Room 139, Floor 1 contained a burned area, postholes, and several other pits (Figure 4.28). Doorways gave access to rooms 138, 142, 144, and 145. Since firepits, mealing bins, and other kinds of features characteristically associated with habitation rooms are missing, it seems reasonable to assume a storage function for this room. The pollen data are quite different, however, from those of rooms 112 and 229, the suggested storage rooms from the West Roomblock. Economic pollen from wild plants (beeweed, purslane, cattail, etc.) and from cucurbits is entirely lacking. Corn pollen is present in very low percentages in the east and central portion, and absent in the western portion of the room (Figure 4.28, Table 4.6), though Cheno-Am percentages are high. Factors such as introduction of Cheno-Am pollen on plants, differing exposure to the outside pollen rain and exposure after abandonment could have produced these high percentages.

Room 145. Room 145 was the result of remodeling of the east end of Room 139. Access to this room was from Room 139 on the west and from Room 148 on the east. Two postholes and a burned area were found on Floor 1. Sampling in Room 145 followed the grid plan developed for site 29SJ 627 in Chaco Canyon (Cully 1977a; Struever 1977) and is slightly different from the modified version used in the rest of the rooms in Pueblo Alto (Figures 4.27 and 4.28). Both composite samples from this room were low in pollen grains. No pollen from economic taxa was found.

Room 142. Floor 1 of Room 142 contained a central row of postholes, several small pits, and burned areas. No firepits or heating pits were present. Doorways opened to Room 139 on the north, and Room 143 on the

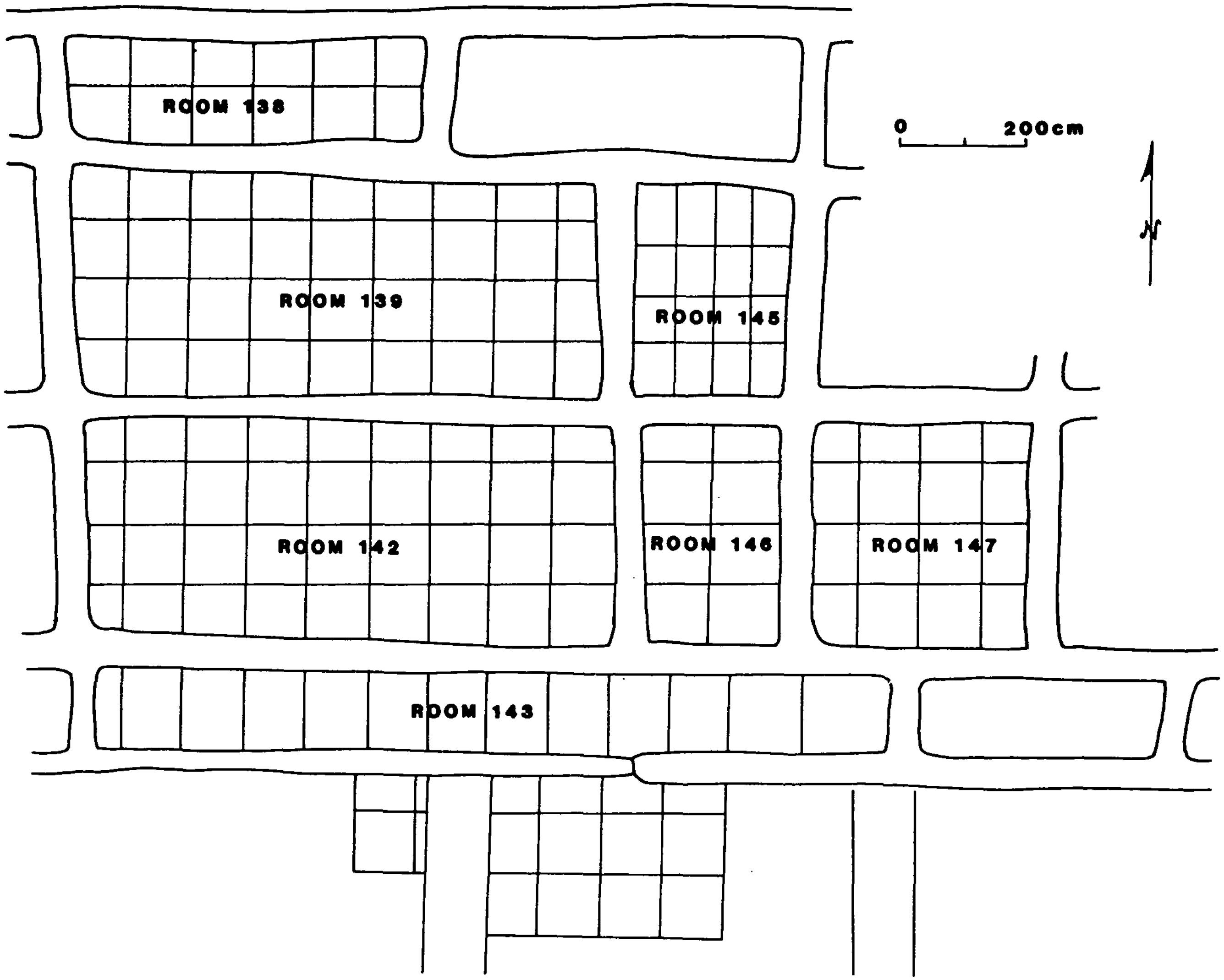

Figure 4.27 North Roomblock and Sample Grids, Pueblo Alto

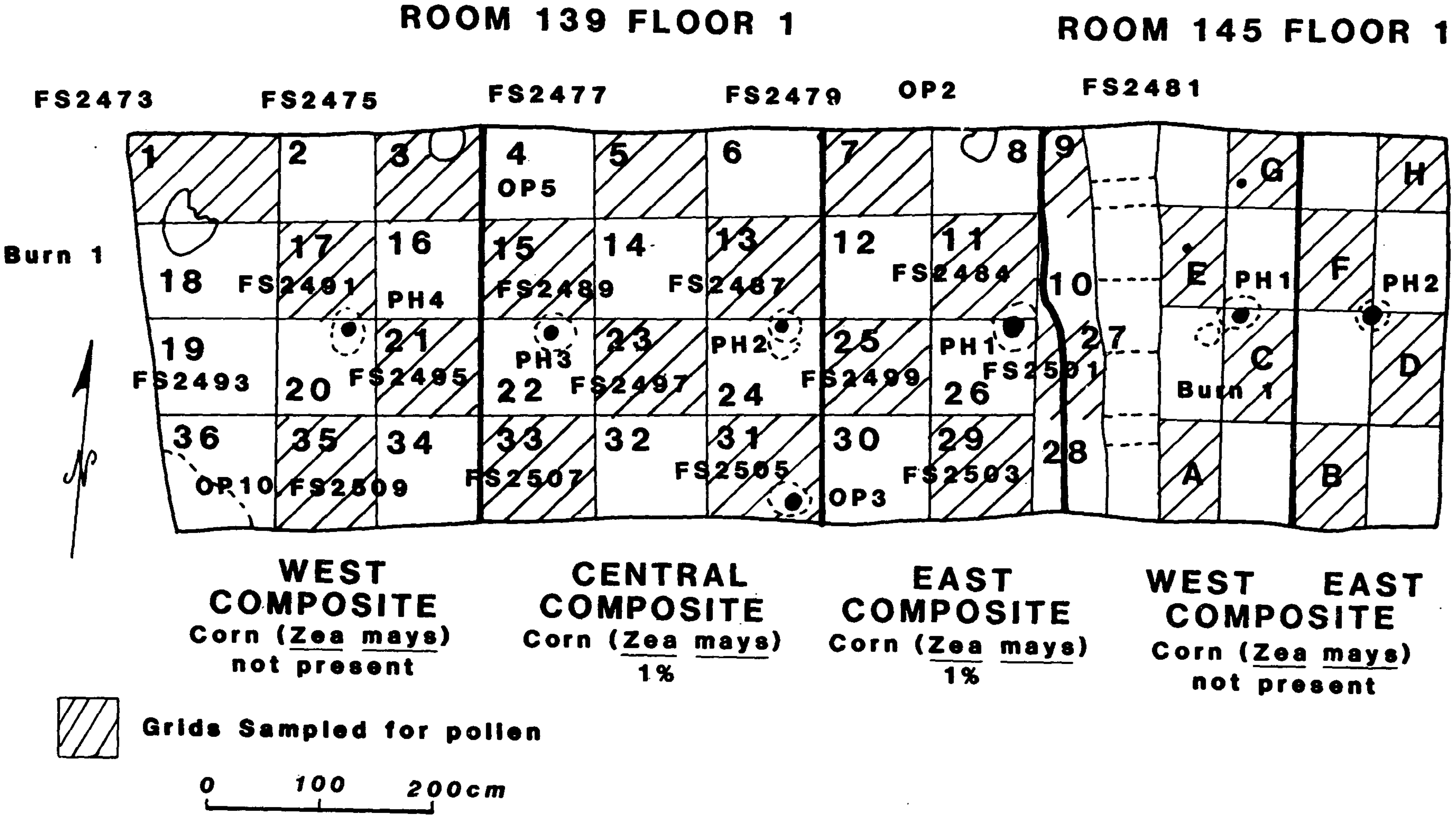

Figure 4.28 Rooms 139 and 145, Pueblo Alto

Table 4.6 Pollen Results in Percentages, North Roomblock, Pueblo Alto

	ROOM 139				ROOM 142			
	East Composite	Central Composite	West Composite	Room Total	East Composite	Central Composite	West Composite	Room Total
Abies (fir)	3	1		2	7	12		8
Acer (maple)					1			1
Picea (spruce)						1		1
Juniperus (juniper)	3	1	1	1	2	1		3
Pinus (pine)	14	29	35	26	10	13		13
Pseudotsuga (Douglas fir)								
Populus (cottonwood)		1	1	0.4	1	1		1
Quercus (oak)								
Salix (willow)	2				1			1
Juglans (walnut)		1		0.2	1			1
Oleaceae (olive family)								
Cheno-Ams (Chenopodiaceae-Amaranthaceae)	64	55	47	55	48	25		39
Sarcobatus (greasewood)	2		1	1	2	14		6
Gramineae (grass family)		2	4	2	4	14		7
Compositae (sunflower family)	6			2	3	4		3
Low-spine Compositae (spines < 2 microns)								
High-spine Compositae (spines > 2 microns)								
Artemisia (sagebrush)	3	4	4	4	9	8		8
Ephedra (Mormon tea)	3	3	2	3	1			1
Celtis (hackberry)								
Cruciferae (mustard family)					3			2
Fraxinus (ash)								
Cyperaceae (sedge family)								
Leguminosea (pea family)	1	2	1	2	2	1		2
Liliaceae (lily family)		1	1	1	1			1
Yucca (yucca)								
Malvaceae (globemallow family)								
Sphaeralcea (globemallow)								
Rosaceae (rose family)								
Solanaceae (potato family)			1	0.2				
Lycium (wolfberry)								
Solanum (wild potato)								
Parthenocissus (Virginia creeper)								
Scirpus (bulrush)								
Opuntia (prickly pear cactus)						1		1
Portulaca (purslane)								
Typha (cattail)								
Type A-Cactaceae								
Cleome (beeweed)								
Cucurbita (squash or gourd)								
Zea mays (corn)	1	1		1	2	5	+	3
Other*			2	0.4		4		2
Total	119	211	120	450	248	129		377

Table 4.6 continued.

	ROOM 143			ROOM 147
	West Composite	FS 6795 East	Room Total	East Composite
Abies (fir)	12	6	10	2
Acer (maple)	1		1	
Picea (spruce)				
Juniperus (juniper)		2	1	
Pinus (pine)	20	14	18	12
Pseudotsuga (Dougla fir)				
Populus (cottonwood)				
Quercus (oak)				
Salix (willow)				
Juglans (walnut)				
Oleaceae (olive family)				
Cheno-Ams (Chenopodiaceae-Amaranthaceae)	50	47	48	55
Sarcobatus (greasewood)	3	1	2	1
Gramineae (grass family)	3		1	6
Compositae (sunflower family)	3	2	3	4
Low-spine Compositae (spines < 2 microns)				
High-spine Compositae (spines > 2 microns)				
Artemisia (sagebrush)	3	17	9	9
Ephedra (Mormon tea)	1	4	2	1
Celtis (hackberry)				
Cruciferae (mustard family)				
Fraxinus (ash)				
Cyperaceae (sedge family)				
Leguminosae (pea family)		1	1	2
Liliaceae (lily family)	1	1	1	3
Yucca (yucca)				
Malvaceae (globemallow family)	1		1	
Sphaeralcea (globemallow)				
Rosaceae (rose family)				
Solanaceae (potato family)				
Lucium (wolfberry)				
Solanum (wild potato)				
Parthenocissus (Virginia creeper)				
Scirpus (bulrush)				
Opuntia (prickly pear cactus)		1	1	1
Portulaca (purslane)				
Typha (cattail)				
Type A-Cactaceae				
Cleome (beeweed)				
Cucurbita (squash or gourd)				
Zea mays (corn)	2	5	3	3
Other*		2		1
Total	159	114	273	201

*For other taxa, see Cully (1983b).
+Total pollen count less than 100, taxon noted in sample.

south (Figures 4.29). There was apparently no access to Room 146, which was created from a remodeling of the east end of Room 142.

Results of pollen analysis are similar to those in Room 139. Composite samples contained low percentages of corn pollen in the east and central portions of the rooms. The west composite sample count was low, with one corn pollen grain out of 37 total grains. No beeweed, cattail, or purslane pollen was noted in any of the samples (Table 4.6).

Fir pollen was 8% and 12% respectively for the east and central portions, and was also present in the single sample from the west end, for a combined percentage of 8%. Fir pollen is not present in any of the surface stations or subsurface samples reported by Hall (1977); this taxon was noted by Cully (1977a) at a surface station near Site 29SJ 627 in Marcia's Rincon.

Room 147. In the earlier building stages, Room 147 was an open plaza, which was completely enclosed later and became a room (see Figure 4.30). Features in the room include a slab-lined firepit, several heating pits, and other pits (see section on Features for description of pollen analysis from heating pits and firepits).

Two composite samples were made from the east and west sections of the room. The west section sample was low in numbers of pollen grains. Corn pollen was present in small amounts in the east section and was not found in the west section of the room (Table 4.6). One prickly pear cactus pollen grain was also found in the east section. No other economic pollen was found in spite of the presence of features associated with habitation rooms.

Room 143. Room 143 is one of a series of narrow corridor rooms (Windes 1980) and runs along the south end of rooms 142, 146, and 147. Access to this room was at the east end, and central doorways in turn opened into rooms 147 and 142 (Figure 4.31). In the east end, Floor 1 contained a row of postholes and one heating pit. The west end contained heating pits, burned areas, and another pit.

In the composite sample from the west end and in the single sample from the east end, the fir pollen percentage was very high (Table 4.6; Figure 4.31). Sagebrush pollen was also high in the east, suggesting the presence of shrubby parts of the plant for ceremonial use or for use as fuel. Corn pollen was present in both east and west portions of the room.

The presence of heating pits and a raised sleeping platform (Figure 4.31) indicates that this room was in part used as a living room. Room 143 may have had other functions as well, e.g., large amounts of fir pollen suggest the presence of fir boughs, perhaps for use as ceremonial items. Corn pollen may have resulted from food preparation activities.

Other Locations

Plaza Feature 1. Plaza Feature 1 (Figure 4.21 and 4.32) is a small,

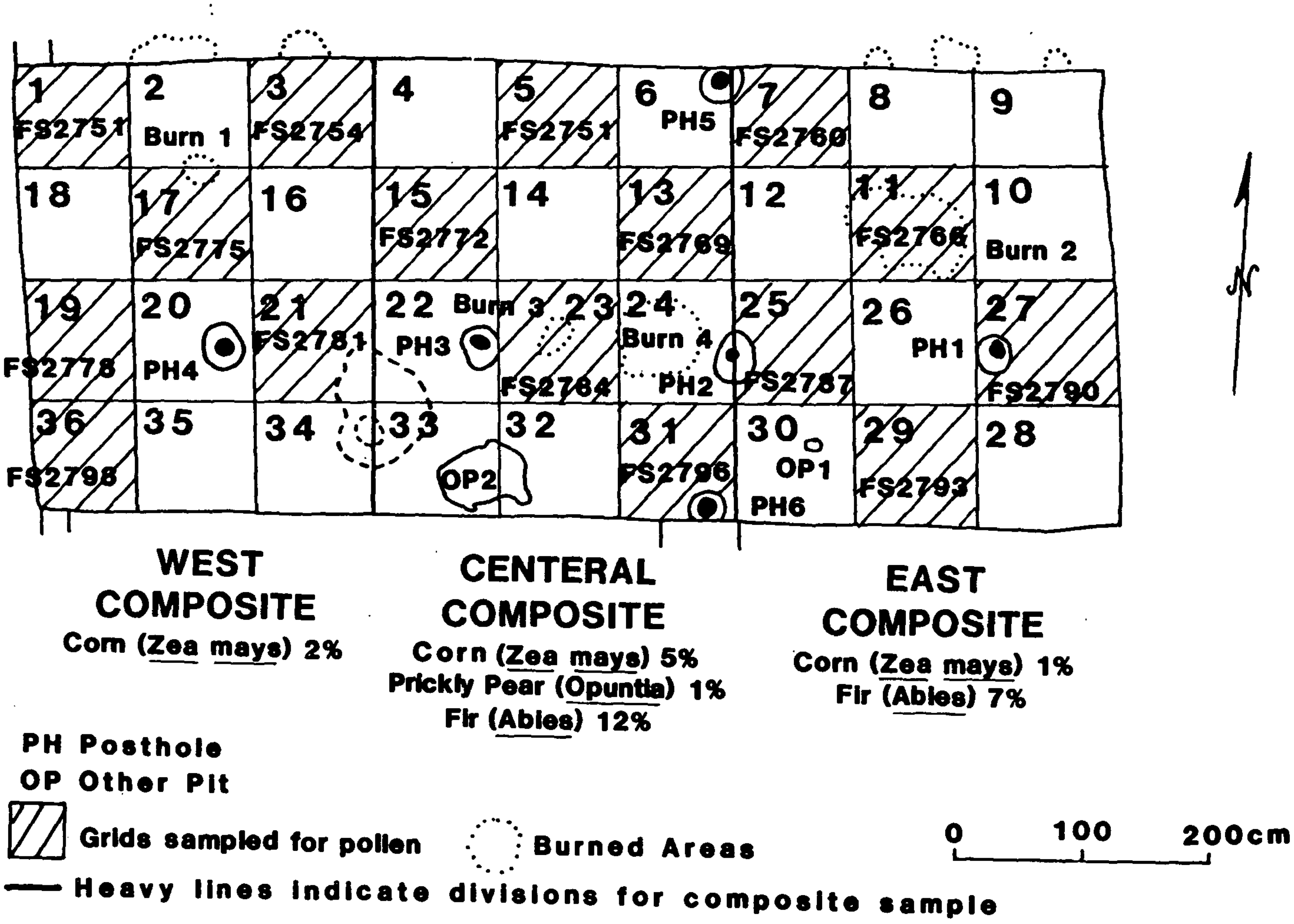

Figure 4.29 Room 142, Pueblo Alto

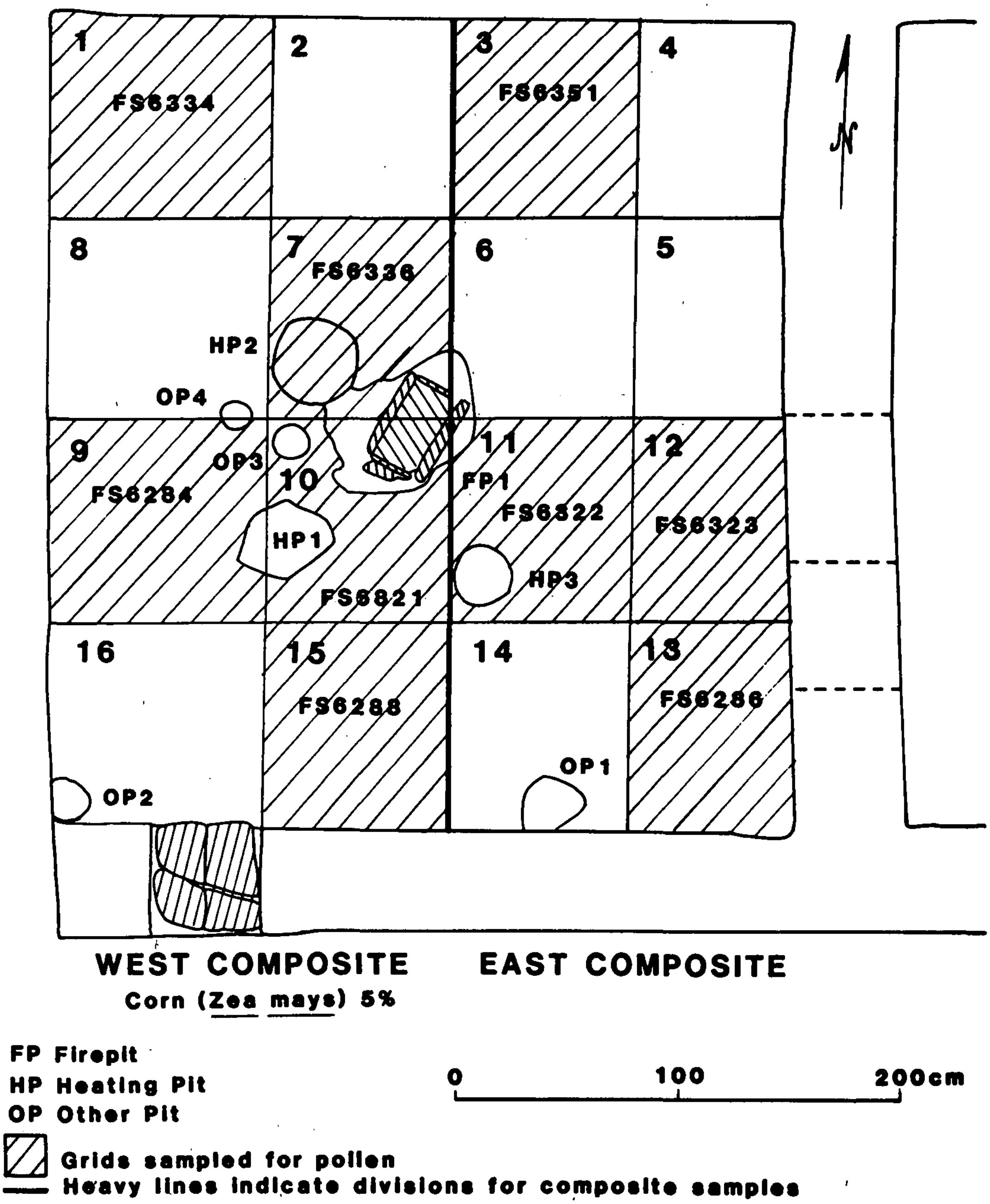

Figure 4.30 Room 147, Pueblo Alto

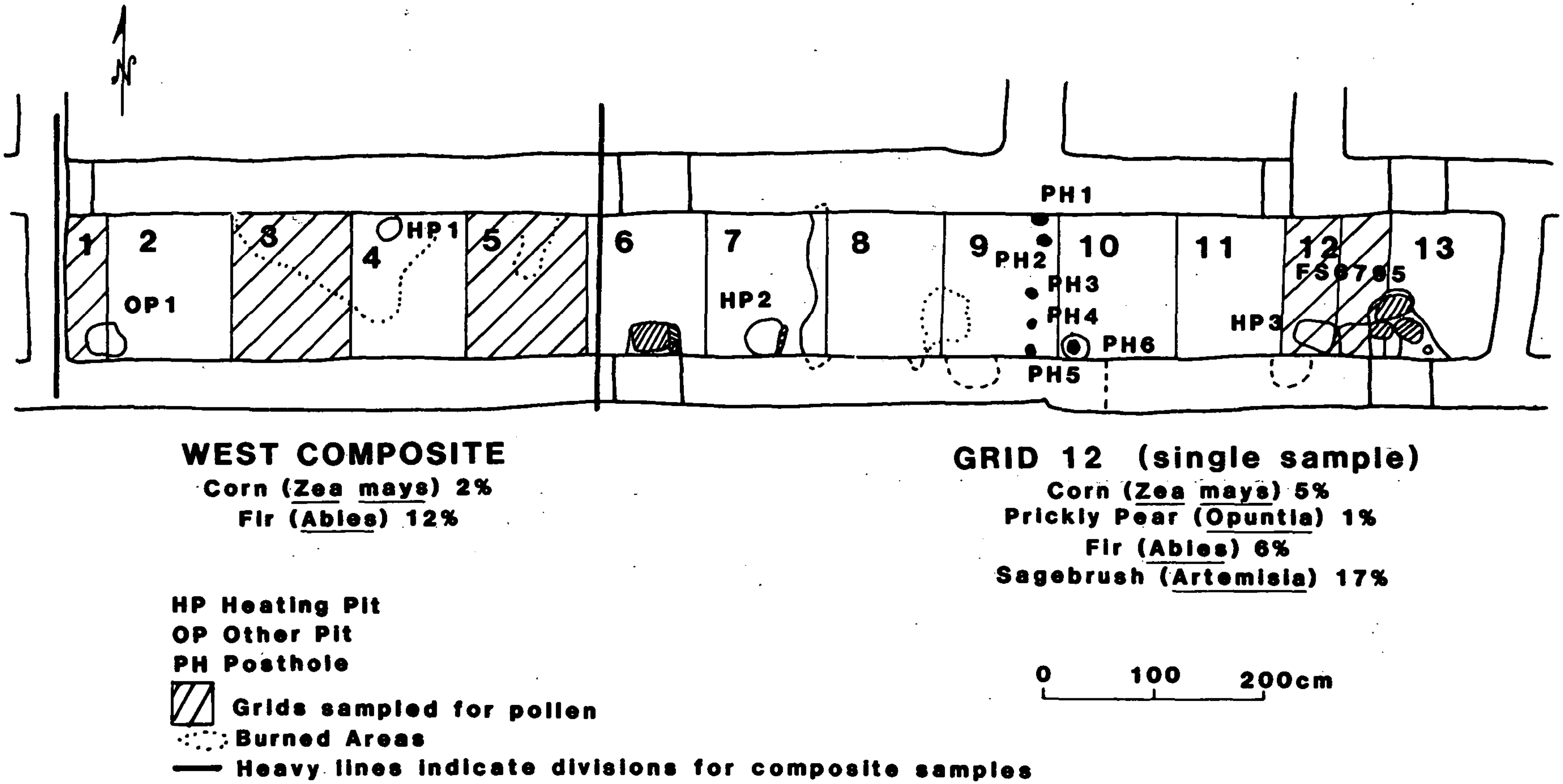

Figure 4.31 Room 143, Pueblo Alto

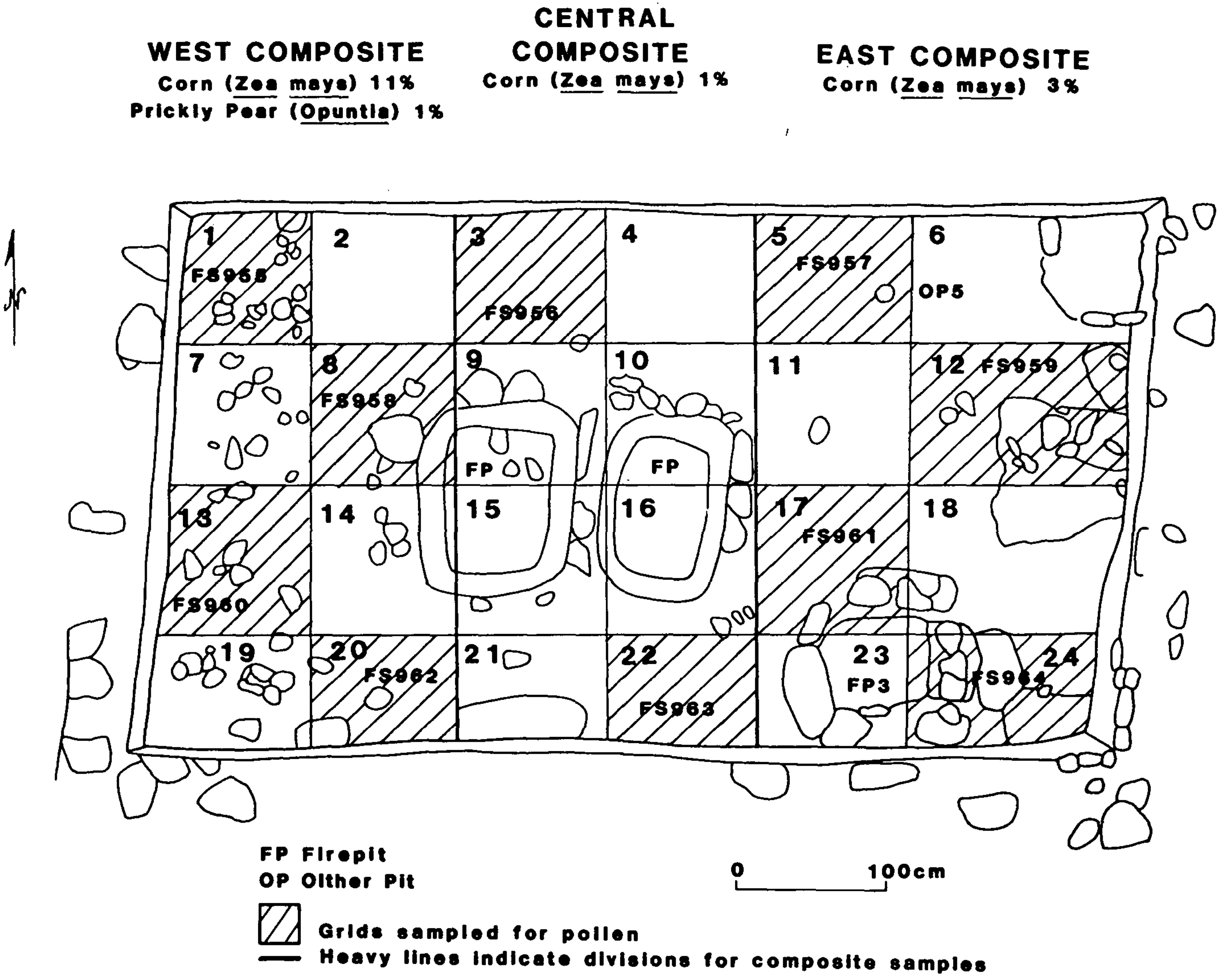

Figure 4.32 Plaza Feature 1, Room 3, Pueblo Alto

separate roomblock located in the main plaza. The feature was constructed in the later stages of occupation at Pueblo Alto. Room 3 contained three deep ovens. Two ovens contained charcoal of white fir (Abies concolor), ponderosa pine (Pinus ponderosa), pinyon pine, juniper, and a small amount of Populus (cottonwood or aspen) wood (Welsh 1978), indicating substantial fires in the pits. In terms of numbers of pieces, pinyon is the most abundant wood from the firepits. Firepit 3, slightly smaller than the other ovens, contained ponderosa pine, pinyon, and juniper charcoal. Room 3 also contained postholes, a bin in the northeast corner, various other pits, and several burned areas.

Individual samples were divided into east, central, and west composite samples (Figure 4.32). Economic pollen of several types was found in this room. Corn pollen was found in all three composite samples and was relatively abundant in the east section (Table 4.8 and Figure 4.32); beeweed and prickly pear cactus were found in this section in unusually high amounts. In the central area, pollen recovery was poor. In the west, a small amount of corn and purslane pollen was found. While the presence of the large ovens suggests some special use for the room, the occurrence of a variety of economic pollen types indicates living activities similar to those which took place in Room 110.

Kiva 15. Kiva 15 (Figure 4.33) was also constructed late in the occupation of the site, perhaps at about the same time as Plaza Feature 1. Kiva 15 was placed directly on top of Room 110 in the West Roomblock. The relationship between the kiva and rooms 112 and 229 to the west is not clear, although architectural modifications indicate that the two rooms continued in use after the construction of the Kiva.

Two individual grid samples were processed from Floor 1 of this Kiva (grids 5 and 9; Figure 4.33 and Table 4.7). No corn pollen was found, in distinct contrast to most other floor contact samples at Pueblo Alto. Cattail pollen was found, however.

Plaza 2. Plaza 2 is located outside the east walls of the East Room Block (Figure 4.21). Two samples were processed and analyzed. Pollen frequencies were low in both, and with the exception of a prickly pear cactus grain, no economic taxa were found (Table 4.7). Samples from plaza-like areas that have been exposed to weathering processes are often low in pollen counts. This is probably due to a combination of occasional moisture and high akalinity, as well as to normal oxidation processes (Hall 1981a).

Features

Mealing Bins. Six mealing bins were located in Room 110 (See Figure 4.23). Bins 1, 2, and 3 were sampled for pollen. The samples contained high percentages of corn pollen (Table 4.5; Figure 4.23). Cucurbit, beeweed and purslane pollen was associated with corn in Bin 2, and cucurbit pollen with Bin 3.

Table 4.7 Pollen Results in Percentages, other locations, Pueblo Alto

				PLAZA FEATURE 1				
		ROOM 3			KIVA 15			PLAZA 2
	East Composite	Central Composite	West Composite	Room Total	Grid 5 FS 5363	Grid 9 FS 5357	Room Total	FS 3574
Abies (fir)						2	1	
Acer (maple)								
Picea (spruce)								
Juniperus (juniper)	1		1	1	2		1	
Pinus (pine)	30		25	27	23	25	24	
Pseudotsuga (Douglas fir)								
Populus (cottonwood)								
Quercus (oak)								
Salix (willow)			1	0.2	1		3	
Juglans (walnut)					1		1	
Oleaceae (olive family)			3	1	3		2	
Cheno-Ams (Chenopodiaceae-Amaranthaceae)	33		37	35	40	51	46	
Sarcobatus (greasewood)				0.2	1		1	
Gramineae (grass family)	7		17	11	16	8	12	
Compositae (sunflower family)								
Low-spine Compositae (spines < 2 microns)	5		1	3	1	5	3	
High-spine Compositae (spines > 2 microns)	2		3	2	4	1	2	
Artemisia (sagebrush)	3		5	4	1	1	1	
Ephedra (Mormon tea)	7		2	2	1	2	1	
Celtis (hackberry)								
Cruciferae (mustard family)			1	0.4	1		1	
Fraxinus (ash)	1			0.4				
Cyperaceae (sedge family)								
Leguminosae (pea family)	0.4		1	1		4	2	
Liliaceae (lily family)	1			0.4				
Yucca (yucca)					2		1	
Malvaceae (globemallow family)						1	0.3	
Spaeralcea (globemallow)								
Rosaceae (rose family)			1	0.2				
Solanaceae (potato family)					2		1	
Lycium (wolfberry)								
Solanum (wild potato)								
Parthenocissus (Virginia creeper)								
Scirpus (bulrush)								
Opuntia (prickly pear cactus)	0.4			0.2				+
Portulaca (purslane)			1	0.4				
Typha (cattail)					2		1	
Type A-Cactaceae								
Cleome (beeweed)	2		1	1				
Cucurbita (squash or gourd)								
Zea mays (corn)	11	+	3	8				
Other*	2		2	1	3	1	2	
Total	263		218	481	182	213	395	

Table 4.7 continued

PLAZA FEATURE 1
MEALING BINS

	Bin 1 FS 5433	Bin 2 FS 54[illegible]	Bin 3 FS 5437	Total
Abies (fir)	1	[illegible]		0.4
Acer (maple)	1			0.2
Picea (spruce)				
Juniperus (juniper)				
Pinus (pine)	58	1[illegible]	16	22
Pseudotsuga (Douglas fir)				
Populus (cottonwood)		0.4		0.2
Quercus (oak)			1	0.2
Salix (willow)			1	0.2
Juglans (walnut)				
Oleaceae (olive family)			1	0.2
Cheno-Ams (Chenopodiaceae-Amaranthaceae)	6	13	3	8
Sarcobatus (greasewood)		0.4		0.2
Gramineae (grass family)	5	1	14	11
Compositae (sunflower family)				
Low-spine Compositae (spines < 2 microns)	3			1
High-spine Compositae (spines > 2 microns)	4	0.4		1
Artemisia (sagebrush)	1	[illegible]	2	3
Ephedra (Mormon tea)	1	0.4	1	1
Celtis (hackberry)				
Cruciferae (mustard family)		0.4		0.2
Fraxinus (ash)				
Cyperaceae (sedge family)				
Leguminosae (pea family)				
Liliaceae (lily family)				
Yucca (yucca)				
Malvaceae (globemallow family)				
Sphaeralcea (globemallow)			1	0.4
Rosaceae (rose family)				
Solanaceae (potato family)				
Lycium (wolfberry)				
Solanum (wild potato)				
Parthenocissus (Virginia creeper)		0.4		0.2
Scirpus (bulrush)				
Opuntia (prickly pear cactus)				
Portulaca (purslane)		0.4		0.2
Typha (cattail)				
Type A-Cactaceae				
Cleome (beeweed)		1		0.4
Cucurbita (squash or gourd)		1	1	1
Zea mays (corn)	20	47	61	47
Other*	1	5	1	3
Total	102	227	213	542

*For other taxa, see Cully (1983).
+Total pollen counts less than 100, taxon noted in sample.

Table 4.8 Economic Pollen Types, North and West Roomblocks, Pueblo Alto

	Cleome	Portulaca	Typha	Opuntia	Type A Cactaceae	Cucurbita	Zea Mays	Sarcobatus	Econ. %	Number of Pollen Grains
North Central Roomblock										
Room 139							0.7		0.7	450
Room 142				0.5			3.0		3.5	414
Room 145										
Room 147				0.4			5.0		5.4	227
Room 143				0.5			3.0		3.5	273
Total				0.29			2.48		2.77	1372
West Central Roomblock										
Room 110	0.1	0.4	0.4	0.4	0.3	0.4	12.2		14.2	1231
Room 112		0.6	7.8	0.3			8.1		16.8	677
Room 227					0.2	0.2	16.2	23.5	40.1	426
Total	0.04	0.38	2.41	0.29	0.21	0.25	10.17	3.58	17.34	2334
Plaza Feature 1										
Room 3	1.0	0.4		0.2			7.8		9.4	487
Kiva 15			1.0						1.0	395
Mealing Bins										
Room 110										
Total 1,2 & 3	0.4	0.2				0.6	474		48.6	542

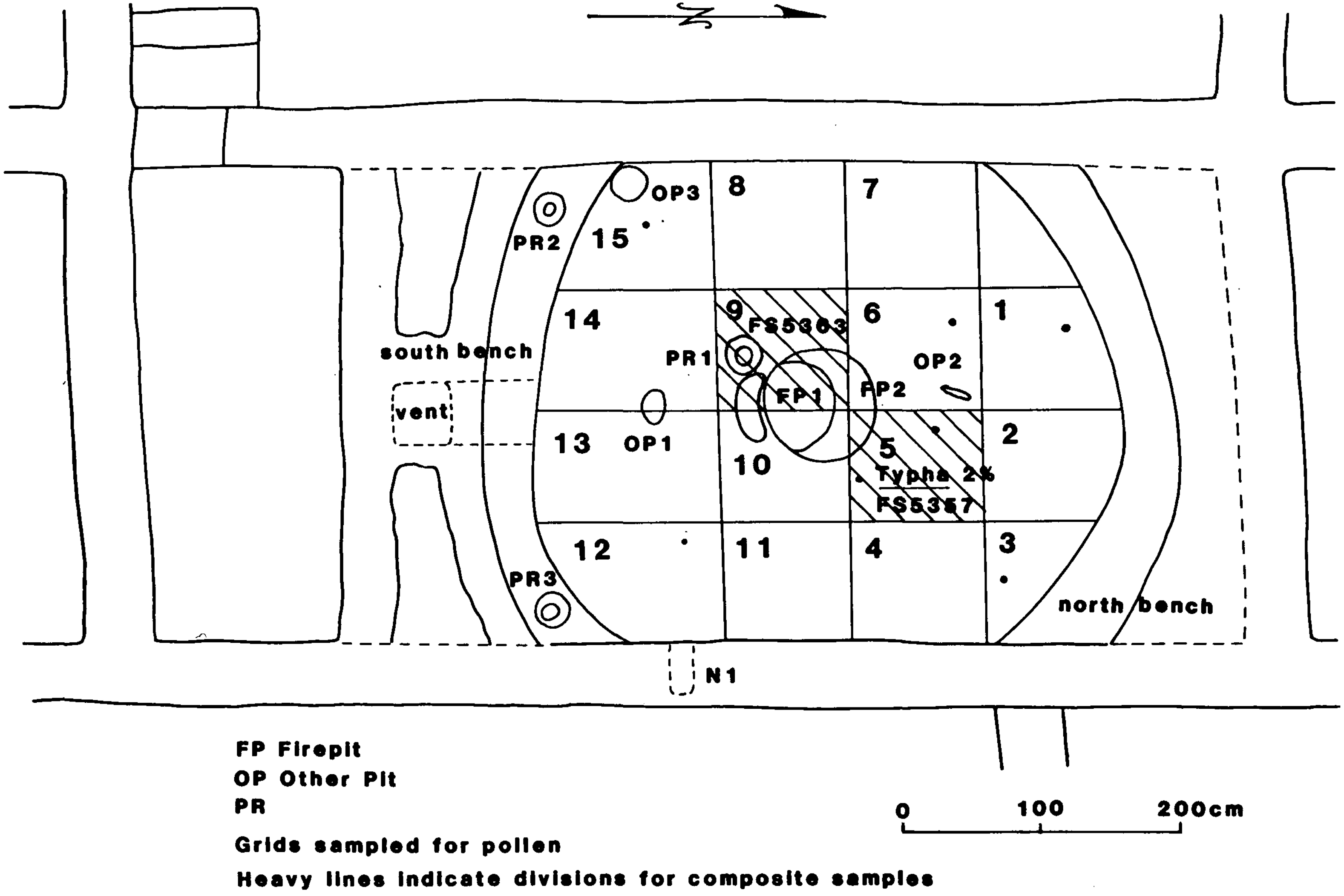

Figure 4.33 Kiva 15, Pueblo Alto

Firepits and Heating Pits. In addition to the floor contact samples, one heating pit and one firepit sample from Room 147 in the North Roomblock were processed and analyzed (Figure 4.30). Unfortunately, these samples proved to be typical of firepits and heating pits that have been previously analyzed at other sites in Chaco Canyon; pollen counts are low (Cully 1983b). The sample is full of charcoal pieces and organic debris with a characteristic red-brown color. No economic pollen types were noted. Hearth samples from other sites at Chaco Canyon and at other locations in the San Juan Basin have yielded similar results (Cully 1982). Under alkaline conditions (due to the wood ashes), pollen is subject to degradation by fungi and bacterial activity, particularly if moisture is present (Dimbleby 1978). Hall (1981a) has noted that pollen is better preserved in a dry cave shelter than in a shelter which receives some precipitation. The hardened basin of the firepit may hold moisture, creating an alkaline solution which promotes destruction of the pollen grains.

Room and Feature Functions

The upper floors of the West Roomblock are dated by ceramics at about A.D. 1050-1100. Kiva 15 was constructed over Room 110 and was probably used during the occupation of the upper floors of the North Roomblock. These upper floors of the North Roomblock appear to have been occupied from around 1100 to 1150-1200. The floor contact samples from these two roomblocks as units are substantially different. The West Roomblock has a higher percentage as well as a wider range of economic pollen taxa than the North Roomblock (Table 4.8).

When the rooms are categorized into storage and living types, based on presence or absence of certain features, differences among frequencies of economic pollen types are less pronounced. Table 4.9 indicates that storage rooms are slightly higher in economic pollen types than rooms with features associated with living functions. Although the differences in the two room types are small, the pattern is similar to that found at Broken-K Pueblo (Hill and Hevly 1968). The true function of some of the rooms in the North Roomblock is in doubt. It seems likely that the North Roomblock was used for functions other than everyday processing, storage, and cooking. Lekson (1984) believes that such rooms in large Chacoan structures were used to store corn for eventual redistribution in the Chacoan system. It is possible that the storage of corn on the cob without husks and after drying would result in mimimal pollen dispersal in rooms. Corn pollen percentages are low in the North Roomblock; however, it is impossible to say whether the presence of corn pollen in these rooms is due to this secondary storage (Fish 1981) or to accidental introduction from sources in other locations in the Pueblo. The association of fir pollen with several of the north rooms suggests that their function may have been ceremonial in part.

There are also differences in pine and Cheno-Am taxa. Even excluding Room 103, the overall pine pollen percentage is much higher in the West Roomblock than in the later dated rooms of the North Roomblock (Table 4.5-4.6). Conversely, the later rooms contain a higher percentage of Cheno-Am taxa than the earlier rooms. It is tempting to speculate that the higher

Table 4.9 Economic Pollen Types, Living and Storage Rooms, Pueblo Alto

Living Rooms	Cleome	Portulaca	Typha	Opuntia	Type A Cactaceae	Cucurbita	Zea Mays	Sarcobatus	Econ. %	Number of Pollen Grains
147				0.4			5		5.4	227
143				0.5			3		4	273
110	0.1	0.4	0.4	0.4	0.3	0.4	12.2		14.2	1231
Total									11.4	1975
Storage Rooms										
139							0.7		0.7	450
142				0.5			3		3.5	414
145										8
112		0.6	7.8	0.3			8.1		16.8	677
229					0.2	0.2	16.2	23.5	40.1	426
Total									15.2	1975

Cheno-Am counts may be due to the accumulated effects of disturbance around Pueblo Alto which could encourage the growth of weedy Cheno-Am species. The results of this disturbance might be seen in a local pollen rain with higher Cheno-Am percentages. The other late proveniences in the Pueblo have lower Cheno-Am percentages. High economic-type pollen percentages may be depressing the Cheno-Am counts in the West Roomblock (see Table 4.5).

With the exception of Kiva 15, the west rooms were probably occupied earlier than the north rooms. As units, the two blocks were very different in pine, Cheno-Am, and economic pollen type percentages. The western suite of rooms was consistently higher in economic pollen types than the north rooms. The actual function of the rooms in the North Roomblock did not seem to be centered around plant food storage and processing. Even the rooms with firepits and heating pits are lower in economic pollen percentages than the storage type rooms in the West Roomblock. Plaza Feature 1, used contemporaneously with the north rooms, contains pollens of economic types missing from the North Roomblock. Perhaps there was a change in the locus for food storage and processing from the West Roomblock to specialized locations like Plaza Feature 1, especially after the construction of Kiva 15 over Room 110.

Site Comparisons

Pollen Taxa of Economic Importance

Corn (Zea mays) Pollen

Corn pollen could have been introduced into the sites in several ways, e.g., as the result of the storage of corn after harvesting, or the use of pollen for ceremonial purposes. Bohrer (1972) has shown that harvesting, storing, and processing activities could result in dispersal of pollen into archeological sites. High relative percentages of corn pollen in archeological sites have often been interpreted as being the result of introduction with corn which was being processed or stored (Fish 1981; Hill and Hevly 1968). Fish (1981) interprets high percentages of corn pollen from floors or storage feature samples as evidence of primary introduction, that is, introduction immediately after harvesting.

Different distributions of corn pollen may indicate different activity patterns. At Pueblo Alto, a division of room types based on the presence or absence of features, resulted in similar corn pollen percentages in storage and living rooms; however, floor samples from the West Roomblock and Plaza Feature 1, Room 3 were consistently higher in corn pollen than those of the North Roomblock (Tables 4.8 and 4.9). The north area may have been the location of ceremonial or other activities that were not oriented around everyday living routines. In spite of the general similarities in construction at 29SJ 627 and 29SJ 629, the distribution of corn pollen within each site is clearly different. Relative corn pollen percentages in aboveground rooms were considerably lower at 29SJ 629 than at 29SJ 627 (Figure 4.34). Corn pollen is concentrated in Pithouse 3 and Other Pit 14 at 29SJ 629, but more uniformly distributed in the above-

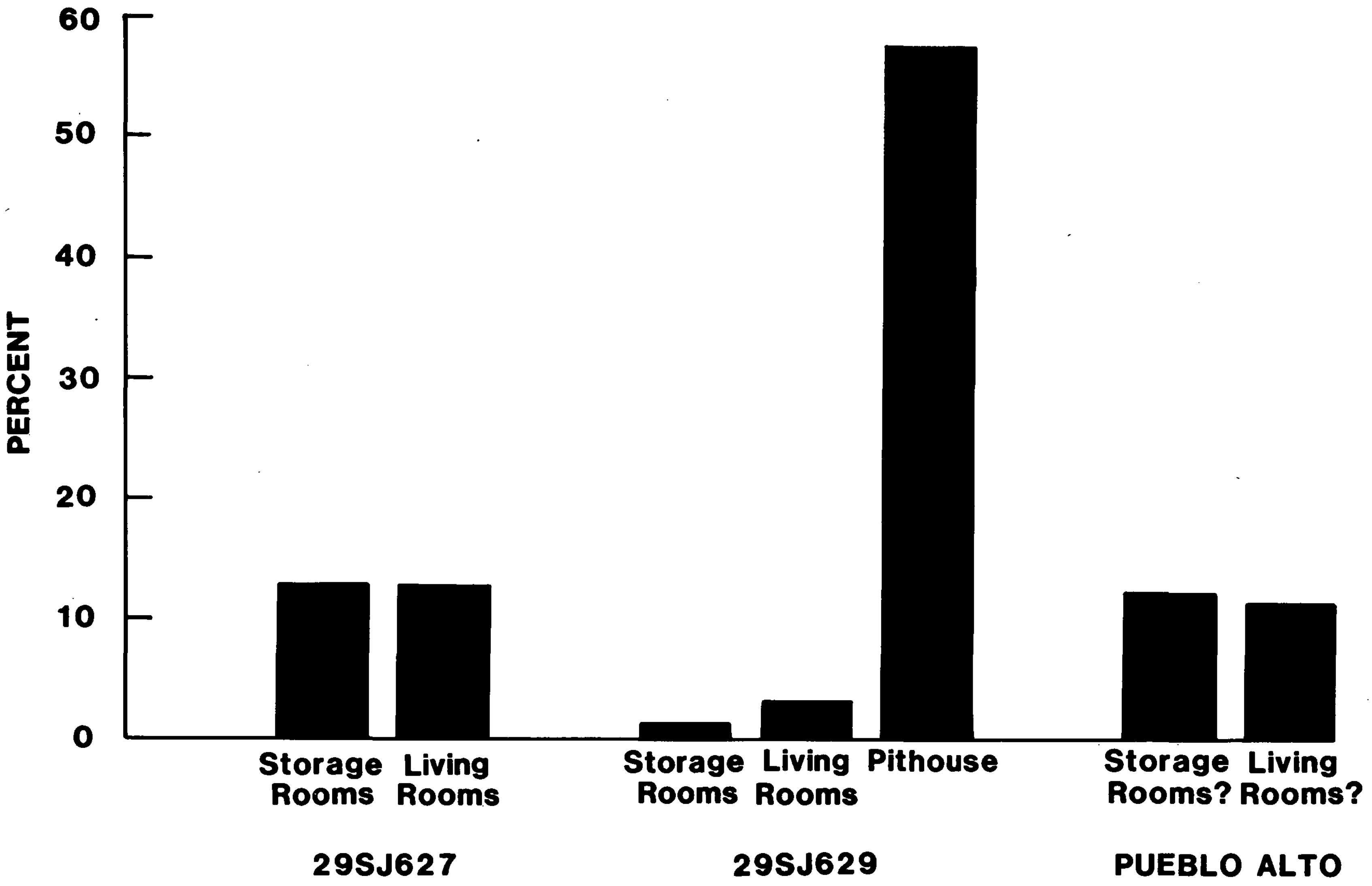

Figure 4.34 Corn pollen percentages in living rooms, storage rooms, and a pit house, from three sites in Chaco Canyon

ground rooms at 29SJ 627. Windes believes that 29SJ 629 may have been occupied seasonally. If this was the case at least during the use of Pithouse 3 and the bell-shaped pits in the plaza, 29SJ 629 was probably occupied during the growing season. Corn may have been stored in these locations immediately after harvesting, causing an abundance of pollen grains to be deposited. At 29SJ 627, year-round occupation and the overlapping living functions in the aboveground rooms would create the more uniform distribution of corn pollen at this site. At 29SJ 629, pollen samples taken from the aboveground rooms which were in use after the abandonment of the pithouse and bell-shaped pits do not contain comparable corn pollen percentages. This may indicate a change from seasonal to year-round occupation of the site, with a pattern of pollen distribution in living and storage rooms more similar to that at 29SJ 629. Alternatively, the high percentages of corn pollen in Pithouse 3 at 29SJ 629 may be the result of ceremonial activities, as subterranean rooms became oriented around ritual rather than domestic functions.

Features that were sampled and productive varied from site to site; high percentages of corn pollen were found in the large bellshaped cists at Site 29SJ 629 and in mealing bins in Room 110 at Pueblo Alto. High percentages of corn pollen also occur in mealing bins (Bohrer 1980; Cully 1983b; Hill and Hevly 1968).

Little or no corn pollen was noted in well-defined kivas at Chaco Canyon (Tables 4.8-4.10; Figure 4.35). Corn pollen was seldom found in kivas at Broken K Pueblo (Hill and Hevly 1968), Bis sa'ani Pueblo (Cully 1983b), Dominguez Ruin in southern Colorado (Scott 1979), and sites in west-central New Mexico (Gish 1982). At Salmon Ruin, however, Bohrer (1980) found high percentages of corn pollen in kivas, which she interprets as the result of medicinal and ceremonial uses. Other subterranean structures (excluding Pithouse 3; Figure 4.35) sampled at the three sites contained very little corn pollen.

Rather than there being similar distributions of corn pollen at the two small sites, and these two differing from Pueblo Alto, each site has an individual pattern. When the results from the samples from each site are combined into one sample and the percentage of corn pollen calculated for each site, these percentages are almost equal (Figure 4.36). This suggests that corn was equally important and available for subsistence and possibly ceremonial purposes at all three sites.

Cucurbit (Cucurbita) Pollen

Pollen evidence for the use of cucurbits was found at all three sites at Chaco Canyon (Tables 4.9 and 4.10). Cucurbit pollen occurred in a bell-shaped storage pit at 29SJ 629, in a storage room at 29SJ 627, and in the West Roomblock at Pueblo Alto (Table 4.8). The pollen could have been introduced on the fruits or with flowers. Cucurbit pollen has been found at Salmon Ruin (Bohrer 1980), and at Bis sa'ani Pueblo (Cully 1983b).

Cattail (Typha) Pollen

Cattail pollen was probably introduced into Pueblo Alto for use as

Table 4.10 Economic Pollen Types, Sites 29SJ 627 and 29SJ 629

Site 29SJ 629	Cleome	Portulaca	Typha	Opuntia	Type A Cactaceae	Cucurbita	Zea Mays	Econ. %	Total Number of Pollen Grains
Storage Rooms									
Room 5							1.7	1.7	248
Room 6					0.1		0.1	0.4	517
Total					0.1		0.7	0.1	765
Living Rooms									
Room 2		0.4		0.2	0.1		7.0	7.7	888
Room 3		0.5		0.5	0.1		2.0	3.3	701
Total		0.5		0.4	0.1		4.8	5.8	1589
Pithouse 3				4.0	0.5		59.0	63.5	600
Pithouse 1/Kiva			2				2		223
Pithouse 2				2	1		1		188
Features (3 Pitstructures)				1.0	0.5	0.5	26.0	28	540
Site 29SJ 627									
Storage Rooms									
Room 16		0.7	0.1	0.45	0.3	0.25	14	15.9	1549
Room 4				0.5	0.2		9	9.6	538
Total		0.7	0.09	0.5	0.3	0.2	12.7	14.3	2087
Living Rooms									
Room 8		0.2		15	0.2		13	13.7	446
Features (Misc. Pit Types)				0.1	0.1	0.1	3	3.5	665
Kiva C				0.1				1	206

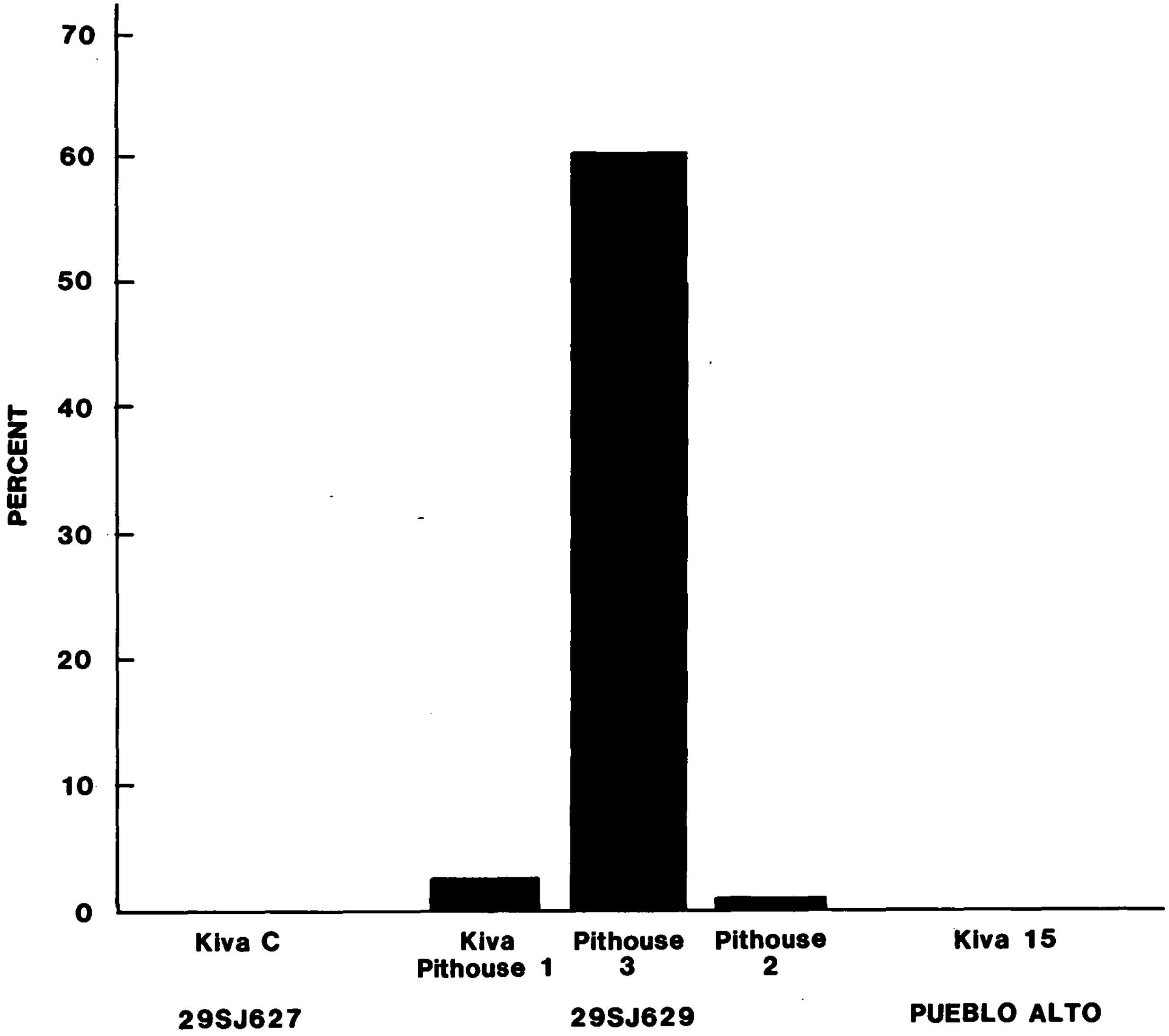

Figure 4.35 Corn pollen percentages, pithouses and kivas, Sites 29SJ 627, 29SJ 629 and Pueblo Alto

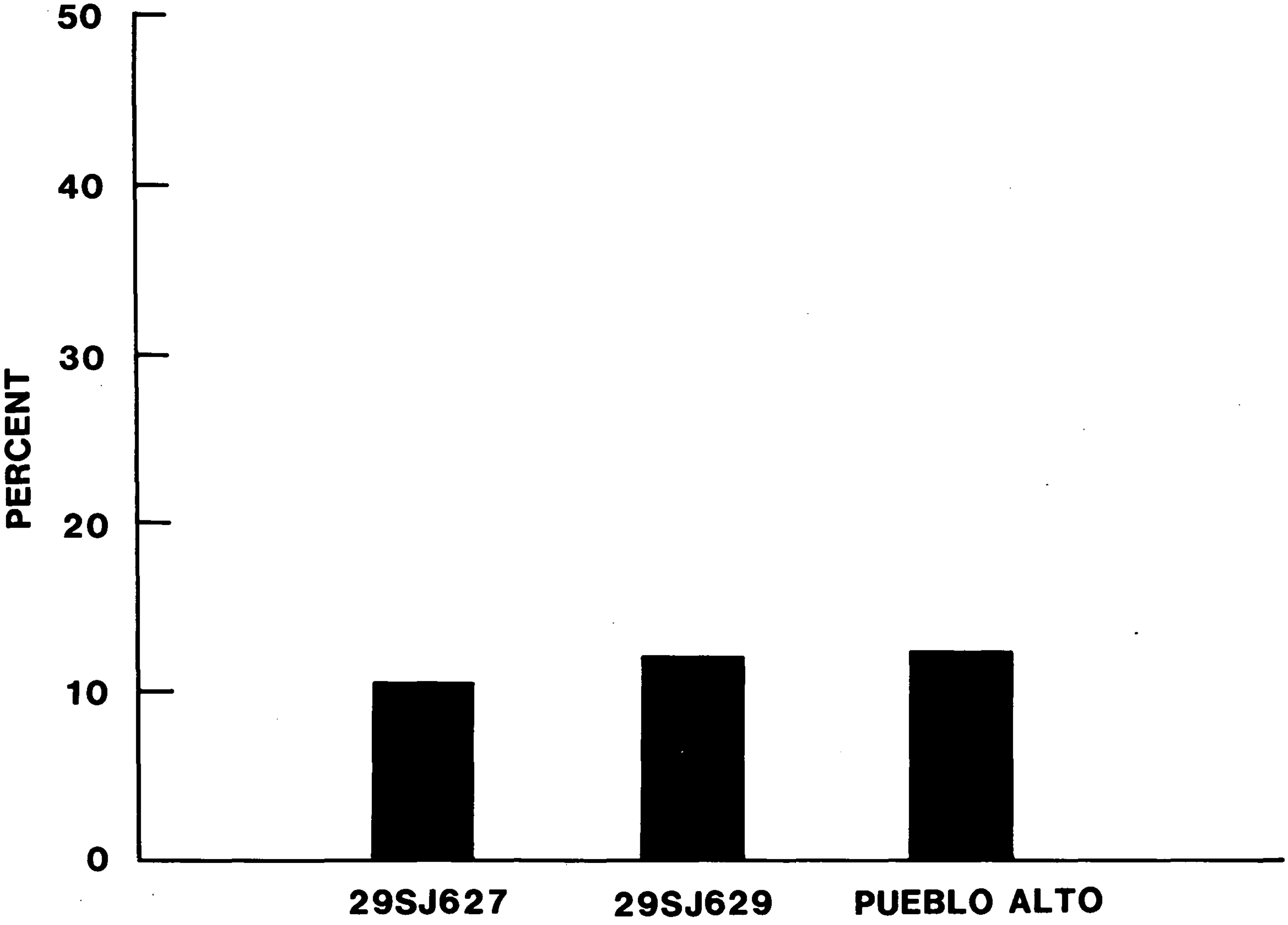

Figure 4.36 Total corn pollen percentages from Sites 29SJ 627, 29SJ 629 and Pueblo Alto

food, for matting or for construction. This pollen type was particularly abundant in Room 112 (Table 4.8). Cattail pollen in samples from Kiva 15 may be the result of ceremonial use of these plants, in ways similar to those described by Stevenson (1915) at Zuni. Cattail pollen has been reported from other sites in the southwest (Bohrer 1972; Hill and Hevly 1968; Madsen 1979).

Purslane (Portulaca) Pollen

Purslane pollen is present in the West Roomblock and Plaza Feature 1 at Pueblo Alto (Table 4.8). It occurs in low numbers in Room 16 at Site 29SJ 627 (Table 4.10). The pollen could have been brought into the sites on plants that were to be consumed immediately or to be stored for winter use. Clary (1981) reports this pollen type is common in coprolites from Chaco Canyon, indicating that purslane was eaten.

Beeweed (Cleome) Pollen

Beeweed pollen was found in very low percentages in Room 110 at Pueblo Alto (Table 4.8). This may be the result of accidental occurrence; however, beeweed pollen was also found in coprolite samples taken from this room (Clary 1981), supporting the interpretation of introduction by man. This pollen type was not found in other sites at Chaco Canyon, although it has been noted at various locations in and around the San Juan Basin (Bohrer 1980; Scott 1979).

Prickly pear (Opuntia-platyopuntia type) Pollen

Prickly pear cactus pollen occurred in every room at Pueblo Alto except Room 145, Room 229 and Kiva 15 (Table 4.8). It was probably introduced on the fruits or stems (Bohrer 1972). This taxon has been found frequently in samples from other sites in Chaco Canyon (Table 4.10), and at Bis sa'ani Pueblo (Cully 1983b).

Greasewood (Sarcobatus) Pollen

Greasewood pollen was found in high percentages in Room 229 at Pueblo Alto and in Pithouse 3 at 29SJ 629 (Tables 4.8 and 4.10). This high percentage may be associated with the use of greasewood for fuel.

Cheno-Am (Chenopidiaceae-Amaranthaceae, Amaranthus) Pollen

High percentages of Cheno-Am pollen were found in features which may have been used for storage of seeds a 29SJ 627 (Table 4.11). At Site 29SJ 629, floor contact samples with high percentages of Cheno-Am pollen suggest the processing, storage, or perhaps the use of chenopodiaceous shrubs in roofing materials.

Fir (Abies) Pollen

Fir pollen was identified in samples from several proveniences at

Table 4.11 Economic Pollen Types, Sites 29SJ 627, 29SJ 629, and Pueblo Alto

Site 29SJ 627	Cheno-Ams (>50%)	Sarcobatus (>10%)	Abies	Gramineae (>10%)	Sphaeralcea (>10%)	Total Number of Pollen Grains
Storage Rooms						
Room 16			0.3	11		1549
Living Rooms						
Room 8				20		
Features						
Miscellaneous	62		0.3			665
Small Pits						
Pit 6, Room 3				75		222
Site 29SJ 629						
Storage Rooms						
Room 5	58					248
Room 6	55					517
Living Rooms						
Room 2				35		888
Room 3			0.4	11		701
Room 9	70					449
Features						
O.P. 1			5			205
O.P. 2			2			113
Pithouse 1	51		5			223
Pithouse 2			2			188
Pithouse 3			1			606
Pueblo Alto						
Living Rooms						
Room 110			3			1231
Room 147	55		2			227
Room 143			10			213
Storage Rooms						
Room 112			0.6			677
Room 229		24				426
Room 139	55		2			450
Room 142			8			414
Features (Bins)			0.4	11		542
Plaza Feature 1, Room 3				11	11	487
Kiva 15			1.3	12	12	395

sites 29SJ 627 and 29SJ 629 (Table 4.11). At Pueblo Alto, fir pollen was found in highest percentages in Rooms 142 and 143 of the North Roomblock. The two areas of high percentages of fir pollen are adjacent to one another near the connecting Door 14 (Figure 4.31). This pollen type was found in lower frequencies in Room 112, West Roomblock, and Kiva 15. The distribution of fir pollen at Pueblo Alto suggests that boughs and twigs may have been used for ceremonies similar to those reported for the Hopis (Whiting 1939) and the Keresans (Swank 1932). Fir pollen was not recorded in either surface or sub-surface samples dating back to early Holocene time (Hall 1977); however, Cully (1977a) reports 1% fir pollen in a surface station at 29SJ 627. The pollen evidence suggests that the prehistoric inhabitants of Chaco Canyon traveled to higher elevations (like the Hopis) to gather fir boughs to use in ceremonies.

Sagebrush (Artemisia) Pollen

At Pueblo Alto, sagebrush pollen was found in an unusually high percentage in Room 143 (Table 4.11). Sagebrush plants may have been brought into this room to use for fuel. Welsh (1978) found sagebrush charcoal from heating pits and firepits in several sites from Chaco Canyon. At Bis sa'ani Pueblo, high percentages of sage pollen were found in a sample from a firepit (Cully 1983b) where sagebrush charcoal had also been identified (Donaldson and Toll 1982). High percentages of this pollen type were also found in grid samples from Room 3 at 29SJ 629. The presence of fir pollen indicates that Room 143 may have been used for the storage of ceremonial materials; sagebrush may also have been brought in for ceremonial or medicinal purposes.

Grass (Gramineae) Pollen

Grass pollen occurred in several grid samples at Site 29SJ 629 in amounts greater than 10% (Table 4.12). Samples from a small pit at 29SJ 627 also contained similar percentages (Table 4.11). At Pueblo Alto, grass pollen percentages were lower; however, the presence in mealing bins and Plaza Feature 1, Room 3 suggests that grasses were used. Pippin (1979) reports high percentages of grass pollen from metate, mealing bin, and mano surfaces at Guadalupe Ruin, a Chacoan site near the Rio Puerco of the east, in New Mexico. Pollen evidence for the use of grasses has been noted by Bohrer (1981) at Salmon Ruin in northwestern New Mexico.

Globemallow (Malvaceae, Spheralcea) Pollen

Unusually high percentages of globemallow pollen were found in Room 3 at Site 29SJ 629 (Table 4.12), Plaza Feature 1, Room 3, and Kiva 15 at Pueblo Alto (Table 4.11). Gish (1982) found evidence of the association of globemallow with burials in pollen samples from Anasazi sites in southwestern New Mexico and Arizona. Scott (1979) found globemallow pollen in high percentages in a sample from a canteen resting on a kiva floor at the Dominguez Ruin in southern Colorado. Scott (1979) also reports that the pollen was clumped or aggregated, suggesting deliberate introduction of flowers into the canteen. Globemallow pollen, in percentages that indi-

Table 4.12 Possible Economic Pollen Types, Site 29SJ 629, Rooms 2 and 3

	Cheno-Ams	Compositae	Artemisia	Gramineae	Malvaceae	Sphaeralcea
Room 2						
Grid A	55.8	2.2		8.7	2.0	
Grid B	72.6	1.6		5.7		
Grid E	4.8			88.6		
Grid F	19.0	1.0	1.0	65.0		
Room 3, F 11						
Grid I	33.3	9.7		22.0	15.1	
Grid K	27.5	2.0	2.0	18.0	11.8	
Grid C	38.0	6.0	2.0	6.0	0.5	
Grid A	11.0	6.0	17.0	5.0		11.0
Grid E	27.0	7.0	4.0	7.0		3.0

cate purposeful introduction, is associated with ceremonial or medicinal uses. Similar uses of globemallow may have been made at Chaco Canyon, e.g., Clary (1981) reports that globemallow pollen occurred in 14% of the 28 coprolite samples from Pueblo Alto and Pueblo Bonito, and was the dominant type in four.

Comparison of Taxa Found at Small and Large Sites

In spite of some intra-site differences in corn pollen distribution, the evidence suggests that corn was of equal importance in subsistence at all three sites. Most of the major, wild economic taxa were also found in each location (Table 4.13), indicating that the inhabitants of both small sites and large structures had access to and used the same domestic and wild plant resources. The occurrence of corn and cucurbit remains along with wild plant taxa, such as beeweed, grasses, cactus, and purslane, in other Anasazi sites indicates that the use of domestic and wild plant resources was a widespread adaptation in the San Juan Basin (Cully and Clary 1983) and surrounding areas (Gish 1982; Scott 1978; Williams-Dean and Bryant 1975).

Room Function and the Percentage of Economic Pollen

At Broken K Pueblo, Hill and Hevly (1968) related the numbers and percentages of pollen from economic taxa (domestic and wild) to room function. There was less pollen from economically important taxa in living rooms, characterized architecturally by firepits, heating pits, mealing bins, etc., than in storage rooms, characterized by the lack of such features. The relative percentages of economic taxa were also lower in living rooms than in storage rooms. At Chaco Canyon, the distribution of economic pollen is distinctive at each site. The pattern observed at Broken K Pueblo appears in the aboveground structures at Site 29SJ 629 (Table 4.14; Figure 4.37). At Site 29SJ 627 and Pueblo Alto, the distribution of economic pollen is about the same in each category of rooms, with the percentage of economic pollen actually slightly higher in the storage rooms. At 29SJ 627, Truell (1981) noted the presence of a few features usually associated with living activities in rooms otherwise similar to storage rooms in location and construction. The dual functions of the storage rooms may have resulted in similar frequencies of economic pollen types in both storage and living rooms. At Pueblo Alto, the rooms of the North Roomblock possibly were reserved for special functions. Rather than a distinction based solely on the presence or absence of features, a more meaningful division of room types seems to be simply one based on location in the North or West Roomblocks. The pollen results from the major divisions are accordingly quite different (Table 4.15; Figure 4.37) and provide evidence for different uses of these areas. The function of the rooms in the North Roomblock may have been ceremonial, or related to another (as yet undetermined) role in the activities of the site. Pithouse 3 (29SJ 629) is a confusing factor when attempting to relate room function to the percentage of economic pollen. The high percentages of corn pollen (contributing most of the economic-type frequency) could have resulted from the primary storage of corn or from ceremonial

Table 4.13 Pollen Taxa of Economic Importance, Small Sites and Large Structures, Chaco Canyon and Bis sa' ani Community

	Chaco Canyon			Bis sa' ani Community	
	Small Sites		Large Structure	Small Sites	Large Structure
	Site 29SJ 627 A.D. 700-1000 1 site, n=80 (Cully 1977)	Site 29SJ 629 A.D. 900-1200 1 site, n=60 (Cully 1981)	Pueblo Alto A.D. 1000-1200 1 site, n=45 (Cully 1982)	10 Sites, n=38 A.D. 1150-1250 (Cully 1985)	Bis sa' ani Pueblo A.D. 1150-1250 (Cully 1982)
Pinus sp.	+				+
Low-spine Compositae				+	+
Cheno-Ams	+	+	+	+	+
Gramineae	+	+	+	+	+
Sphaeralcea		+	+		
Eriogonum					+
Portulaca	+	+	+		
Cleome			+	+	+
Opuntia	+*	+*	+*		+*
Typha	+	+	+	+	+
Cucurbita	+	+	+	+	+
Zea Mays	+	+	+	+	+

* platy opuntia type

Table 4.14 Percentages of Economically Important Pollen Types in Storage and Living Rooms, Sites 29SJ 627, 29SJ 629, and Pueblo Alto

Site	Number of Economic Grains	Total Economic Pollen %	Total Pollen Grains
29SJ 629			
Storage Rooms			
Room 5	4	1.7	248
Room 6	2	0.4	517
Total	6	0.1	765
Living Rooms			
Room 2	69	7.7	888
Room 3	23	3.3	701
Total	92	5.8	1589
29SJ 627			
Storage Rooms			
Room 16	246	15.9	1549
Room 4	52	9.6	538
Total	298	14.3	2087
Living Rooms			
Room 6	61	13.7	446
Pueblo Alto			
Storage Rooms			
Room 139	3	0.7	450
Room 142	13	3.5	414
Room 145	-	-	8
Room 112	114	16.8	677
Room 229	171	40.1	426
Total	301	15.2	1975
Living Rooms			
Room 147	12	5.4	227
Room 143	10	3.5	273
Room 110	175	14.2	1231
Total	197	11.4	1731

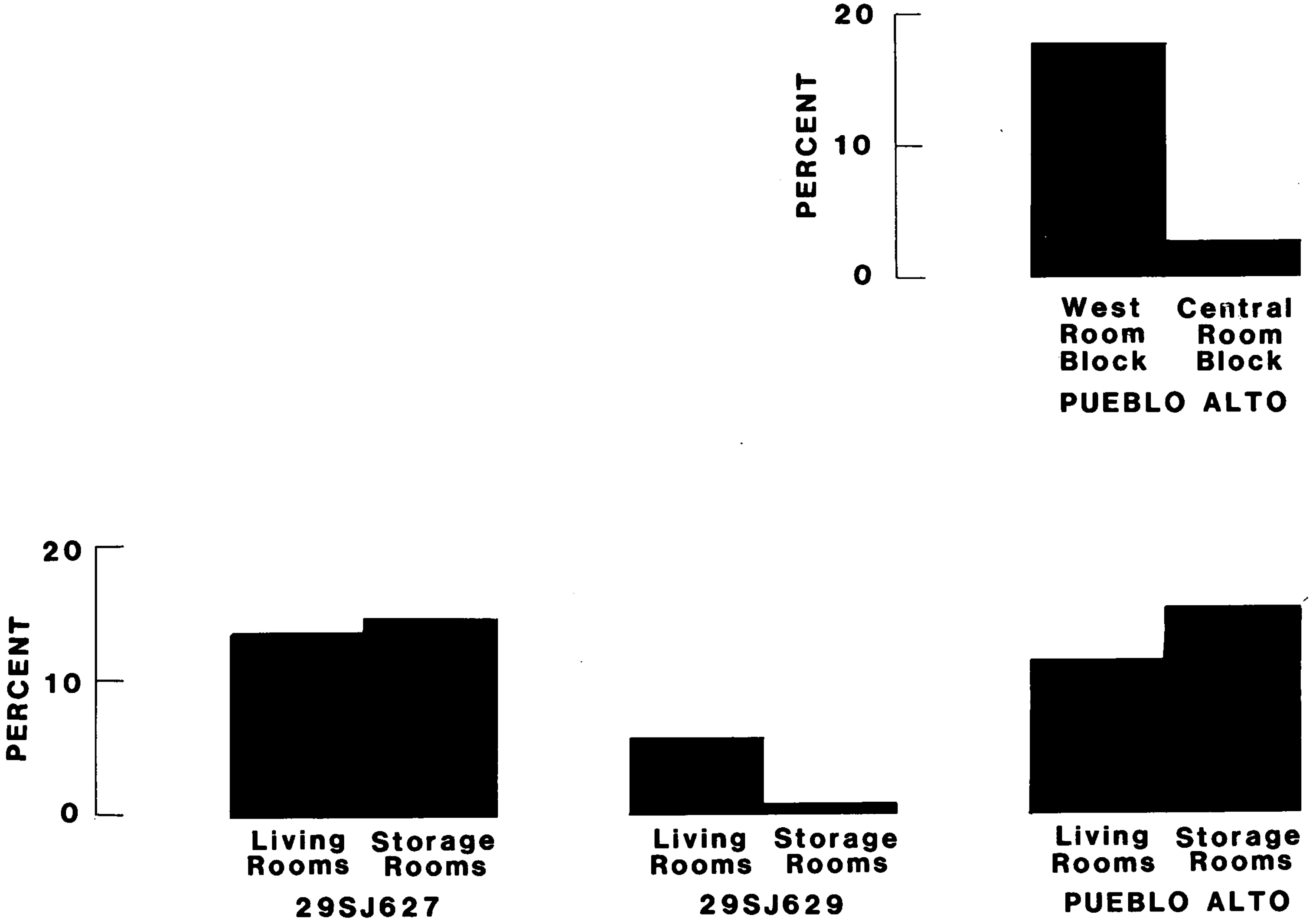

Figure 4.37 Total economic pollen percentages, living rooms and storage rooms, Sites 29SJ 627, 29SJ 629 and Pueblo Alto

Table 4.15 Total Economic Pollen Percentages in North and West Room Blocks at Pueblo Alto

	Total Economic Pollen Types		
Location	Number of Economic Grains	%	Total Pollen Grains
North Roomblock			
Room 137	3	0.7	450
Room 142	13	3.5	416
Room 145	-	-	-
Room 147	12	5.4	227
Room 143	10	3.5	273
Total	38	2.8	1372
West Roomblock			
Room 110	175	14.2	1231
Room 112	114	16.8	677
Room 229	170	40.1	426
Total	460	17.3	2334
Plaza Feature 1			
Room 3	46	9.4	487

activities. In contrast, samples from other pit structures were low in economic pollen percentages (Table 4.14; Figure 4.38).

Complementary Botanical Information

Paired pollen and flotation samples from the same grid sections at 29SJ 627 were compared (Table 4.16). The results indicated that much of the pollen and flotation data were complementary in nature, that is, many of the taxa found in one form of analysis were not found in the other. The complementarity was especially significant for such ecomonically important taxa as corn, corn cucurbit, prickly pear, and purslane. Cheno-Ams, on the other hand, commonly occurred in both pollen and flotation samples.

A similar comparison was made at 29SJ 629, although the information was considered on a room or feature basis, rather than on a paired sample basis. Results from individual grid samples from each room were combined and treated as one sample. Larger, or macrobotanical remains, were also included in this comparison. Table 4.17 is taken from a compilation of botanical data listed in Cully (1983a).

Corn pollen in varying amounts was present in all the rooms and features analyzed for pollen at 29SJ 629. Most of the samples from features and rooms also contained corn remains in the flotation. Fewer than half the rooms contained larger, or macro-remains, of corn (Table 4.17). Larger cattail remains were absent from the rooms and features under consideration. Pollen was the only evidence of the use of this plant. As at Site 29SJ 627, pollen and flotation samples both consistently contained remains of plants in the Cheno-Am category. Tansy mustard seed occurred regularly at 29SJ 629, sometimes in a burned condition signifying human introduction and use. It is difficult to identify pollen to the genus level in the Cruciferae or mustard family; however, it is possible that the mustard family pollen identified at 29SJ 629 accompanied tansy mustard seeds. Purslane is also a common weedy species; however, the plants produce very little pollen. Pollen evidence for the use of purslane occurred in several rooms where larger remains were absent. Micro- and macro-remains of cucurbits occurred very infrequently at 29SJ 629; squash or gourd pollen was found in one location without accompanying evidence from flotation or macro-remains. Grass pollen was found consistently throughout the site. Grass seeds occurred in many of the same locations; macro-remains occurred infrequently.

The distribution of the pollen and seeds of several taxa reflects the dispersal mechanisms evolved by the plant species; tansy mustard is a weedy annual that produces an abundance of seed but little pollen. Cheno-Ams are prolific producers of pollen and seed. Purslane, a weedy annual, also produces a large crop of seed but very little pollen. Determining whether or not seeds identified in flotation samples are there because they were introduced by humans has been discussed by Toll (1978b, 1979, 1981a). In pollen analysis, the mere presence of Cheno-Am, grasses, and many other pollen types does not necessarily indicate that these plants were being used by the sites' occupants. If these taxa occur in higher

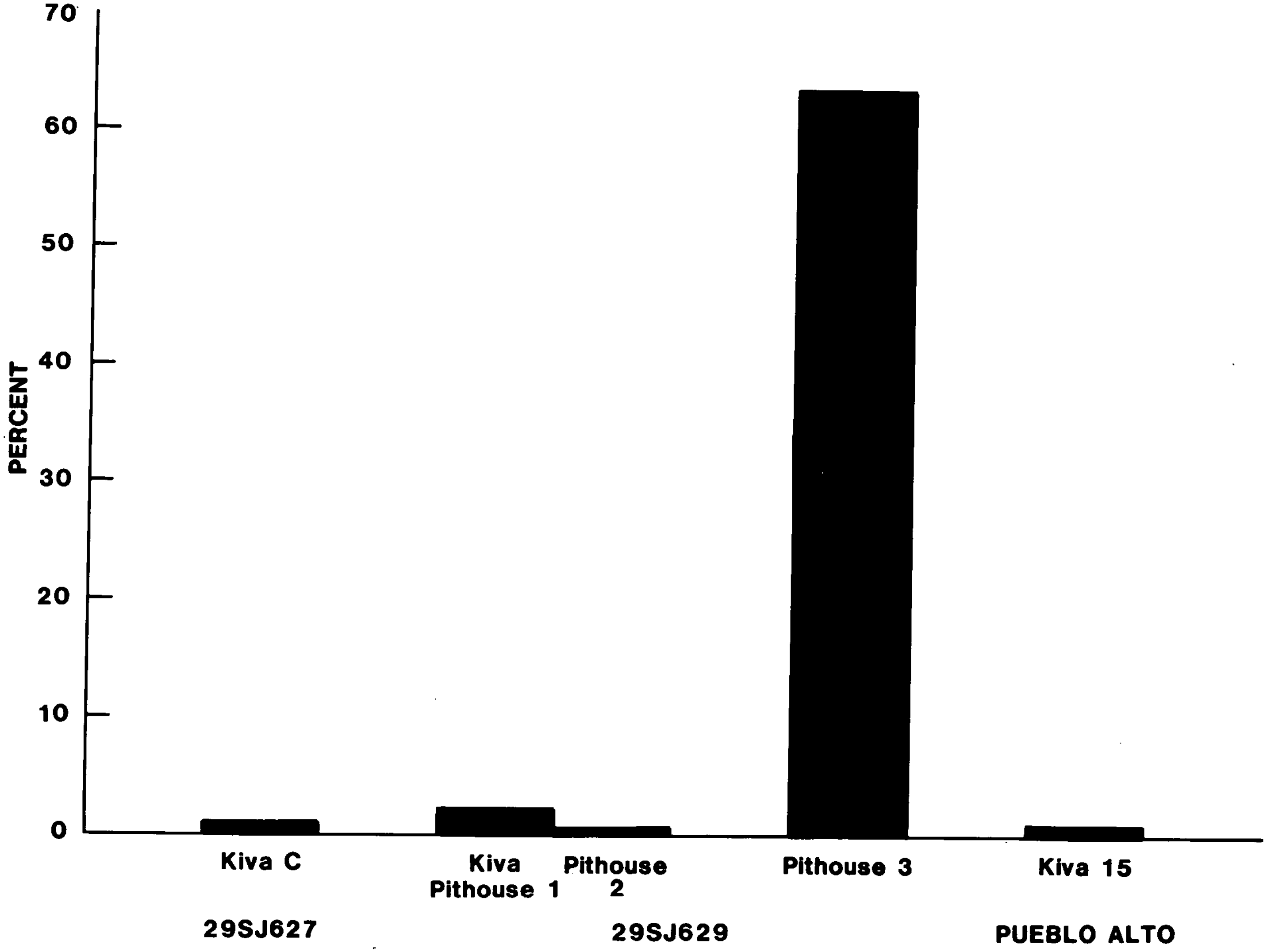

Figure 4.38 Total economic pollen percentages, pit structures and kivas, Sites 29SJ 627, 29SJ 629 and Pueblo Alto

Table 4.16 Taxa Occurring in Paired Pollen and Flotation Samples, Site 29SJ 627

	Zea Mays		Cucurbita		Opuntia		Pinus sp.		Abies		Juniperus		Cheno-Ams		Sarcobatus		Ephedra		Gramineae		Portulaca		Malvaceae		Scirpus		Typha	
	P	F	P	F	P	F	P	F	P	F	P	F	P	F	P	F	P	F	P	F	P	F	P	F	P	F	P	F
Room 16																												
Floor 2																												
Grid B	+		+				+		+		+		+	+			+		+		+			+		+	+	
Grid E	+																											
Floor 3																												
Grid H	+				+		+										+		+			+						
Grid B	+	+			+		+						+	+					+				+	+				
Grid C	+				+		+						+	+					+				+			+		
Room 8																												
Floor 3													+	+														
Grid C	+						+						+	+					+		+	+						
Floor 2																												
Pit 4	+		+				+		+				+	+			+		+			+				+		
Pit 6							+				+		+	+								+	+	+		+		
Room 4																												
Floor 2																												
Grid A	+						+						+	+					+		+							
Grid B	+						+						+	+					+									
Grid C	+													+														
Grid D	+				+		+		+				+	+	+				+				+					
Grid E	+				+		+						+	+			+		+									
Room 3																												
Floor 1																												
Firepit 2		+											+	+								+						

Table 4.17 Taxa Present in Pollen Float and Macro-botanical Samples from Other Pits, Rooms and Pithouses, Site 29SJ 629

	OP 1	OP 14	Room 5	Room 6	Room 2	Room 3	Room 9	Plaza Grid 8	Pithouse/ Kiva	Pithouse 2	Pithouse 3
Zea mays											
Pollen	+	+	+	+	+	+	+	+	+	+	+
Float	+	+	+		+	+	+		+	+	+
Macro-remains		+			+				+	+	
Cucurbita											
Pollen	+										
Float	+	+							+	+	
Macro-remains											
Typha											
Pollen				+				+			+
Float											
Macro-remains											
Portulaca											
Pollen	+		+	+	+	+	+				
Float		+	+		+	+	+	+	+	+	+
Macro-remains											
Cheno-Ams											
Pollen*	+	+	+	+	+	+	+	+	+	+	+
Float**	+	+	+	+	+	+	+	+	+	+	+
Macro-remains	+					+			+	+	+
Descurainia											
Pollen (Cruciferae)				+	+				+	+	
Float	+	+	+	+	+	+	+	+	+	+	+
Macro-remains											
Gramineae											
Pollen (Gramineaea)	+	+	+	+	+	+	+	+	+	+	+
Float***		+			+	+	+		+	+	
Macro-remains	+				+						
*Cactaceae*****											
Pollen		+			+		+			+	+
Float					+					+	
Macro-remains										+	

* Pollen category includes plants in the family Chenopodiaceae, and family Amaranthaceae, genus Amaranthus.

** In float, I have lumped Cheno-Ams, *Cycloloma atriplicifolium*, *Atriples* sp., *Chenopodium* sp., and *Salsola kali*. For the appropriate breakdown of this category by provenience see Struever (1978a, 1978b; 1979). Sarcobatus/Atriplex is a category recognized by Stanley Welsh, 1978, in his report on charcoal analysis at this site and is included in the macro-remains section.

*** Includes *Sprobolus*, *Oryzopsis hymenoides*.

**** Includes *Opuntia* and *Echinocereus*.

relative frequencies than in surface samples or other archeological samples from the area and are known from ethnographic literature to have been important subsistence items to modern southwestern Indian groups, it is likely that pollen from such plants has been introduced into the site by man. Plants which are adapted to insect pollination or are self-pollinated produce fewer pollen grains. The presence of these types and corresponding ethnographic documentation of their use suggest that these taxa were being used in the site.

The results at Site 29SJ 627 indicated that much of the pollen and flotation data was complementary in nature. With more samples from each room, this complementarity is less marked; however, pollen analysis does seem to be sensitive to the presence of certain taxa such as corn, cattail, grass, and cactus. A comparison of the results of pollen, flotation, and macrobotanical remains at the two sites suggest that the different forms of botanical analysis should be used together in order to achieve the broadest possible picture of plant resources used in subsistence.

Pollen Evidence of Subsistence from Archeological Sediment Samples and Coprolites

Direct evidence that parts of corn, cucurbit, purslane, and beeweed plants were actually consumed by people living at Pueblo Alto has been documented in the study of the pollen and larger plant remains from coprolites (Clary 1981; Toll 1981b). Coprolites from Pueblo Bonito also contained pollen from corn, cucurbit, beeweed, purslane, and prickly pear cactus plants. Type A - Cactaceae pollen was actually more abundant than the prickly pear (Opuntia - platyopuntia) type. Larger plant remains from the Pueblo Alto coprolites included corn and purslane seeds. Coprolites from Pueblo Bonito contained corn, cucurbit, and purslane seed remains.

The two different studies have established a stronger relationship between the occurrence of some taxa in archeological samples from the site and their introduction by man for use as food. Table 4.10 indicates the occurrence of pollen types determined to be of economic importance in soil samples from Pueblo Alto (Cully 1983b) and from coprolites from Pueblo Alto. Many of the taxa determined to be of economic importance from soil samples were also found in abundance in coprolite samples. In another study of archeological soil samples and coprolites from Bis sa'ani Pueblo, many of the same economically important taxa were also found in both contexts (Table 4.18). Corn, Cheno-Ams, grasses, beeweed, and prickly pear pollen were found to be economically important in both soil and coprolite samples. Thus, we gain confidence in the potential for assessing economic taxa from soil samples when coprolite evidence is lacking.

Seasonality of Occupation

Consideration should be given to several factors when using pollen taxa to assess possible seasonal occupation at Chaco Canyon. Stored food may have been moved from storage areas to living areas. Pollen types in-

Table 4.18 Economic Pollen Taxa from Sediment and Coprolite Samples, Pueblo Alto and Bis sa' ani Pueblo

	Pueblo Alto (Clary 1981[1]) (Cully 1982[2])	Bis sa' ani (Cully 1982[3])
High-spine compositae	+	+
Low-spine compositae		A
Cheno-Ams	A+*	A+*
Coramineae	+	A+*
Spaeralcea	A+	
Erigodonum		
Portulaca	A+	
Cleome	A+*	A+*
Type A Cactaceae	A+	
Opuntia	A+	A+
Typhia	A	A
Cucurbita	A+	A
Zea mays	A+*	A+*

\+ Taxa found in coprolites in numbers and frequencies indicating dietary components.

* Most important pollen types in coprolites, occurring in high percentages and or high frequencies in total sample number.

A Taxa considered to be present in distributions indicating economic importance.

[1] 12 coprolite samples

[2] pollen samples

[3] 8 coprolite samples
25 pollen samples

itially deposited in a storage room would then be carried later in the year to the living areas, as the stored products were brought in to be processed or cooked. Stored food transferred from one site to another might have the same effect on the pollen rain, thus obscuring any seasonal information. There is documentation on the gathering and storage of wild plant foods, in addition to cultivated crops, by modern Indian groups. Castetter (1935) reports the gathering and storing of purslane plants for the winter as Isleta. Beeweed plants were dried and stored indoors for the winter at Zuni. Prickly pear fruits were stored and dried for winter use by the Hopi (Whiting 1939).

It is difficult to identify many pollen taxa beyond the genus level; the blossoming times must therefore encompass those of several, and sometimes many, species. For example, blossoming and fruiting times of species of the prickly pear or Opuntia taxon overlap from May to October. Purslane, cattail, and greasewood are taxa that are easier to restrict in time and thus provide evidence of seasonal collection.

Using the pollen results at Chaco Canyon the blossoming times of the domesticated crops and important wild plant taxa present in the pollen results were plotted (Martin and Hutchins 1980; Table 4.19). Certain species of prickly pear cactus may have been available throughout the summer and fall. Cattail flowering is in the early summer; it may still be possible for pollen to be shed from the dried infloresences even after flowering and seed set have taken place, however. Purslane is a late summer plant. Buffalo gourd (Cucurbita foetidisima), a wild cucurbit, begins to flower early in the summer. Domesticated cucurbits flower later, and, depending on date of planting and first killing frost, would be available from late summer into the fall. Corn pollen could be gathered from green plants for ceremonial use; they could be shed in living areas from the time of picking the first green corn ears to the final harvesting. The dates of maturation would depend on the initial planting time, but could be as early as late June or early July. The pollen evidence indicates that the sites were used throughout the growing season. Although food storage would have made year-round occupation of all three sites possible, any seasonal occupation of rooms or sites may have been obscured by the effects of plant storage on the pollen rain within the sites.

Archeological Pollen Analysis and the Past Environment

The percentages of Cheno-Ams, grass, pine, and other pollen taxa, and their changes in relative frequencies over time were often used as indicators of environmental changes in the past. The percentage of these types may be affected by human activity in and around an archeological site. Since percentages are relative, one percentage figure may vary with another. The effect of high frequencies of such obviously introduced taxa, e.g., corn pollen, on the relative percentages of other taxa can be eliminated by counting separately from the rest of the pollen, as described by Fish (1981). Exactly which of the other, naturally occurring taxa are co-varying, and which may have been affected by local disturbance or introduction, are difficult to determine; however, a much higher percent (in comparison to surface and other archeological samples from the same

Table 4.19 Potential Blossoming Time of Important Plant Taxa, 29SJ 627 and 29SJ 629

Site	April	May	June	July	August	September	October
29SJ 627							
Living Rooms							
Opuntia		X	X	X	X	X	X
Portulaca					X	X	
Zea mays				X	X	X	
Storage Rooms							
Opuntia		X	X	X	X	X	X
Portulca					X	X	
Typha		X	X	X			
Cucurbita		X	X	X	X	?	
Zea mays				X	X	X	
29SJ 629							
Living Rooms							
Opuntia		X	X	X	X	X	X
Portulaca					X	X	
Zea mays				X	X	X	
Storage Rooms							
Opuntia		X	X	X	X	X	X
Portulaca					X	X	
Cucurbita		X	X	X	X	?	
Zea mays				X	X	X	
Pueblo Alto							
Living Rooms							
Opuntia		X	X	X	X	X	X
Cleome			X	X	X	X	X
Portulaca					X	X	
Typha		X	X	X			
Cucurbita		X	X	X	X	?	?
Zea mays				X	X	X	
Storage Rooms and West Roomblock							
Opuntia		X	X	X	X	X	X
Cleome							
Portulaca					X	X	
Typha		X	X	X			
Cucurbita		X	X	X	X	?	
Zea mays				X	X	X	
Sarcobatus				X	X	X	X
Central Roomblock							
Opuntia		X	X	X	X	X	X
Zea mays				X	X	X	

site) of a pollen type such as grass may be interpreted as the result of some use of the plant by man. The comparison of intra-site results may also suggest which taxa were affected by man's activities. At 29SJ 627, the variablility in Cheno-Ams, grasses, pine, and corn pollen among grid samples from the same floors was extremely high. The pattern was repeated at 29SJ 629 and Pueblo Alto (Figure 4.39). For example, in Room 2 at 29SJ 629, grid samples B and E range from 5% to 72% Cheno-Am pollen and from 6% to 77% grass pollen. The implication for enviromental reconstruction based on a single sample are clear; one sample from one location does not reflect the variability within a room or site, and environmental reconstructions based on such data may be wrong. Pippin (1979) and Hevly (1981) have also recognized the unreliability of archeological pollen analysis, used without supporting evidence, in the reconstruction of short-term environmental changes. In a general way, pollen analysis can provide information about the past environment in the form of records of the plants present in the community and those that were brought in for use in subsistence.

Despite the problems associated with using pollen samples from archeological sites for environmental reconstruction, it is of interest to compare the archeological pollen results with those from surface samples analyzed by Hall (1977) (Figure 4.40). For this purpose the pollen sum from which the percentages were calculated was considered to be the sum of results of all pollen samples from a particular site. Hall's surface samples from stations B and G did contain a higher percentage of composite pollen (other than sage) than the archeological samples. This could be due to a seasonal abundance of this type of pollen at the time the surface samples were taken in June, when many plants of this family are in bloom. The Cheno-Am group has been discussed as being affected by human activity in and around sites (Bohrer 1972); however, Cheno-Am percentages for 29SJ 627 and 29SJ 629 are almost identical to Surface Station B sampled by Hall (1977). Total Cheno-Am percentages for Pueblo Alto are likewise nearly identical to those from Surface Station G. Pine pollen, on the other hand, exhibits a less clear-cut pattern. It is more abundant at Site 29SJ 627 than in the sample from Surface Station B. Pine pollen at Site 29SJ 629 is less abundant than at the Surface Station. The percentage of pine pollen may be depressed by the higher percentage of grass pollen at 29SJ 629. Site samples from Pueblo Alto are also higher in the percentage of pine pollen than those from Surface Station G (Figure 4.40). Pine pollen counts at this station may be depressed by a seasonal influx of composite pollen. If the information from archeological pollen is considered to be accurate, pine pollen percentages from 29SJ 627 and Pueblo Alto indicate that pine may have been more abundant during Anasazi times. Percentages from 29SJ 629, occupied contemporaneously with the two other sites and located in the same rincon as 29SJ 627, suggest a drier environment and a woodland less extensive than it is today. The introduction of pollen from economically important plants may have been an important factor in changing the relative percentages of taxa which are indicators of environmental conditions. While the varibility between sites is not so extreme as when single grid samples from the same floor are compared, it seems likely that the inter-site variability, and the conflicting information, are also at least partially the result of man's activities.

Figure 4.39 Percentages of certain pollen taxa from grid squares, Sites 29SJ 627, 29SJ 629 and Pueblo Alto

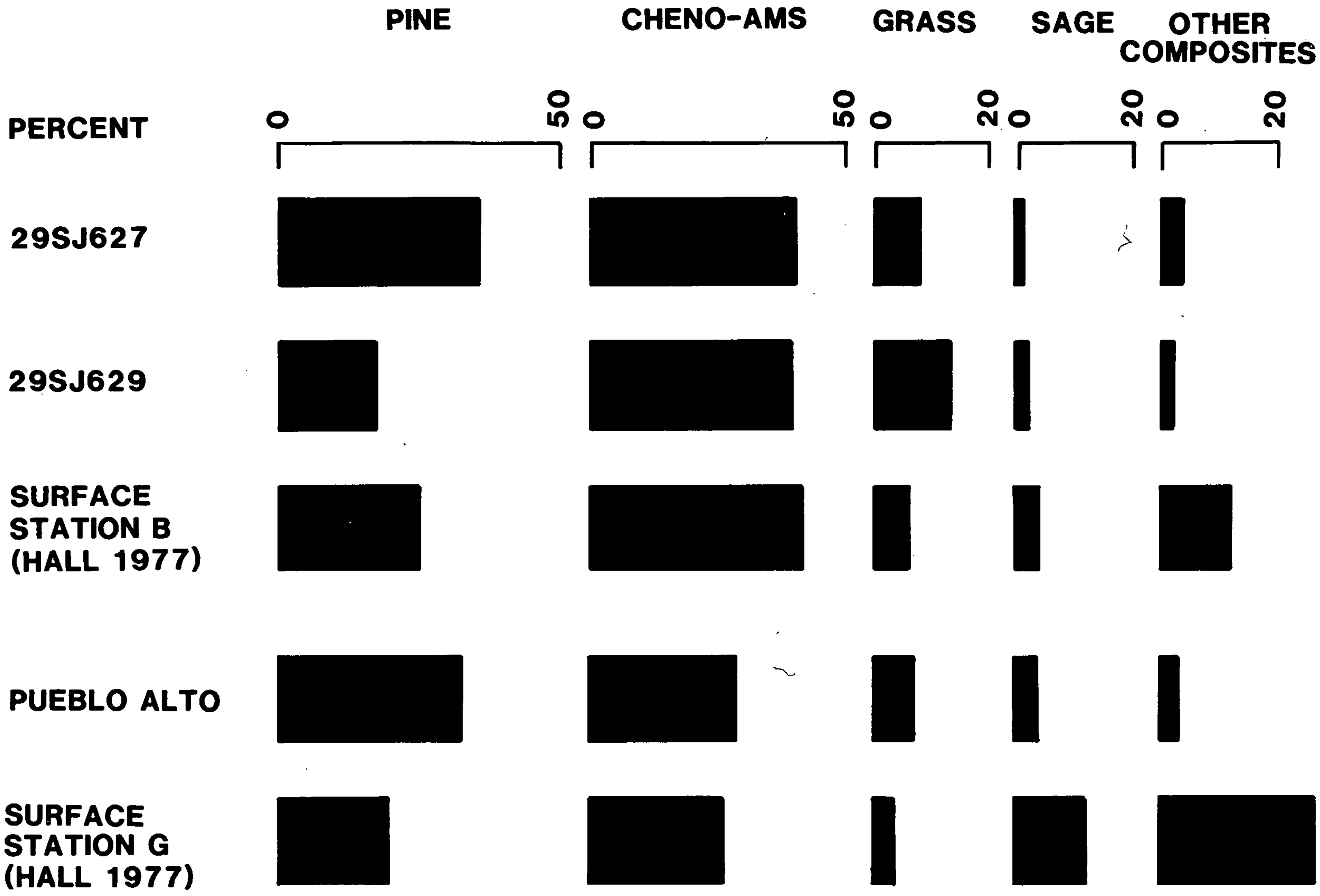

Figure 4.40 Pollen percentages, Sites 29SJ 627, 29SJ 629 and Pueblo Alto

In a study of packrat middens, Betancourt and Van Devender (1981) state that the pinyon-juniper woodland association was more extensive at Chaco Canyon prior to Anasazi times than it is today. They believe that the Anasazi aggravated the climatic effects of increasingly warmer and drier conditions on depletion of the woodland by woodcutting for fuel and construction. From the results of pollen analysis from the alluvium at Chaco Canyon, Hall (1977) interpreted the mid-holocene environment as being warmer and drier than the present, with the pinyon-juniper woodland at its lowest ebb. Pine pollen begins to increase in succeeding strata, indicating that during Anasazi times, because of increasing moisture, the woodland area may have been increasing. Information pertaining to differing origins of sediment affecting pollen results from the alluvial strata (with sediments from upstream bearing higher percentages of pine pollen than sediments deposited from local runoff) has been brought to bear on the subject by Love (1977). More recently, Hall (1981b) has also analyzed pollen samples from packrat middens. He concludes that there is no doubt there were more pinyon and juniper trees in Chaco Canyon at the time of deposition of these middens, but whether there was actually an extensive woodland is debatable. Pinyon-juniper woodland exists today on Chacra Mesa, which forms the southeast scarp of Chaco Canyon upstream from the confluence of Gallo and Chaco washes. Junipers and a few pinyon trees are found today in isolated stands on South Mesa and the north side of the canyon (Betancourt and Van Devender 1981; Cully 1977b).

Pollen analysis of samples from archeological sites has not provided supporting evidence for either of the two ideas about the past environment. While it is likely that pollen from archeological sites is affected by human activities (Hevly 1981), pollen analysis from these sites does indicate that the plant community was similar to the present. Most of the taxa, for which there is evidence of use by man, are represented in the present-day vegetation (Cully 1983a; see also Cully and Cully, this volume). Other botanical studies of material from archeological sites support this view. Charcoal studies, from firepits and heating pits at 29SJ 627 and 29SJ 629 by Welsh (1978), show that while pinyon and juniper were used as fuel, chenopodiaceous shrubs (*Sarcobatus/Atriplex* types being difficult to distinguish) were the dominant fuel used. Both saltbush and greasewood shrubs are present on the valley floors in abundance at Chaco Canyon today (see Cully and Cully, this volume). Welsh (1978) identified charcoal of sagebrush, rabbitbrush, (*Chrysothamnus* spp.), chokecherry (*Prunus virginiana*), three-leaf sumac (*Rhus trilobata*), and willow from firepits and heating pits. Rabbitbrush and willow are present today on the valley floor, sagebrush on benches and mesa tops, chokecherry, mountain mahogany, and three-leaf sumac are found from rincons and rocky slopes of the canyon. Minnis (1978) reports charcoal from shrubby taxa found in firepits and hearths at the Tsaya Project, near Chaco Canyon. At Bis sa'ani Pueblo, many taxa identified from pollen, flotation, and charcoal remains were from wild plant resources that are locally common today, although some (pinyon pine, *Rhus phragmites*) are not presently found in the immediate environs of the site (Cully 1982; Donaldson and Toll 1982).

Hough (1897) states that juniper was the most important fuel at Hopi; Whiting (1939), however, believes that the juniper woodland near the Hopi towns was drastically affected by the wood cutting ensuing after the introduction of the steel axe, and that pinyon and juniper then replaced the use of desert shrubs as fuel. The four plant species used for sacred kiva fuel are all shrubby; fourwing saltbush, greasewood, rabbitbrush (Chrysothamnus sp.), and three-leaf sumac (Rhus trilobata). Whiting also mentions that the Hopis today avoid cutting green wood. Large timbers for construction are obtained by trading with the Navajos for these items. With the exception of the later occupations at Pueblo Alto (Toll 1981a), botanical evidence from archeological sites shows that the Anasazi at Chaco Canyon also satisfied most of their fuel needs with shrubby, nonconiferous species, utilizing what was available and convenient. This suggests two things: one, that the pinyon-juniper component of the vegetation was not extensive enough for these species to be as available and convenient for use as firewood as non-coniferous species; and two, that the Anasazi did not play a significant role in depleting a more extensive woodland for fuel use. While pinyon and juniper may have been more abundant, the pattern of isolated groups or single pinyon and junipers in protected locations seen today may have already been established in Anasazi times.

Summary and Conclusions

Corn and cucurbit pollen from Site 29SJ 627 indicate the use of these domesticates by the prehistoric inhabitants. Prickly pear, Cheno-Ams, grasses, cattail, and other taxa were noted, and were probably introduced into the site by man for use as food, fuel, or for manufacturing purposes.

Several important factors for pollen analysis in archeological sites were evident at Site 29SJ 627. The variability among pollen samples from grid sections within a single room was extremely high. Dependence on one sample from the floor contact in any of the three rooms could lead to mistaken interpretation of room function or environmental conditions at the time of occupation. The grid scheme for sampling was useful for the determination of the location of activities related to food storage or preparation.

Economic pollen percentages were similar in both living and storage rooms. As noted by Truell (1981), cooking or parching activities may have occurred in the shallow, lightly burned firepits associated with storage rooms 16 and 4, resulting in a localized pollen rain which included economic types.

Using the sampling plan developed at Site 29SJ 627, pollen analysis at 29SJ 629 indicated that corn, cucurbits, and wild plant resources were used for subsistence. The use of a grid system for sampling revealed an array of pollen taxa from wild plant resources in rooms 2 and 3. Sagebrush pollen may have been brought into the site with plants used for fuel. Cheno-Am pollen may reflect the use of chenopodiaceous perennials for construction or fuel, or (with annuals) for food. Globemallow may have been used medicinally. Prickly-pear cactus, grasses, purslane, and bulrush may have been used for food. Economically important pollen taxa found in other proveniences include willow, cattail, and greasewood.

Living rooms 2 and 3 contained a greater diversity of economically important taxa as well as a slightly higher percentage of corn pollen than the storage rooms 5 and 6. Activities involving the preparation of plant foods seem to have been centered around rooms 2, 3, and possibly 9. Many of these activities were also carried out in the plaza area. Rooms 5 and 6 may have been used for storage and for non-plant related activities.

Pithouse 3 and Other Pit 14, a bell-shaped cist in the plaza, contained remarkably high percentages of corn pollen. These locations may have been used for the initial or primary storage of corn immediately after harvesting. Occupation at this site may have been seasonal (at least during the growing season) in Phases II - IV. Lower corn pollen percentages on the later-occupied floors of the surface rooms may have resulted from continual influxes of pollen from other economic as well as ambient taxa, and suggests a shift to year-round occupation during Phase V. Alternatively, Pithouse 3 may have served as the center of ceremonial activities for the site, activities that may have been accompanied by the use of corn pollen. The center for these activities may have shifted to Pithouse 2, after the addition of storage and living rooms above ground.

Pollen analysis at Pueblo Alto was unusually productive, especially in the West Roomblock. Room 110 contained the most taxa representing wild plant resources. The presence of cultivated and wild types of economic pollen substantiates the living room functions indicated by the presence of mealing bins and firepits. Rooms 112 and 229, although lacking features characteristic of living rooms, also contained corn pollen. Cattail and greasewood pollen were found in abundance. Cattail plants may have been used for matting or food, and greasewood for fuel.

The Central Roomblock also included storage and living rooms. Rooms 139, 142, and 145 lacked firepits and heating pits. Room 147 contained firepits and heating pits, as did the corridor Room 143. Fir pollen was present in high percentages in rooms 142 and 143, perhaps as the result of the use of boughs in ceremonies. A high percentage of sagebrush pollen was also found in Room 143; it may have been associated with medicinal and ceremonial or fuel use. Corn pollen was present in all the rooms (except Room 145) in low percentages. Other economically important taxa common in the rooms of the West Roomblock were almost entirely lacking. The pollen evidence suggests that these rooms served ceremonial functions different that those of the West Roomblock.

Plaza Feature 1, Room 3 contained three deep ovens with evidence of substantial fires. Corn, beeweed, purslane, and prickly pear cactus pollen were found in this room, indicating storage and/or preparation of plant foods. In this respect, Room 3 is similar to the West Roomblock.

The upper floors of the West Roomblock were occupied earlier than those in the North. Plaza Feature 1 was used contemporaneously with the

North Roomblock and with Kiva 15. Pollen evidence suggests that there was a change in the locus of living activities involving food preparation and storage from the West Roomblock to Plaza Feature 1.

Pollen taxa considered to be of economic importance at these three sites in Chaco Canyon include those from both domestic and wild plant resources. Rather than following the pattern observed at Broken K Pueblo by Hill and Hevly (1968) of higher percentages of economic pollen in storage rooms, the economic pollen types at Chaco Canyon are distributed in different ways at each site. The pollen evidence does indicate that the same plant resources, both domestic and wild, were available to and used by the inhabitants of both the small and large structures.

Results of the analysis of pollen, flotation, and macro-remains were complementary, that is, many taxa found in one form of botanical analysis were often not found in the others. In order to gain a more complete understanding of the plant resources used by the prehistoric inhabitants of the site, the different botanical analyses should all be used.

Results from soil samples and coprolites from archeological sites were compared. Inferences of the economic importance of pollen taxa, especially wild plant resources, based on their presence in significant distribution and numbers in soil samples, are substantiated for many taxa by the presence of these same types in coprolites. Cheno-Ams, globemallow, purslane, beeweed, and prickly pear pollen were determined to be economically important taxa in separate soil sample and coprolite studies.

Palynological evidence indicates that the sites were all occupied at least from spring through fall. Although food storage would have made it possible to live there all year round, any evidence for seasonal occupation of rooms or sites may have been obscured by the effects of stored plants on the pollen rain within the sites.

The intra- and inter-site variability in pollen results found at Chaco Canyon was probably caused, in part, by human activity. This factor reduces the opportunity for detecting short-term environmental changes, but also expands our knowledge of plants used for subsistence in the past. At Chaco Canyon, the taxa identified as important for subsistence are found in local plant communities today, suggesting that the past environmental conditions were essentially similar to those of today.

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References Cited

Adams, Karen
1980 Pollen, Parched Seeds and Prehistory: A Pilot Investigation of Prehistoric Plant Remains from Salmon Ruin, a Chacoan Pueblo in Northwestern New Mexico. Eastern New Mexico Contributions in Anthropology 9. Portales.

Barkley, Fred A.
1934 The Statistical Theory of Pollen Analysis. Ecology 15(3):283-289.

Beaglehole, Ernest
1937 Notes on Hopi Economic Life. Yale University Publications in Anthropology 15. New Haven.

Betancourt, Julio, and T.R. Van Devender
1981 Holocene Vegetation in Chaco Canyon, New Mexico. Science 214:656-658.

Bohrer, Vorsila L.
1960 Zuni Agriculture. El Palacio 67:181-202.

1972 Paleocology of the Hay Hollow Site, Arizona. Fieldiana, Anthropology 63 (1):1-30.

1980 Salmon Ruin Ethnobotanical Report. Part 7 of Investigations at the Salmon Site: The Structure of Chacoan Society in the Northern Southwest. Final report to funding agencies, edited by C. Irwin-Williams and P.H. Shelley. Eastern New Mexico University, Portales.

1981 Methods of Recognizing Cultural Activity from Pollen in Archeological Sites. The Kiva 46(3):135-142.

Brand, Donald D., Florence M. Hawley, and Frank C. Hibben
1937 Tseh So, a Small House Ruin, Chaco Canyon, New Mexico: A Preliminary Report. The University of New Mexico Anthropological Series 308, 2(2). Albuquerque.

Castetter, Edward F.
1935 Uncultivated Native Plants Used as Sources of Food. University of New Mexico Bulletin 226:4(1). Albuquerque.

Clary, Karen H.
1981 Pollen Analysis of Coprolites from Chaco Canyon, New Mexico. Report prepared for Division of Cultural Research, National Park Service, University of New Mexico, Albuquerque.

Cully, Anne C.
1977a Some Aspects of Pollen Analysis in Relation to Archeology. The Kiva 44(2-3):95-100.

1977b Check List of Plants at Chaco Canyon. Report prepared for Natural Resources Division, Southwest Region, National Park Service, Santa Fe.

1982 Pollen Analysis from Sites on Blocks VIII-XI, Navajo Indian Irrigation Project, San Juan County, New Mexico. Ms. on file, Navajo Nation Cultural Resources Management Program, Window Rock, Arizona.

1983a Final Report on Pollen Analysis from Site 29SJ 629, Chaco Canyon, New Mexico; Progress Report of Check-list of Plants. August 15, 1978. Report prepared for the Division of Cultural Research, National Park Service, University of New Mexico, Albuquerque.

1983b Prehistoric Subsistence at Pueblo Alto: Evidence from Pollen Analysis. Report prepared for the Division of Cultural Research, National Park Service, University of New Mexico, Albuquerque.

Cully, Anne C., and Karen H. Clary
1983 Pollen Evidence for Subsistence on the New Mexico Mine Archeological Project, San Juan County, New Mexico. Report prepared for Office of Contract Archeology, University of New Mexico, Albuquerque.

Cully, Anne C., Marcia Donaldson, Klara Kelley, and Mollie S. Toll
1982 Agriculture in the Bis sa'ani Community Area. Ms. on file, Navajo Nation Cultural Resources Management Program, Window Rock, Arizona.

Cushing, Frank H.
1920 Zuni Breadstuff. Indian Notes and Monographs, no. 8, Museum of the American Indian, Heye Foundation, New York.

Dimbleby, Geoffrey
1978 Plants and Archaeology: The Archaeology of the Soil. Granada Publishing, New York.

Donaldson, Marcia, and Mollie S. Toll
1982 Prehistoric Subsistence in the Bis sa'ani Community Area: Evidence from Flotation, Macro-remains, and Wood Identification. Report prepared for Navajo Tribe Cultural Resources Management Program, Window Rock, Arizona.

Elmore, Francis H.
1943 Ethnobotany of the Navajo. University of New Mexico Bulletin, Monograph Series 1(7).

Fish, Suzanne
1981 Palynological Investigations at the Bis sa' ani Outlier, Alamito Coal Lease. Report on file, Navajo Nation Cultural Resources Management Program, Window Rock, Arizona.

Ford, Richard I.
1968 *An Ecological Analysis Involving the Population of San Juan Pueblo, New Mexico*. Unpublished Ph.D. Dissertation, Department of Anthropology, University of Michigan.

Gish, Jennifer W.
1982 Pollen Results. In The Coronado Project Archeological Investigations, the Specialists Volume: Biocultural Analyses. *Museum of Northern Arizona Coronado Series* 4, *Research Paper* no. 23. Flagstaff.

Hall, Stephen A.
1977 Late Quaternary Sedimentation and Paleologic History of Chaco Canyon, New Mexico. *Geological Society of America Bulletin* 88:1593-1618.

1981a Deteriorated Pollen Grains and the Interpretation of Quaternary Pollen Diagrams. *Review of Paleo-botany and Palynology* 32(1981): 193-206.

1981b Holocene Vegetation at Chaco Canyon: Pollen Evidence from Packrat Middens. Paper presented at 46th Annual Meeting, Society for American Archeology, San Diego, California.

Hevly, Richard
1964 *Pollen Analysis of Quaternary Archeological and Lacustrine Sediments from the Colorado Plateau*. Unpublished Ph.D. Dissertation, University of Arizona, Tucson.

Hevly, Richard
1981 Pollen Production, Transport and Preservation: Potentials and Limitations in Archeological Palynology. *Journal of Ethnobiology* 1:1(39-54).

Hill, James N., and Richard H. Hevly
1968 Pollen at Broken K Pueblo: Some New Interpretations. *American Antiquity* 33(2):200-210.

Hill, W.W.
1938 Agricultural and Hunting Methods of the Navajo Indians. *Yale University Publications in Anthropology* no. 18. New Haven, Ct.

Hough, Walter F.
1897 The Hopi in Relation to Their Plant Environment. *American Anthropologist* 10:33-44.

Jones, Volney H.
1930 *The Ethnobotany of the Isleta Indians*. Unpublished Master's Thesis, Department of Anthropology, University of New Mexico, Albuquerque.

Kapp, Ronald O.
1969 *How to Know the Pollen and Spores*. Wm. C. Brown. Dubuque, Iowa.

Kluckhohn, Clyde, and Paul Reiter
1939 Preliminary Report on the 1937 Excavations, Bc 50-51, Chaco Canyon, New Mexico. University of New Mexico Bulletin no. 345, Anthropological Series, vol. 3, no. 2.

Krenetsky, John C.
1964 Phytosociological Study of the Picuris Grant and Ethnobotanical Study of the Picuris Indians. Unpublished Master's Thesis, Department of Biology, University of New Mexico, Albuquerque.

Lange, Charles H.
1959 Cochiti: A New Mexico Pueblo Past and Present. University of Texas Press, Austin.

Lekson, Stephen
1984 Great Pueblo Architecture of Chaco Canyon, New Mexico. Publications in Archeology 18B, Chaco Canyon Studies. National Park Service, Albuquerque.

Love, David W.
1977 Dynamics of Sedimentation and Geomorphic History Chaco Canyon National Monument, New Mexico. New Mexico Geologic Society Guidebook, 28th Field Conference, San Juan Basin III, pp. 291-300.

Madsen, D.B.
1979 The Fremont and the Sevier: Defining Prehistoric Agriculturalists North of the Anasazi. American Antiquity 44(4):711-722.

Marshall, Michael P., John R. Stein, Richard W. Loose, and Judith E. Novotny
1979 Anasazi Communities in the San Juan Basin. Public Service Company of New Mexico and the New Mexico State Historic Preservation Bureau, Albuquerque, and Santa Fe.

Martin, William C., and Charles R. Hutchins
1980 A Flora of New Mexico. J. Cramer. Verlag, Braunschweig, Germany.

Minnis, Paul
1978 Early Prehistoric Ethnobotany in Chaco Wash: Plant Remains from the Tsaya Project, New Mexico. Report prepared for the Laboratory of Anthropology, Museum of New Mexico, Santa Fe.

Pippin, Lonnie C.
1979 The Prehistory and Paleoecology of Guadalupe Ruin, Sandoval County, New Mexico. Unpublished Ph.D. Dissertation, Department of Anthropology, Washington State University, Pullman.

Potter, Loren D., and Joann Rowley
1960 Pollen Rain and Vegetation, San Agustin Plain, New Mexico. Botanical Gazette 122(1):1-25.

Raynor, Gilbert S., Eugene C. Ogden, and Janet V. Hayes
1972 Dispersion and Deposition of Corn Pollen from Experimental Sources. Agronomy Journal 64:420-427.

Robbins, W.W., J.P. Harrington, and Barbara Freir-Marreco
1916 Ethnobotany of the Tewa Indians. Bureau of American Ethnology Bulletin 55.

Schoenwetter, James
1962 Pollen Analysis of Eighteen Archeological Sites in Arizona and New Mexico. Fieldiana: Anthropology 53:1568-237.

1974 Pollen Records of Guila Naquitz Cave. American Antiquity 39(2): 292-303.

Schoenwetter, James, and Frank W. Eddy
1964 Alluvial and Palynological Reconstruction of Environments, Navajo Reservoir District. Museum of New Mexico Papers in Anthropology, Santa Fe.

Scott, Linda J.
1978a Pollen Analysis at Sites LA 14695, 14702, 14703, 14704, and 14705, West of Chaco Canyon National Monumentm New Mexico. Report prepared for Laboratory of Anthropology, Museum of New Mexico, Santa Fe.

1978b Dietary Inferences from Hoy House Coprolites: A Palynological Interpretation. Paper presented at the First Annual Conference on Ethnobiology, Prescott, Arizona.

1979 Pollen Analysis of Dominguez Ruin. In The Archeology and Stabilization of the Donimguez and Escalante Ruins. Bureau of Land Management, Cultural Resource Series 7.

Stephen, Alexander M.
1936 Hopi Journal of Alexander M. Stephen, edited by Elsie C. Parsons. Columbia University Contributions to Anthropology 23. New York.

Stevenson, Matilda Coxe
1904 The Zuni Indians: Their Mythology, Esoteric Fraternities and Ceremonies. 23rd Annual Report of the Bureau of American Ethnology. Washington.

1915 Ethnobotany of the Zuni Indians. 30th Annual Report of the Bureau of American Ethnology. Washington.

Struever, Mary B.
1977 Relation of Pollen and Flotation Analyses to Archeological Excavations (Flotation Component). Unpublished Master's Thesis, Biology Department, University of New Mexico, Albuquerque.

Swank, G.R.
1932 The Ethnobotany of the Acoma and Laguna Indians. Unpublished

Master's Thesis. University of New Mexico, Albuquerque.

Toll, Mollie S.

1981a Flotation and Macro-botanical Analysis at 29SJ629: A Pueblo I-II Village in Chaco Canyon. Report prepared for the Division of Cultural Research, National Park Service, Albuquerque, New Mexico.

1981b Macro-botanical Remains recovered from Chaco Canyon Coprolites. Report prepared for the Division of Cultural Research, National Park Service, Albuquerque.

Truell, Marcia

1981 Excavations at 29SJ627, Chaco Canyon, New Mexico. Ms. on file, Division of Cultural Research, National Park Service, University of New Mexico.

1982 Summary of Small Site Architecture, Chaco Canyon, New Mexico. Ms. on file, Division of Cultural Research, University of New Mexico.

United States Department of Agriculture

1978 *Field Guide to Native Vegetation of the Southwest Region.* U.S. Government Printing Office, Washington.

Vivian, R. Gordon, and Tom W. Mathews

1964 Kin Kletso: A Pueblo III Community in Chaco Canyon, New Mexico. *Southwestern Monuments Association Technical Series* 6(1):1-115.

Watts, William A., and Thomas C. Winter

1966 Plant Macrofossils from Kirchner Marsh, Minnesota: A Paleological Study. *Geological Society of America Bulletin* 77:1339-1360.

Weir, Glendon H.

1976 *Palynology, Flora and Vegetation of Hovenweep National Monument: Implications for Aboriginal Plant Use on Cajon Mesa, Colorado and Utah.* Unpublished Ph.D. Dissertation, Texas A&M University, Bryan.

Welsh, Stanley

1978 Report of Wood and Charcoal Specimens from Excavations in Chaco Canyon National Monument, New Mexico. Parts I and II. Report prepared for the Division of Cultural Research, National Park Service, Albuquerque.

White, Leslie A.

1938 Notes on the Ethnobotany of the Keres. *Papers of Michigan Academy of Science, Arts, and Letters* 30.

Windes, Thomas C.
1978 Excavations at 29SJ 629 Chaco Canyon: The Spade Foot Toad Site. Ms. on file, Division of Cultural Research, National Park Service, Albuquerque.

1980 Tests and Excavations at the Pueblo Alto Complex, 1974-1979. Preliminary report to the Division of Cultural Research, National Park Service, Albuquerque.

Wodehouse, R.P.
1959 Pollen Grains: Their Structure, Identification and Significance in Science and Medicine. Hafner Publishing Co., New York.

Wyman, Leland C., and S.K. Harris
1951 The Ethnobotany of the Kayenta Navaho. University of New Mexico Publications in Biology no.5. Albuquerque.

Chapter Five

An Overview of Chaco Canyon Macrobotanical Materials and Analysis to Date

by

Mollie S. Toll

Collections of plant remains made over the years at Chaco Canyon sites reflect vastly different research aspirations and some significant differences in preservation. This paper serves as an opportunity to review flotation and macrobotanical work in Chaco to date, as well as to present for the first time data from a variety of sites that help to amplify the picture of Chacoan paleoethnobotany. Included will be an inventory of the known collections and their disposition, a synthetic evaluation of these materials, and a comparison with other San Juan Basin sites. Emphasis is given to distinguishing variability in site assemblages due to true differences in subsistence from variability which may be due to differences in collection, analysis methods, or preservation.

The Data

Chaco has attracted a near-steady stream of excavators since the 1890s. This century of archeological work has witnessed radical changes in collecting and analysis techniques, with the result that what we know botanically about different site types is highly keyed to when these sites were excavated. Archeology during the era of the Hyde Expedition (1896-1900) was largely devoted to amassing whole, pretty artifacts (Lister and Lister 1981). Undoubtedly the reason we have a considerable volume of botanical materials from these early excavations is that Pueblo Bonito enjoyed excellent preservation conditions; plant remains were abundant, easily recognizable, and frequently incorporated in decorative and ceremonial artifacts. The bulk of non-artifactual material in the Pepper-Hyde collection consists of uncarbonized corncobs and cucurbit rind (Table 5.1) from 30 excavated rooms. Corn kernels are numerous but concentrated in a few locations. Squash seeds and peduncles, and beans are present in smaller quantities, and a few wild taxa make up a very small portion of the assemblage.

We know with some confidence that the overwhelming majority of retrievable botanical subsistence information at Pueblo Bonito ended up on the backdirt pile, because the assemblage bears little resemblance to well-preserved Puebloan collections inventoried in detail in recent times (Ambrose n.d.; Gasser 1981; Toll 1981c). "Fill" items such as juniper bark, corn stalks and leaves, and yucca in various stages of fiber preparation are very rare (compare this with approximately 60% by weight of

Table 5.1 Chaco Botanical Assemblies and Their Disposition

				Flotation Samples			Macrobotanical Remains									
							Corn				Squash			Beans	Others	Wood
	Materials Source	Curation	Reference	Collected	Analyzed	Cop	Total (est.)	Analyzed	Kernels	Other parts	seeds	rind	peduncles			
LARGE SITES:																
Pueblo Bonito	P-H	AMNH	Pepper 1920 (This study)	---	---		108	108	499	+	88	561	46	62	*Pinus edulis*, *Juglans*, *Yucca*, *Rumex*, *Juniperus*	
	NGS	USNM	Judd 1954	---	---		34	34	+	---	+	+	+	---	*Cleome*, *Solanum*, *Juglans*, *Vitis*, *Opuntia*, *Pinus edulis*	
			(This study) Toll 1981A			13	19	19	---	---	+	+	+	---	*Cleome*	TR: Bannister 1965
Pueblo del Arroyo	NGS	USNM	Judd 1959	---	---		+	---	---	---	+	+	+	---	*Juglans*, *Opuntia* *Pinus edulis*, *Apocynum* & *Yucca* in cordage and sandals	
			(This study)				15	15			+	+	+		*Juglans*, *Opuntia*	
	CC	CC	---	1	0											TR: Bannister 1965
Chetro Ketl	NGS	USNM	(This study)	---	---		---	---	---	---	+	+	+	---	---	
	SAR-UNM	MNM	---	---	---		+	---	?	?	+	+	?	?	*Yucca* cordage and knots	
		MAX														TR: Hawley 1934
		Santa Fe City Dump														Bannister 1965
	CC	---	Lekson 1983 (see p. 317)	---	---											TR: Dean & Warren, in Lekson 1983
Una Vida	NPS	CC	---	---	---											TR: Bannister 1965
	CC	CC	---	2	0											
Kin Kletso	NPS	CC	Vivian & Matthews 1965	---	---		---	---	---	---	---	---	---	---	"reed" arrowshaft (*Phragmites*?) unid.'d basketry & matting	TR: Bannister 1965
			Toll 1981A			6										
Pueblo Alto	CC	CC	Toll 1985A	1069	123[1]		6153	871	20	+	21	8	---	2	*Opuntia*, *Yucca*, *Juniperus*, *Pinus edulis*, *Sporobolus*, *Cleome*, *Amaranthus*, *Chenopodium*, *Euphorbia*, *Portulaca*, *Atriplex*, and 20 additional taxa from flotation	
			Toll 1981A			23										TR: Dean 1979 Charcoal: Welsh 1979

Table 5.1 continued

				Flotation Samples			Macrobotanical Remains: Corn				Squash					
	Materials Source	Curation	Reference	Collected	Analyzed	Cop	Total (est.)	Analyzed	Kernels	Other parts	seeds	rind	peduncles	Beans	Others	Wood
SMALL SITES:																
Tseh So	SAR-UNM	CC MNM	Hibben, in Brand et al. 1937	---	---		"200+"	---	---	---	+	+	+	---	Juglans, Equisetum, Sporobolus, Yucca	P. ponderosa, P. edulis, Populus TR: Bannister 1965
Bc 51	SAR-UNM	CC MNM	Kluckhohn, in Kluckhohn & Reiter 1939	---	---		+	---	---	---	+	+	+	---	Pinus edulis	
Leyit Kin	SAR-UNM	CC MNM	Dutton 1938	---	---		+	---	---	---	+	---	+	---	Pinus edulis	TR: Dutton 1938
Bc 236	NPS	CC	Jones, in Bradley 1971	---	---										Amaranthus, Chenopodium	
Bc 288 (Gallo Cliff Dwelling)	NPS	CC[2]	---	---	---		+	---	?	+	(	+	)		Typha, Yucca, cactus, pine (pinyon?) cones, grass, reed, cotton	
			Kaplan n.d.											29		
			Koeppen n.d.													unworked wood (species i.d.)
			Callen n.d.			8										
29SJ 299	CC	CC	(This study)	3	2		11	---	---	---	---	---	---	---	(3)	
29SJ 627	CC	CC	Struever 1977	412	75		104	25	---	---	123	---	1	---	+23 additional taxa from flotation	Charcoal: Welsh 1979
29SJ 628	CC	CC	(This study)	3	0		29	29	2	---	---	---	---	2	(4)	
29SJ 629	CC	CC	Toll 1981B	408	74		205	205	263	+	14	---	---	7	Pinus edulis, Oryzopsis, Yucca and 24 additional taxa from flotation	Charcoal: Welsh 1979
29SJ 633	CC	CC	(This study)					97	210							
29SJ 724	CC	CC	(This study)	45	13		24	---			(	10	)	---	(4)	
29SJ 1360	CC	CC	Toll, in McKenna 1985	2	0		31	31	+	---	---	---	---	---	---	

Footnotes:

P-H Hyde Exploring Expedition, under George Pepper and Richard Wetherill 1896-1899
NGS National Geographic Society, under Neil Judd 1921-1927
SAR-UNM School of American Research and University of New Mexico Field School 1929-1947
NPS National Park Service (chiefly stabilization and salvage) 1947-1971
CC Chaco Center 1971-1984
AMNH American Museum of Natural History, New York
USNM U.S. National Museum, Smithsonian Institution, Washington, D.C.
MAX Maxwell Museum, University of New Mexico, Albuquerque
MNM Museum of New Mexico, Laboratory of Anthropology, Santa Fe
TR Tree Ring report (includes species identifications)

[1] plus 54 scanned floor samples

[2] corn and many other macro-remains sent to Hugh Cutler in 1969 and never heard of since

vegetal assemblages at two dry sites in Canyon de Chelly [Ambrose n.d.; Toll 1981c]) and nearly all the corn cobs are complete (compare this with less than 1% of cobs at Chaco sites 29SJ 627, 29SJ 629, and Pueblo Alto). Though the Pepper-Hyde collection from Pueblo Bonito is highly skewed as to what was saved, it contains valuable materials not seen elsewhere at Chaco (such as whole bean plants from Room 92). These early excavators had the only opportunity to explore a unique treasure trove of Puebloan subsistence data. Pepper and Wetherill systematically removed the perishables from all the "dry" rooms they encountered, and we are dependent on what they saved or recorded for our view of what was there.

Neil Judd, excavating several decades later in the early 1920s, took a careful interest in evidence of prehistoric foodstuffs, but was not so lucky in what he encountered. At Pueblo Bonito he lamented, "The 34 fragments of corn cobs brought to the Museum laboratories provide but little for study. Most are charred; all are much shrunken" (Judd 1954:63), while at Pueblo del Arroyo he noted that the "staff of life" was "represented by a mere hatful of charred cobs from Room 65" (Judd 1959:125). The number and condition of specimens contrasts starkly with those recovered by the Hyde Expedition. Pueblo del Arroyo lacks Pueblo Bonito's sheltered rooms with intact roofs and "as in other ruins long exposed to summer rains and winter snows, few perishable substances have survived" (Judd 1959:123). Curiously, Judd found cucurbit seeds, rind, and peduncles more widespread than corn at Pueblo del Arroyo (1959:125)--the reverse of the usual relationship.

It is discouraging, but not surprising, that there are significant inconsistencies between Pepper (1920) and Judd's (1954, 1959) published accounts of botanical remains they found, and the museum collections they left behind. Both describe items which were never or are no longer curated, and specimens in their respective collections do not always correspond with the published descriptions. The two small batches of corn described by Judd (1954, 1959; see quotations above) appear to be the only specimens he saw at these two sites; yet the specimens we can actually look at today in the Smithsonian archives bear no resemblance in morphometrics (Pueblo Bonito) or provenience (Pueblo del Arroyo).

Chetro Ketl and the numerous "small" sites excavated by the School of American Research and University of New Mexico suffer from grossly inadequate reporting and curation. There are final reports from only two of the ten excavated sites (Tseh So and Bc 50-51), and the great majority of artifactual materials have disappeared. From the Chetro Ketl field notes, Lekson concludes that the "amount of material recovered from Chetro Ketl was substantial and variety comparable to the collections from Pueblo Bonito, [and that] perishables were...well represented" (1983:317).

One of the few surviving morsels of hard data from this and the succeeding era of National Park Service "salvage" excavations is species composition of construction beams sent for dendrochronological analysis. For these sites we lack sufficient samples of cultivars for morphometric analyses and documentation of wild food taxa used. Flotation, the principal source of information about utilized grasses and edible weeds, was not implemented until the establishment of the Chaco Center in the 1970s. Perennial economic taxa, e.g., pinyon, cacti, and manufacturing materials such as reeds and yucca, are more often recoverable as macrobotanical materials during excavation, but care and attention is required. The period between the excavations of Judd and the Chaco Center is an archeobotanical wasteland. Materials visible and recognizable were collected irregularly, were usually not analyzed, and have mostly disappeared.

The Chaco Center was created in 1970, with some commitment to clarifying the economic basis for life in Chaco's harsh environment and the role of changing climate in Chaco's abandonment. A new level of attention was paid to saving all plant remains encountered in the field, and sampling experiments were used at Site 29SJ 627 (Cully 1977; Struever 1977) to generate cost-efficient pollen and flotation sampling plans for subsequent excavations. Sites excavated in this most recent era hold the only hope for a faintly consistent overview of currently recoverable plant remains. No Chacoan site has measured up to Pueblo Bonito in terms of the sheer mass of botanical remains, but we are at last beginning to understand the relationship between retained information and data left in unexcavated or unsampled portions of a site.

An Integrative Chaco Assemblage

Grasses

Two grasses which recur consistently in Archaic through Puebloan assemblages of the Colorado Plateau occupy a small but dependable segment of the Chacoan wild food diet. Both *Oryzopsis* (Indian ricegrass) and *Sporobolus* (dropseed) grow abundantly in Chaco today. Ricegrass is adapted to sandy habitats and produces a spring (late May to June) seed crop in response to winter moisture levels, while the most common Chaco dropseed (*S. airoides*) tolerates the alkaline soils of the canyon bottom and produces mid-summer crops in response to spring or summer precipitation.

Distributions of the two taxa follow a parallel pattern in Chaco sites (Table 5.2). Charred seeds of both taxa are highly associated with heating pits (suggesting the likelihood of parching in these features) with lesser quantities in firepits; seeds in trash and on floors are less abundant and less likely to be carbonized. At 29SJ 627, 29SJ 629, and Pueblo Alto, grass seeds constitute less than 1% of all seeds recovered by flotation. Yet the seeds are frequently charred and occur often in locations appropriate to food processing, as well as in coprolites; consequently, there is good reason to link them to prehistoric subsistence activities. Absence of grass records at pre-Chaco Center excavations is attributed to lack of recognition (and small size of dropseeds) and lack of an appropriate retrieval method.

Weeds

In terms of both variety and total number of seeds, annual weeds account for a heavy segment of the flotation record in Chaco (Table 5.3) and throughout the San Juan Basin. These taxa figure prominently in ethno-

Table 5.2 Occurrence of Grasses in Chaco Sites

	29SJ 627 75 flotation samples	29SJ 629 74 flotation samples	Other Small Sites 15 flotation samples[a]	Pueblo Alto 124 flotation samples	Other Large Sites
Oryzopsis Indian ricegrass	7% flotation samples (burned seeds in all samples)	22% flotation samples (burned in most samples)	-----	13% flotation samples (burned seeds strongly associated with heating pits)	In one Pueblo Bonito coprolite[b]
Sporobolus dropseed	1% flotation samples (burned seeds)	7% flotation samples (burned in most samples)	-----	14% flotation samples (includes large conc. in one heating pit) (burned in a third of samples) one concentration (>100 seeds) recovered as macro	In one Pueblo Bonito coprolite[b]

[a] 29SJ 299 (2 samples) and 29SJ 724 (13 samples)
[b] Toll 1981a

Table 5.3 Occurrence of Annual Weeds with Known Economic Uses

	29SJ 627 75 flotation samples	29SJ 629 74 flotation samples	Other Small Sites 15 flotation samples	Pueblo Alto 124 flotation samples	Other Large Sites
Amaranthus pigweed	17% FS (burned in over half)	39% FS (burned in only two samples)	20% FS (burned in one firepit) concentration of unburned seeds found at Bc 236[a]	41% FS (burned seeds associated w/ heating features); one concentration of >100 seeds tecovered as macro.	In one Kin Kletso coprolite[b]
Chenopodium goosefoot	54% FS (burned in a third)	92% FS (burned in about a fifth of samples)	67% FS (burned in two firepits) concentration of unburned seeds at Bc 236[a]	68% FS (burned seeds associated w/ heating pits) two concentrations of >100 seeds recovered from plaza locations	NOT FOUND
Portulaca purslane	62% FS (burned in a third)	92% FS (burned in a fourth of samples)	47% FS (burned in half--all firepits)	58% FS (burned seeds associated w/ heating features and trash)	In coprolites from Pueblo Alto, Pueblo Bonito, and Kin Kletso[b]
Cleome beeweed	NOT FOUND	7% FS (burned in one floor location)	NOT FOUND	6% FS (burned in two heating pits); conc. of >100 seeds recovered as macro	seeds at Pueblo Bonito[c]
Cycloloma winged pigweed	7% FS	32% FS (burned in a sixth of samples)	7% FS	20% FS burned seeds associated w/ heating pits)	NOT FOUND
Descurainia tansy mustard	41% FS (burned in trashfill of a posthole, storage pit, and Kiva C	81% FS (burned in a fifth of samples--chiefly heating features and trash	33% FS (burned in most-e.g. all firepit locations)	37% FS (burned mostly in heating features and trash)	In coprolites from Pueblo Alto, Pueblo Bonito, and Kin Kletso[b].
Helianthus sunflower	14% FS (burned in one)	26% FS (burned in one firepit)	20% FS	10% FS (burned in one floor sample)	In one Pueblo Bonito coprolite[b]
Mentzelia stickleaf	29% FS	65% FS	7% FS	27% FS (burned in 5 samples, including 3 from floors)	In a covered Kiva jar at Una Vida (approximately 1 liter or 4 million seeds)[d]
Nicotiana tobacco	9% FS	15% FS	20% FS	3% FS (all 4 samples are on Floor 2, Room 139; seeds unburned)	NOT FOUND
Physalis groundcherry	13% FS (burned in a third)	24% FS (burned in one firepit)	13% FS	19% FS (the few burned seeds were found in heating features)	NOT FOUND
Sphaeralcea globemallow	35% FS (burned in a fifth)	34% Fs (burned in a third)	13% FS	17% FS (burned in half of samples--mostly heating features	NOT FOUND
Solanum[e] wild potato	NOT FOUND	NOT FOUND	NOT FOUND	2% FS (burned in one heating pit)	In one Pueblo Bonito coprolite[b] Tubers at Pueblo Bonito[c]

[a] Jones, in Bradley 1971

[b] Toll 1981a

[c] Judd 1954

[d] Bohrer 1975:10

[e] May be more wide spread, some *Solanum* seeds may have been classified as *Physalis* at 29SJ 627 and 29SJ 629.

graphic accounts of Puebloan and Athabaskan wild plant utilization, but are practically invisible in archeological studies lacking pollen or flotation analyses. Weedy annuals generally produce a double crop of tender spring greens and abundant tiny seeds in early to late summer. Prolific seed crops and an adaptive advantage under disturbed conditions (such as those surrounding human habitations and fields) encourage both human utilization and spurious inclusion of non-cultural seeds in site deposits. Sorting out economic from intrusive data is a particularly difficult problem in the category of annual weeds. Local flora, individual site characteristics, provenience association, and whether or not seeds are burned are significant clues.

Purslane, spruge, mustard, and stickleaf are abundant in the flora of the rincon where sites 29SJ 627 and 29SJ 629 are located, and unburned seeds are common in site deposits (particularly in relatively shallow 29SJ 629). These taxa tend to be less numerous and more frequently charred in Pueblo Alto's considerably deeper rooms. Further, on several Pueblo Alto habitation floors, certain economic weeds exhibit a pattern of repeated occurrence as charred seeds in heating features together with a distribution of unburned seeds on the floor in decreasing frequency with greater distance from the concentration of plant processing features.

Perennials

Food and Manufacturing. The archeological record of cacti and succulent use in Chaco is characterized by patchy distribution and low quantities (Table 5.4). The low profile of these taxa is usual for Anasazi sites and relates in large part to reproductive strategies (production of few, larger seeds) and to differential preservation of yucca fiber products. The total number of cacti seeds recovered from Chaco sites is a miniscule percentage (<.01%) of all seeds, yet they are found in a variety of small and large site contexts. As fleshy-fruited prickly pears seem to be absent and hedgehog cacti rare in present Chaco, the archeological record of these two cacti points to a wider natural distribution during the Puebloan period, or to non-local collecting expeditions.

Economically useful parts of yucca include fibrous leaves grown in a basal rosette, the root, and fleshy edible fruits. A narrow-leafed yucca (Y. baileyi) grows in rocky areas with shallow soil in Chaco, but is not common. Evidence of use of yucca leaves or fiber for basketry, matting, sandals, or cordage is confined chiefly to better preserved sites such as Pueblo Bonito, Pueblo del Arroyo (and Chetro Ketl, by rumor), and Bc 50. The caudex and root, rich in saponins and widely used for soap, have yet to be recovered in identifiable form from a Chacoan site. Seeds at 29SJ 627 and Pueblo Alto likely relate to food use of the fruit. Lack of association with any feature type (such as firepits or heating pits) is consistent with the role of both cacti and yucca seeds as discards, rather than directly-utilized food products.

High calorie pinyon nuts are the principal perennial food product utilized in Chaco. Evidence of pinyon nut consumption was absent at 29SJ 627 and rare at 29SJ 629. By contrast, pinyon shell fragments were re-

Table 5.4 Occurrence of Perennials used for Food and Manufacturing in Chaco Sites

	29SJ 627 75 flotation samples	29SJ 629 74 flotation samples	Other Small Sites 15 flotation samples	Pueblo Alto 124 flotation samples	Other Large Sites
Cacti & Succulents:					
Echinocereus Hedgehog cactus	NOT FOUND	3% FS (two floor locations)	NOT FOUND	6% FS (charred in a third)	NOT FOUND
Opuntia prickly pear	NOT FOUND	16% FS (chiefly hearths) A seed cache and charred pads and buds recovered from trash fill.	NOT FOUND	13% FS (charred in heating features and trash)	unspecified parts at Pueblo Bonito[a], seeds at Pueblo del Arroyo[b]
Yucca yucca	one seed in a late firepit	NOT FOUND	cordage and a sandal at Bc 50[c]	2% FS (seeds) 11 seeds recovered as macro-remains, chiefly from floors	cordage and sandals at Pueblo Bonito[a] and Pueblo del Arroyo[b]
Fruit & Nuts:					
Juglans walnut	NOT FOUND	NOT FOUND	nuts at Bc 50[c]	NOT FOUND	nuts at Pueblo Bonito[c] and Pueblo del Arroyo[b]
Juniperus juniper	5% FS (burned twigs and scale leaves)	15% FS (burned twigs and scale leaves)	13% FS (burned scale leaves)	29% FS (mostly burned twigs and scale leaves); also recovered as macro, inc. seeds	2 seeds at Pueblo Bonito[f]
Pinus edulis pinyon	NOT FOUND	5% FS charred nuts also recovered as macro-remains	nutshell at Leyit Kin[g]	35% FS (charred in less than half) also recovered as macro-remains	nutshell at Pueblo Bonito[a] and Pueblo del Arroyo[b], and in coprolites and Pueblo Alto, Pueblo Bonito, and Kin Kletso[d]
Rhus squawberry	NOT FOUND	NOT FOUND	NOT FOUND	2% FS (burned in two heating pits	NOT FOUND
Vitis grape	NOT FOUND	NOT FOUND	NOT FOUND	NOT FOUND	Pueblo Bonito[a]
Reeds & Rushes:					
Equisetum horsetail	NOT FOUND	NOT FOUND	matting at Bc 50[c]	NOT FOUND	?
Juncus rush	NOT FOUND	NOT FOUND	NOT FOUND	NOT FOUND	? matting at Pueblo Bonito[a], Pueblo del Arroyo[b], and Kin Kletso[e]
Phargmites reed	NOT FOUND	NOT FOUND	NOT FOUND	NOT FOUND	? arrowshaft at Kin Kletso[e]
Scirpus	10% FS (seeds)	4% FS (seeds)	NOT FOUND	1% FS (one seed on a floor)	? matting at Pueblo Bonito[a], Pueblo del Arroyo[b], and Kin Kletso[e]
Typha cattail	NOT FOUND	NOT FOUND	NOT FOUND	NOT FOUND	? matting at Pueblo Bonito[a], Pueblo del Arroyo[b], and Kin Kletso[e]

[a] Judd 1954:61
[b] Judd 1959:125
[c] Hibben, in Brand et al. 1937:107-111
[d] Toll 1981a
[e] Vivian and Mathews 1965
[f] Pepper-Hyde collection at AMNH
[g] Dutton 1938

covered in over a third of all Pueblo Alto flotation samples (and half of all heating features), as well as turning up as macro-remains at two other large sites. Recovery of pinyon nutshell fragments from human coprolites at several sites confirms that these remains relate to food use.

Juniper is most widespread in the form of twigs and scale leaves recovered by flotation. Their distribution is consistent with use of branches as fuel; charred twigs are found almost exclusively in heating features and trash. The resinous berries are listed in the ethnographic literature as medicinal or ceremonial products, or as a flavoring or starvation food. Juniper seeds are, not suprisingly, relatively rare in Chaco sites.

Two non-local food crops, walnuts and grapes, are known to date only from early excavations at Chaco (but include an appearance at small site Bc 50). Walnut trees are most often found along canyon streams, at elevations of 1,980-2,290 m. Taxonomic authorities indicate natural distribution limits considerably to the south and west of the San Juan Basin (Benson and Darrow 1981:372; Kearney and Peebles 1960:214; Martin and Hutchins 1981:509), although isolated populations may exist in the Chuska Mountains. A wild grape (Vitis arizonaca Engelm.), also found in protected canyons, grows to the southeast in the Rio Grande Valley (Benson and Darrow 1981:153) and probably in southern Colorado (Harrington 1964:368). Squawberry (Rhus) grows in a small number of protected talus and side canyon locations in Chaco. It is known only from two heating pits at Pueblo Alto, though seed fragments occur in human coprolites at Bis sa'ani, a Chacoan outlier 15 km to the northeast (Donaldson and Toll 1982b).

Remains of reed and rushes, like fibrous yucca leaves, tend to be limited to excellent preservation situations and consequently have been recovered chiefly as artifacts from early excavations at the large sites. With the exception of horestail matting at Bc 50, most of these artifacts have not been identified as to material. Scirpus (bulrush) is suspected as one possible raw material, as the seeds (not a significant food resource) are found in flotation samples at several sites. Although reeds (Phragmites communis Trin.), cattails (Typha latifolia L.); and small sedges (Carex filifolia Nutt.) grow near seeps in Chaco today, Equisetum, Juncus, or Scirpus have not been observed or collected during the historic period (Cully 1978). At nearby outlier Bis sa'ani, also lacking ready access to most of these water-loving species, three fragments of painted reed (Phragmites) arrows, with remnants of sinew wrapping and feather fletching, have been preserved (Donaldson and Toll 1982b).

Wood

Wood use in Chaco Canyon is documented by two data sources with little functional overlap. Charcoal specimens sent to Stanley Welsh for identification largely represent primary and secondary deposits of fuel debris from heating features and trash. Charcoal and wood specimens sent to the University of Arizona Laboratory for Tree-Ring Research include chiefly in-place, unburned construction timbers from large sites, plus large chunks of charcoal (at least in some cases likley to be construction wood re-used as fuel) from Pueblo Alto and small sites. In contrast to most categories of utilized wild plant species, wood used in Chaco shows distinct differences between small and large site types, and significant changes over time.

Fuel use in the San Juan Basin as a whole (Table 5.5) is typified by predominant use of non-coniferous shrubs and lesser use of local conifers (pinyon and juniper) and riparian woods (cottonwood/willow). Saltbush/greasewood is the single largest component of shrub fuel everywhere except in the Bis sa'ani community area, where sage is locally abundant. Coniferous wood is superior fuel, owing to relatively high resin content and density (Graves 1919), and was used where accessible throughout the region. In Chaco, the upland plateau of Chacra Mesa is strongly dominated by juniper, while pinyon is a subdominant (Potter 1974) and both taxa occur in all Chaco site types. At slightly lower elevations, only juniper (Ford 1980) or no coniferous wood at all (Minnis 1980; Toll 1958b) are found.

A greater proportion of coniferous vs. shrubby fuel was used at Pueblo Alto compared to the smaller sites of 29SJ 627 and 29SJ 629. Though coniferous fuel becomes more prominent later in Chaco, the differences in fuel use between small and large sites are not primarily attributable to time. Pueblo Alto's lowest coniferous fuel use level (15%) during the early Red Mesa occupation is significantly higher than that at contemporaneous small sites.

Conifers were the preferred or necessary building material; of the timbers available or procurable, this large group provided the required combination of strength and span. A pattern parallel to fuel use can be seen in the construction beams, with desirable materials in short supply locally increasing in use over time and at large sites vs. small sites. Breternitz notes that the greatest occurrence of non-local construction materials "coincides with the height of both the population and social organization in the canyon" (1977:27). Pinyon and juniper are the predominant materials in Basketmaker III proveniences, replaced by ponderosa pine and other higher elevation conifers in later sites (Table 5.6). Differences in use by site type account for some of the observed temporal shift. Beams from large sites include more higher elevation conifers (Table 5.7) in part because longer logs are required to span bigger rooms; large site specimens make up the bulk of the Pueblo III sample in Table 5.6. Building material allocation provides some clue as to fuel use changes over time. If roof timbers were recycled for fuel late in site occupations (Windes 1980), we would expect an increase of coniferous fuel with time.

Domesticates

Corn is without doubt the single most abundant plant food taxon at Chaco Anasazi sites, particularly when the amount of usable foodstuff represented is considered. At Pueblo Alto, for instance, corn macro-remains account for 97% of the 6,313 vegetal items inventoried in the field. Though corn may indeed have had top dietary importance, it is important to recognize that its artifactual visiblility is at least as much due to fac-

Table 5.5 Anasazi Fuel Use in the San Juan Basin

	Chaco[a]		Bis sa'ani[c]		NIIP Block II[d]	NMAP[e]	Tsaya Wash[f]
	Small Sites[b]	Pueblo Alto	Small Sites	Bis sa'ani	Small Sites	Small Sites	Small Sites
n	218	602	337	176	280	475	737
Juniperus	4%	21%			40%		
Pinus edulis	3%	11%			0		
Total conifer	7%	32%	48%	53%	40%	0	<1%
Atripex/Sarcobatus	74%	53%	7%	11%	46%	38%	66%
Artemisia	3%	5%	21%	17%	6%	0	1%
Other shrub taxa	5%	4%	0	0	0	6%	5%
Total local shrub	82%	62%	28%	28%	52%	44%	72%
Populus/Salix	3%	1%	7%	3%	8%	16%	11%
Undet. non-conifer and unknowns	8%	4%	13%	15%	0	36%	17%

[a] Welsh 1979
[b] 29SJ 627 and 29SJ 629 combined
[c] Donaldson and Toll 1982b (coniferous wood not differentiated as to taxon)
[d] Ford 1980
[e] Toll 1985b
[f] Minnis 1982

Table 5.6 Species Composition of Construction Wood in Chaco Sites over Time[a]

Time Period	Local Conifers		Non-local Conifers		Non-Conifers		Total	
BM III	214	96%	3	1%	6	3%	223	10%
PI-PII	141	61%	71	30%	21	9%	233	11%
PIII	411	25%	1262	75%	3	<1%	1676	79%
Total	766	36%	1336	63%	30	1%	2132	100%

[a] adapted from Breternitz [1977]; based on Tree-Ring Lab species identifications of "charcoal and... primary beams."

Table 5.7 Species Composition of Construction Wood at Small versus Large Sites in Chaco

	Conifers							Non-Conifers		Total
	Local			Higher elevation						
BMIII - PI Small sites[b] n = 231	42%	44%	86%			3%	3%	9%	4%	13%
PII - PIII Small sites[c] n = 226	18%	19%	37%	3%	4%	26%	33%	22%	9%	31%
PII - PIII Large Sites: Pueblo Alto n = 484	31%	9%	40%	8%		51%	59%	<1%		<1%
Other Large sites[d] n = 580	10%	2%	12%	14%	8%	66%	88%			0

[a] Data from Robinson [1979] and Windes [1977]

[b] 29SJ 423, Shabik'eshchee, Half House, Judd Pithouse No. 2, 29SJ 721, 29SJ 299, 29SJ 628, 29SJ 724

[c] 29SJ 1360, Bc 50, Bc 59, Bc 192, Leyit Kin, 29SJ 627, 29SJ 629

[d] Pueblo del Arroyo, Kin Bineola, Pueblo Bonito, Casa Chiquita, Chetro Ketl and dump, Kin Kletso, Penasco Blanco, Rinconada, Talus Unit 1, Una Vida, Wijiji.

tors of differential deposition and preservation as to actual use. Corn has a very durable waste product, the cob, which is further recyclable as fuel, while squash and beans decompose readily and are less likely to be preserved by carbonization.

Tiny carbonized corn and kernel fragments are among the most widespread taxa recovered by flotation. Distribution patterns of these and macrobotanical corn debris reveal use and discard practices. At both small and large site types (Struever 1977; Toll 1981b, 1985a), corn is associated primarily with trash deposits and secondarily with those proveniences--heating features--probably producing the bulk of the trash. Carbonized kernels, presumably representing food processing accidents, turn up most consistently in heating features, while cobs alone are distributed more generally. Only at sites with excellent preservation do we find signficant association of corn with storage rooms and features. Preservation of corn in storage contexts depends chiefly on conditions conducive to preservation of unburned debris (as at Pueblo Bonito) (Pepper 1920) or to catastrophic, low oxygen fires (as at Salmon and Arroyo Hondo)(Doebley and Bohrer 1983; Koschik 1973). At Pueblo Alto, for example, corn occurred in 48% of all habitation or ceremonial room flotation samples but in only 13% of those from storage rooms.

The focus of analyses of prehistoric corn remains has traditionally been on cob attribute measurements, with the aim of assigning varietal names. While this business is fraught with substantial problems, morphometrics of Chaco cobs can provide some clues as to growing conditions, to genetic relationships within Chaco, and to corn grown at other sites in the San Juan Basin, over time. Hot debate over the character, source, and timing of different genetic stock inputs is a passionate sport with many corn researchers, yet some consensus on underlying trends seems to have been reached. The earliest known southwestern corn, Chapalote, has been recovered from several dry shelters (Bat, Jemez, Tularosa and Cordova caves) dating to 1000 B.C. or later (Cutler 1952; Ford 1975; Kaplan 1963). This small cob popcorn "demonstrates greater range in size and overall lower productivity" than later pueblo maize (Ford 1981: 11). Even greater variablility characterizes the period to 500 B.C., when teosinte introgression is presumed to result in appearance of some more productive ears (Winter 1973; Ford 1981). A major shift in cob row number is observed at ca. A.D. 700 in southwestern New Mexico, between A.D. 1000-1100 at Mesa Verde, and ca. A.D. 1100 at Salmon Ruin. Hybridization of the developed Chapalote type with a Mexican 8-rowed flour corn immigrant, Mais de Ocho, is generally held responsible (though many date the postulated introduction of this low-rowed genotype to many centuries before the observed phenotypic shift). In many late Pueblo II and Pueblo III corn assemblages, the percentage of 8-rowed cobs increases (from about 8% to 20% or more), while cob size likewise increases (Winter 1973). Meanwhile, 12- to 16-rowed cobs decrease in number, average row number shifts from in the neighborhood of 12 to 10. This broad pattern of continuity in corn morphology from late Basketmaker through Pueblo II, followed by a change to a lower-rowed Pueblo III type, is seen at site after site in the Anasazi area.

With this background and a look at Chaco area cob morphometrics over time (Table 5.8), we note immediately that Chaco corn does not fit smoothly into the observed regional pattern, and that there is some significant variability within Chaco itself. While Doebley and Bohrer (1983) find that Salmon Ruin's "Chacoan" occupation can be characterized by an average row number of 12 (followed by a distinct decrease to 10 in the later occupation), we find corn averaging 10 rows both within and surrounding Chaco Canyon, from Basketmaker III through Pueblo III (Table 5.8; also LA 26749 [Donaldson 1981a, 1981b] and H21-1 and H29-19 [Struever and Knight 1979]). In the largest Chaco cob population measured, at Pueblo Alto, the major change in row number over time is a shift from a very large segment of 8-rowed cobs (Red Mesa phase) to a preponderance of 10-rowed cobs in the Gallup and Late Mix period; average row number increases (from 9.8 to 10.8) rather than decreases.

The wider Chaco area pattern (based on many small sites, but including at least one very much larger site, Pueblo Alto) seems to be one of generally small cobs, increasing in row number to reflect more 10-rowed cobs and decreasing in size, over time. Cobs at village sites 29SJ 627 and 29SJ 629 are smaller than Pueblo Alto's are at any given time period, and Bis sa'ani cobs are smaller yet. Departures from this general pattern include some strange bedfellows. Two small sites representing late Basketmaker (29SJ 628) and Red Mesa (29SJ 1360) periods show slightly higher average row number (fewer 8-rowed cobs, more 12-rowed cobs) and larger cob diameters than elsewhere in Chaco at this time. Corn from two of Chaco's greathouses (Pueblo Bonito and Pueblo del Arroyo) and the Talus Unit near Chetro Ketl and Pueblo Bonito has much higher row numbers and larger cobs; these samples are all small and doubtlessly unrepresentative, yet the magnitude of difference and consistency within these related sites makes the statistics noteworthy. Cobs from Salmon Ruin correspond in size and row-number characteristics to these larger cobs from Chaco greathouses. Salmon cob diameters are substantially larger than those at most Chaco sites. Salmon cupules are very much bigger, and become wider over time as row number decreases. No such clear trend in cupule shape change is seen in Chaco, though again 29SJ 629 and Bis sa'ani show diminutive features relative to Pueblo Alto.

The substantial morphological differences seen here may be most likely attributed to variability in growing conditions and redistribution, rather than racial variation. Salmon Ruin, on the banks of the San Juan River, is located in a relative green belt of the arid Southwest; prehistorically as well as today, the river provides substantial dependable soil moisture for crops. We know that moisture, temperature, and mineral stress affect reduction in size of the plant as a whole, as well as the cob, and often result in irregular row configuration and undeveloped kernel rows (Denmead and Shaw 1960; Robins and Domingo 1953). Both irregular and unfilled rows are common in Chaco cobs, and smaller cob size may also reflect environmental factors which we know to be poorer in the Chaco area (Cully et al. 1982; Schelberg 1982). I suggest that cob populations at Chaco small sites, Pueblo Alto and Bis sa 'ani represent local crops from the center of the San Juan Basin, while corn from the largest of Chaco's

Table 5.8 Zea Cob Morphometrics Over Time (11th-13th c.) in the Chaco Area

	Row Number						Cob Diameter[1]			Cupule Width[1]			Cupule Aperature Width[1]		
	% 8 or less	% 10	% 12	% 14+	n	$\bar{x}$	n	$\bar{x}$ mm	cv	n	$\bar{x}$ mm	cv	n	$\bar{x}$ mm	cv
29SJ 628 late·AD 700s	14%	33%	37%	16%	51	11.1	51	14.9	.220	14	7.3	.174	36	3.5	.280
Pueblo Alto[2] Red Mesa Phase AD 1020-1040/50	49%	22%	21%	9%	150	9.8	152	12.6	.244	71	6.7	.253	36	3.0	.215
29SJ 627[3]	33%	33%	33%	0	9	10.0	196	11.9	.275	196	6.2	.231			
29SJ 629[4] Main site occupation AD 925-1050	34%	38%	25%	3%	182	9.9	196	11.9	.275	196	6.2	.231			
29SJ 1360[5] late AD 900s-early 1000s	10%	45%	39%	6%	31	10.8	31	14.8	.190	31	7.3	.203			
Pueblo Alto[2] Gallup Phase AD 1050-1100	18%	41%	34%	6%	474	10.6	473	12.4	.224	116	6.1	.208	189	3.3	.272
Pueblo Bonito[6] Gallup/Late Mix Room 3	25%	13%	50%	13%	8	11.0	8	19.8	.130						
Chaco Talus Unit[7] Gallup/Late Mix AD 1025-1125	7%	20%	46%	37%	15	13.7									
29SJ 633 Gallup/Late Mix	24%	56%	18%	3%	34	9.8	35	11.0	.217	14	5.8	.089	21	2.8	.422
Pueblo Alto[2] Late Mix Phase AD 1100-1150	23%	39%	33%	5%	252	10.8	254	12.2	.227	64	6.1	.199	103	3.2	.285
Pueblo Bonito Late Mix Rooms 87, 160, 170[6]	12%	15%	45%	27%	33	11.6	33	17.9	.151						
Rooms 227, 256, 348[8]	0	26%	47%	27%	19	12.4	19	19.3	.105						
Pueblo del Arroyo Late Mix-kiva J[8]	7%	53%	40%	0	15	10.7	15	15.8	.166						
29SJ 629[4] 12th c Kiva Trash	17%	67%	17%	0	6	10.0	6	9.6	.411	6	4.9	.449			
Bis sa'ani[9] AD 1100+	32%	33%	31%	3%	290	10.1	300	11.1	.229	292	5.5	.189			
Salmon Ruin[10] Chacoan Occupation AD 1080/1090-1130					50	11.9	11	16.0	.080				50	6.4	.128
29SJ 633 Mesa Verde Occupation	15%	18%	63%	5%	40	11.3	40	12.5	.179	21	5.6	.177	19	3.5	.352
Salmon Ruin[10] Mesa Verde Occupation AD 1180-1280					60	10.6	50	14.0	.181				60	7.2	.209

[1] Figures reflect 21% added to measurements of carbonized specimens, to compensate for average shrinkage during carbonization. Salmon cv's are approximate, as they are averages of the constituent subsample cv's.

[2] Toll 1985a

[3] Struever 1977

[4] Toll 1981b

[5] McKenna 1985

[6] AMNH Pepper-Hyde Collection

[7] Cutler and Meyer 1965

[8] USNM Judd collection

[9] Donaldson and Toll 1982b

[10] Doebley and Bohrer 1983

greathouses was probably imported from the San Juan River Valley or the Chuska foothills.

Cultivated beans are present in very small numbers at Chaco, as they are in nearly all archeological collections. Convincing explanations for this low representation of beans include treshing away from habitations and cooking by boiling (Kaplan 1956), as well as quick susceptibility to deterioration processes and lack of a durable by-product (Gasser and Adams 1981). All beans found in Chaco are varieties of the common bean, Phaseolus vulgaris; no "exotic" beans--scarlet runners, teparies, or limas--cultivated outside the Four Corners area have been recovered to date. The great majority of Chaco beans are unburned specimens from protected localities at Pueblo Bonito and Bc 288 (Table 5.9). Intact seed coat, hilum, coloration, and patterning on these specimens allows determination of varieties according to Kaplan's regional typology (1956). Pod and plant fragments are also present at both sites. The rare beans at other, more open Chaco sites are carbonized and lack such distinguishing characteristics. Size and shape allow classification to the species level but no further. Bean epidermis was also present in seven of eight human coprolites at Bc 288 (Callen n.d.).

Cucurbits are similarily highly differentiated as to quantity and quality of the existing specimens (Table 5.10). Counts by plant part and taxon are lacking for Judd's Pueblo Bonito, Pueblo del Arroyo, and Chetro Ketl collections at the Smithsonian, and for Bc 288 cucurbits shipped off to Hugh Cutler and never returned; consequently, Pepper's Pueblo Bonito cucurbits are the only well-documented and well-preserved materials we have. Uncarbonized fruit exocarp (rind) fragments were recovered in considerable numbers at Pueblo Bonito, chiefly from rooms 85 and 92; as in several other well-preserved assemblages (Ambrose n.d.; Gasser 1981; Toll 1981c), only a small percentage are bottle gourd. Most peduncles conform to characteristics of Cucurbita pepo, earliest introduced of prehistoric squashes (ca. 300 B.C. at Tularosa and Cordova caves [Martin et al. 1952; Kaplan 1963] and ca. 1,000 B.C. at Bat Cave [Ford 1981]). C. moschata and C. mixta both appeared considerably later and were less widespread (Cutler and Whitaker 1961). Seed body and margin characteristics are frequently eroded, precluding reliable species-level identification. Consumption of squash seeds in Chaco is indicated by presence of seed fragments in three coprolites from Bc 288 (Callen n.d.) and two from Pueblo Bonito (Toll 1981a).

Discussion

Room and Feature Functions

Distinctions of floral variability according to room and feature types can be made reliably only at those sites which have been excavated and sampled thoroughly. Sitewide patterning observed at 29SJ 627, 29SJ 629, and Pueblo Alto is supported by isolated examples from other Chaco sites. In differentiating flotation and macrobotanical results by provenience category, the principal dichotomy observed is that between heating features (with numerous carbonized economic plant remains) and floor sur-

Table 5.9 Occurrences of Beans (<u>Phaseolus vulgaris</u>) in Chaco Sites

					Average Dimensions in cm		
Site	Provenience	n	Color	Type	L	W	Th
Pueblo Bonito[a]							
#3118	Room 25	2	red-brown	-----------	---	---	---
#8451	Room 107	5	red-brown	-----------	---	---	---
#10624	Room 170	2	cream mottled	C-14 (Jacob's cattle)	---	---	---
		2	tan-brown	cf. C-23	---	---	---
		20	red-brown	cf. (Kidney)	---	---	---
(no #)	Room 92	3	brown flecked	pinto or garrapata	---	---	---
		3	brown w/ longitudinal stripe	cf. C-11	---	---	---
		25	red-brown		---	---	---
Pueblo Alto[b]	Plaza Grid 8	1*	----------	-----------	---	---	---
#4775	Trash Mound Layer 44	1*	----------	-----------	---	---	---
Bc 288[c]		23	red-brown	C-11	1.38	.73	.54
		1	orange-brown mottled	C-14 (Jacob's cattle)	1.29	.72	---
		5	----------	cf. C-15 (Red Mexican)	.93	.66	.48
29SJ 628		2*		-----------	---	---	---
29SJ 629[d]							
Room 2, Layer 2		5*	----------	-----------	1.20	.70	.50
Pithouse 2		2*	----------	-----------			

*carbonized, lacking seed coat

[a] AMNH Pepper-Hyde collection; morphological opinions by Robert E. Gasser

[b] Toll 1985a:60-61

[c] Kaplan n.d.; also present in coprolites (Callen n.d.)

[d] Toll 1981b

Table 5.10 Cucurbit Remains in Chaco Sites

		Exocarp			Peduncles					Seeds				
Pueblo Bonito[a]	number [percent]	552 [98%]	9 [2%]	561 [100%]	38 [73%]	2 [4%]	3 [6%]	9 [17%]	52 [100%]	1 [1%]		32 [36%]	5588 [63%]	[100%]
	weight [percent]	349.3g [99%]	3.8g [1%]	353.1g [100%]										
Pueblo Bonito[b]			+	+	+?	+?								---
Pueblo del Arroyo[b]					+								+	
Chetro Ketl[b]				+				+					+	
Pueblo Alto[c]		8*		8*									21*	21*
Tseh So[d]		+		+		+			+		+			+
Bc 288[e]				?					?					?
29SJ 627[f]					1*				1*	118			5	123
29SJ 629[g]										14*				14*

*some or all specimens carbonized

[a] AMNH Pepper-Hyde collection

[b] USNM Judd collection (Identified as to probable taxon by A.T. Erwin, Iowa State College of Agriculture, but not counted)

[c] Toll 1985

[d] Hibben, in Brand et al. 1937:107-108

[e] Chaco Center collections (listed simply as "gourd material")

[f] Struever 1977

[g] Toll 1981b

faces (with sparser and usually unburned floral debris). Trash flora bear many similarities to items found in heating features (probably because most household debris consists largely of firepit and heating pit dumpings). Firepits and heating pits, highly differentiated in terms of size, morphology, and fuel composition, appear nonetheless to have been used in very similar ways at Pueblo Alto. In contrast to essentially empty heating pits at Chaco village sites 29SJ 299, 29SJ 627, and 29SJ 629, Pueblo Alto's heating pits characteristically exhibit much the same high density and diversity of edible plant taxa found in firepits. Carbonized ricegrass caryopses appear in firepits and trash at small sites, but are highly associated with heating pits instead at Pueblo Alto.

Several habitation rooms at Pueblo Alto provide a unique opportunity to map plant processing activities, uncluttered by overlying post-occupational trash. In each case, a constellation of economic species occurs, carbonized in multiple heating features and then unburned on floors, in decreasing frequency with increasing distance from the greatest concentration of heating and mealing features. Several weeds are chiefly involved, but dropseed, ricegrass, pinyon, and prickly pear also occur in this burned-in-features/unburned-on-floors pattern. This convincing evidence of the association of specific taxa with food processing techniques, such as parching and boiling, gains weight by repetition in many features and floor grids within each room, and then in successive rooms.

A relatively small number of room floors at 29SJ 627, 29SJ 629, and Pueblo Alto fit the pattern of classic habitation rooms (with many features and much artifactual debris); the floors invariably exhibit distinctive patterning of economic plant remains appropriate to full-scale subsistence activities. At the other end of the scale, empty rooms presumed to have served for storage are generally devoid of floral materials. This neat habitation/storage room dichotomy corroborates patterning seen at other Puebloan sites of moderate preservation (Hill 1970; Toll 1985b). Other rooms with some features and poorly prepared floors defy neat categorization into habitation vs. storage functions; these probably represent hybrid or temporary use. Plant remains in such rooms include everything from sparse to moderate quantity and diversity of economic floral debris. Diverse habitation-like assemblages found in kivas at 29SJ 629 and Pueblo Alto repeat those found in several cases at Salmon Ruin (Bohrer 1980:336) but contrast with empty ceremonial rooms Hill (1970) found at Broken K.

Chaco Developments over Time

Chaco flotation and macrobotanical assemblages are characterized by general continuity or low-level shifts in wild plant usage, together with some temporal shifts in domesticates and wood usage that may indicate significant adaptive and/or environmental changes. The Red Mesa period at Pueblo Alto and the main occupation at 29SJ 629 are marked by wide use of all categories of wild plants (Table 5.11). At Pueblo Alto we see particularly high occurrences of some important wild perennials (pinyon, prickly pear, and hedgehog cactus) as well as certain of the weedy annuals (especially sunflower); concurrently, the ubiquity of corn remains is at its lowest level. As at Salmon Ruins (Doebley and Bohrer 1983), corn and wild

Table 5.11 Overview of Botanical Assemblages Characteristics (at Chaco, Bis sa'ani, and Salmon) Over Time

Time	Cultivars	Wild Plants	Wood
Pueblo Alto Red Mesa Phase AD 1020-1040/50	corn: avg. row number ca. 10	Perennial, grass, and woody economics all relatively widespread	Coniferous fuel is minimal (15%) and is associated predominantly with big firepits and trash. Most fuel is shrubby (80%; largely saltbush but many other types used also)
29SJ 629[1] Main site occup. AD 925-1050	corn: avg. row number ca. 10 slightly smaller in diam. than Pueblo Alto's	Grass and weedy economics widespread Lower ubiquity and diversity with respect to Alto's affects perennial category particularly (juniper, pinyon, cacti, yucca, squawberry)	Coniferous fuel only 9% Most fuel is shrubby (75%; largely saltbush, etc.)
Pueblo Alto Gallup Phase AD 1050-1100	corn: avg. row number approaching 10; cobs slightly smaller than in Red Mesa Phase	Perennial, grass, and weedy economics all at their narrowest distribution level at Pueblo Alto	Major jump in importance of coniferous fuel (41%); shrub fuel 53% (largely saltbush)
Pueblo Alto Late Mix Phase AD 1100-1150	corn: more widespread; avg. row number ca. 11; cobs slightly smaller than in Gallup Phase	Perennials and some weedy species slightly lower than their sitewide occurrence. Grasses at peak use	Coniferous fuel totals 57%, now associated significantly with heating pits as well. Shrub fuel 37%; little variety beyond saltbush
29SJ 629[1] 12th C. Kiva Trash	corn: avg. row number = 10	Decreased diversity re. the earlier main occupation, but small sample size and specialized function may be responsible	----------
Bis sa'ani[2] AD 1100+	corn: avg. row number ca. 10. cobs even smaller than Pueblo Alto $\bar{x}$ diam. 11.1 mm. squash: *Cucurbita pepo* plus poss. *C. mixta*; rind mostly *Cucurbita* but little bit of *Lagenaria*. bean: 1 *Phaseolus vulgaris* cotyledon	Perennial, grass, and weedy economics are both diverse and widespread. Beeweed and winged pigweed are more widespread than at other sites, while stickleaf is rarer. Presence of economic taxa rarely found in other Chacoan sites (walnut, onion, reed, yucca) can be attributed largely to excellent preservation conditions	Conifers constitute 53% of fuel. Shrub fuel (28%) includes more sage (locally abundant) than saltbush
Salmon Ruin[3] Chacoan occup. AD 1080/ 1090-1130	corn: widespread (77% of trash strata); avg. row number ca. 12 Much larger cobs tha Pueblo Alto or Bis sa'ani; no clear assoc. of bean with this occup. Squash remains are widespread and all appear to be *C. pepo*.	Cheno-ams, purslane, grasses most common. Ample diversity of weeds; perennial economics less so	Construction wood is 55% ponderosa and higher elevation conifers, 45% juniper
Salmon Ruin[3] Mesa Verde Occup. AD 1180-1280	corn: less widespread (57% of trash strata); avg. row number ca. 11; cupules wide, cobs smaller than first Salmon occupation, but still much larger than Chaco. Nearly all beans recovered at Salmon come from trash and roof strata of this occupation Squash remains not so widespread as in earlier occupation	Diversity of wild plants used increases with respect to the earlier Salmon occupation	Construction wood is 83% juniper ----------

[1] Toll 1981b

[2] Donaldson & Toll 1982

[3] Bohrer & Doebley 1983; Bohrer 1980; Doebley 1981

economic plants show an inverse relationship. The ubiquity of Pueblo Alto corn remains increases perceptibly and steadily over time, and some perennials (pinyon and cacti) diminish substantially in prominence, while annual weeds and grasses, the backbone of wild food products, taper off only slightly. Some decrease in diversity can be seen over time at 29SJ 629, though data from the later occupation may be colored by both specialized function of the kiva context and small sample size. The *increased* diversity seen in the latest occupation at 29SJ 627 may be due to sample characteristics (lack of primary deposits in early floors and features). While (locally grown?) corn decreases in size during Late Mix contexts at Pueblo Alto and 29SJ 629, we see some populations of markedly more robust (imported?) corn at some of the largest Chaco greathouses.

Wood used for both fuel and construction material shows temporal changes on a higher scale. Firewood in earlier contexts is dominated by a variety of shrubby species, while by the Late Mix period occupations coniferous fuel is the predominant component and shrub fuel is both less important and less diverse (almost entirely saltbush). Construction materials all shift markedly from a preponderance of local pinyon and juniper in the late Basketmaker period to the importation of 75% of the timber from higher altitude conifer forests during the Pueblo PIII building boom. Wood and wild plant use appear to follow opposite diachronic patterns in Chaco, i.e., fuel use progresses towards greater use of valued local woods presumed to be in short supply, while construction materials come increasingly from further afield. Meanwhile, the dated evidence we have of wild perennial utilization points to *decreasing* use over time of these important food and manufacturing resources available in limited supply in the canyon area.

This review of the progress of economic plant use over time in Chaco leads directly to a consideration of Chaco's place in a wider regional perspective. The nearby outlier, Bis sa'ani, shares Chaco's difficulties in coping with making a living in the central San Juan Basin and bears similarities to Chaco in paleobotanical temporal trends (such as increasing corn ubiquity and decreasing cob size) (Donaldson and Toll 1982b). Along the San Juan River, Salmon Ruin is doing well (i.e., corn is widespread in the site and large in size [Bohrer and Doebly 1983]), while survival is precarious in the central Basin. During Salmon Ruin's Mesa Verdean occupation, at the close of Chaco's florescence, corn diminishes in size and ubiquity while the diversity of wild products increases. If smaller cob size is taken as a reliable indicator of decreased agricultural productivity, responses to farming stress seem to have varied from increased agriculture effort in the Chaco area to stepped-up reliance on wild food products at Salmon Ruin (and further afield at Mesa Verde) (Stiger 1977).

Chaco in Regional Perspective

In the San Juan Basin, a shift to widespread year-round habitation and masonry structures during the Anasazi period results in conditions affording potentially better preservation. Accordingly we have a great deal more data on botanical correlates of Anasazi subsistence practices than we do for the Archaic period, represented characteristically by depauperate assemblages from shallow deposits in structureless sites. Anasazi assemblages, from small as well as large sites throughout the region, consistently reveal tapping of a wide resource base, spanning the entire growing season. Both plant food and wood use reflect widening of Anasazi site-catchment area with respect to the Archaic period.

On a region-wide basis we see consistent use of two grass taxa, ricegrass and dropseed. A large number of weeds are particularly well-represented, with goosefoot the most reliably occurring taxon. West of Chaco in the Chuska Valley, purslane becomes more important, occurring in 31-62% of samples and frequently charred. Other weed taxa whose use seems to be widespread are pigweed, beeweed, and mustard, with tickseed, sunflower, groundcherry, and stickleaf (a major weed seed crop in Chaco) used less often. Several non-weedy economics typically recovered in low quantity--cacti, yucca, reed, sedges, and shrub fruits--make an appearance in Anasazi sites; retrieval in this period may be due in part to better preservation, not solely to a more broadly based adaptation. The recovery of pinyon nutshell is more consistent in the Chuska Valley and Chaco, where this important resource is available locally. Corn remains are ubiquitous in Anasazi sites, while squash seeds and beans are far less common. The relative importance of cultivated crops may be accurate simply insofar as corn is emphasized, though the low profile of squash and beans may be an inaccurate reflection of their actual importance due to factors of differential deposition and preservation. Better-preserved assemblages at Chaco large sites, Salmon Ruin, and Bis sa'ani reveal substantial quantities of squash and bean remains.

The Anasazi of the San Juan Basin drew heavily on local shrubs for firewood, but diversified by drawing from a wider catchment area than their Archaic predecessors. Local fuel resources include saltbush in most areas as in Chaco, with significant components of juniper and greasewood in the N.I.I.P. Blocks north of Chaco (Ford 1980), and sage in the Bis sa'ani community to the east (Donaldson and Toll 1982b).

Better-preserved assemblages from larger, internally differentiated pueblos provide the most appropriate direct comparison to larger sites in Chaco. Flotation assemblages at Salmon Ruins, Bis sa'ani, and Pueblo Alto are highly comparable. Macrobotanical collections contain much the same taxa though distribution (especially of low frequency taxa) is subject to localized preservation conditions throughout each site. Both Salmon Ruin and Bis sa'ani have post-occupational trash lying directly on most floors, complicating attempts to distinguish plant-related activity patterns within rooms, and to correlate plant remains with room function. Pueblo Alto's general escape from this predicament is an unusual gift.

Directions for Future Work

Based on suggestive patterning in corn morphometrics, a principal topic at issue is whether significant differences in plant utilization exist on the level of the major greathouses (Pueblo Bonito, Pueblo del Arroyo, Chetro Ketl, and perhaps Hungo Pavi, Una Vida, and others) vs. all other sites, and/or on the more commonly invoked dichotomy of small vs. large sites. Plant utilization patterns under particular scrutiny include access to perennial species for food and fuel in short supply in the canyon itself, as well as to agricultural imports.

The similarity to diminutive, drought-stressed cobs from Pueblo Alto and several village sites is compelling, and stands in considerable contrast to large, even cobs from Pueblo Bonito and Pueblo del Arroyo. The disturbing possibility that unburned cobs from the Pepper-Hyde collection might represent historic Navajo use of Pueblo Bonito's roofed rooms for overflow crop storage is tempered by corresponding morphology of charred cobs recovered at Pueblo Bonito and Pueblo del Arroyo by Judd (1954, 1959; Table 5.8). Clearly a very different corn population is associated with these very large greathouses, though the evidence is limited. We are in particular need of additional corn measurements from other greathouses (Chetro Ketl and Una Vida warehouse collections are possibilities) as well as from additional villages and "smaller large sites" (such as unexcavated Wijiji and Casa Chiquita). Though much of the Gallo Cliff Shelter material seems to have disappeared forever, the remainder of this well-preserved small Pueblo PIII site's vegetal assemblage still stored at the Chaco Center offers a special opportunity for sorting out true small vs. large site adaptations from the effects of preservation.

Scheduled flotation and macrobotanical analyses at 29SJ 626, Kin Nahasbas, and Una Vida (a small site, Great Kiva, and large site) will provide data to strengthen or minimize distinctions between small and large sites. Species composition of charcoal from heating features at these and other sites is data critical to defining diachronic trends in fuel use, as well as differences among various sites types.

References Cited

Ambrose, James E.
n.d. The Past Environment of Canyon de Chelly. Chapter 10, in Antelope House volume. Ms. on file, Western Archeological Center, National Park Service, Tucson, Arizona.

Bannister, Bryant
1965 Tree-ring Dating of the Archeological Sites in the Chaco Canyon Region, New Mexico. Southwestern Monuments Association Technical Series 6(2).

Benson, Lyman, and Robert A. Darrow
1981 Trees and Shrubs of the Southwestern Deserts (third edition). University of Arizona Press, Tucson.

Bohrer, Vorsila L.
1975 The Prehistoric and Historic Role of the Cool-Season Grasses in the Southwest. Economic Botany 29(3):199-207.

1980 The Analysis of Ethnobotanical Remains. In Investigations at the Salmon Site: The Structure of Chacoan Society in the Northern Southwest, vol. III, edited by Cynthia Irwin-Williams and Phillip H. Shelley. Final report to funding agencies, Part 7, pp. 163-354. Portales, New Mexico.

Bradley, Zorro A.
1971 Site Bc 236, Chaco Canyon National Monument, New Mexico. National Park Service, Division of Archeology, Office of Archeology and Historic Preservation, Washington.

Brand, Donald D., Florence M. Hawley, Frank C. Hibben, and Donovan Senter
1937 Tseh So, a Small House Ruin, Chaco Canyon, New Mexico: Preliminary Report. University of New Mexico Bulletin, Anthropology Series 2(2). Albuquerque.

Breternitz, Cory Dale
1977 Botanical Remains from Archaeological Sites as a Basis for Determining Cultural Activity in Chaco Canyon. Ms. on file, Division of Cultural Research, National Park Service, Albuquerque.

Callen, Eric O.
n.d. Coprolites from Bc 288. Ms. on file, Division of Cultural Research, National Park Service, Albuquerque.

Cully, Anne C.
1977 Relation of Pollen Analyses to Archeological Sites, Chaco Canyon: 29SJ627. Ms. on file, Division of Cultural Research, National Park Service, Albuquerque.

1978 Check-list of Plants Present in Chaco Canyon National Monument, New Mexico. Ms. on file, Division of Cultural Research, National Park Service, Albuquerque.

Cully, Anne C., Marcia L. Donaldson, Klara Kelley, and Mollie S. Toll
1982 Farming in the Bis sa'ani Community Area: An Experiment in Determining Agricultural Potential. Ms. on file, Cultural Resources Management Program, Navajo Nation, Window Rock, Arizona.

Cutler, Hugh C.
1952 A Preliminary Survey of Plant Remains of Tularosa Cave. In Mogollon Cultural Continuity and Change: The Stratigraphic Analysis of Tularosa and Cordova Caves, Paul S. Martin, John B. Rinaldo, Elaine Bluhm, Hugh C. Cutler, and Roger Grange, Jr., pp. 461-479. Fieldiana, Anthropological Series no. 40.

Cutler, Hugh C., and Winton Meyer
1965 Corn and Cucurbits from Wetherill Mesa. In Contributions of the Wetherill Mesa Archaeological Project, assembled by Douglas Osborne, pp. 136-152. Memoirs of the Society for American Archaeology 19.

Cutler, Hugh C., and Thomas W. Whitaker
1961 History and Distribution of the Cultivated Cucurbits in the Americas. American Antiquity 26(4):469-485.

Dean, Jeffrey S.
1979 List of Tree-ring Dates from Pueblo Alto. Ms. on file, Division of Cultural Research, National Park Service, Albuquerque.

Denmead, O.T., and R.H. Shaw
1960 The Effects of Soil Moisture Stress at Different Stages of Growth on the Development and Yield of Corn. Agronomy Journal 52:272-274.

Doebley, John F.
1981 Plant Remains Recovered by Flotation from Trash at Salmon Ruin, New Mexico. Kiva 46(3):169-188.

Doebley, John F., and Vorsila Bohrer
1983 Maize Variability and Cultural Selection at Salmon Ruin, New Mexico. Kiva 49(1-2):19-38.

Donaldson, Marcia L.
1981a Flotation Analysis of Samples from Six Sites in the Gallo Wash Mine Area. Ms. on file, Cultural Resources Management Program, Navajo Nation, Window Rock, Arizona. Castetter Laboratory for Ethnobotanical Studies, Technical Series 30.

1981b Corn Remains Recovered from LA 26749, a Basketmaker III Site Near Crownpoint, New Mexico. Ms. on file, Division of Conservation

Archeology, Farmington, New Mexico. Castetter Laboratory for Ethnobotanical Studies, Technical Series 37.

Donaldson, Marcia L., and Mollie S. Toll

1982a Analysis of Flotation Samples and Macrobotanical Remains: NIIP Blocks VIII and IX Mitigation and X and XI Testing. Ms. on file, Navajo Nation Cultural Resources Management Program, Window Rock, Arizona.

1982b Prehistoric Subsistence in the Bis sa'ani Community Area: Evidence from Flotation, Macro-botanical Remains, and Wood Identification. In Bis sa'ani: A Late Bonito Phase Community on Escavada Wash, Northwest New Mexico, vol. 3, by Cory Dale Breternitz, David E. Doyel, and Michael P. Marshall, pp. 1099-1180. Navajo Nation Papers in Anthropology 14. Navajo Nation, Cultural Resources Management Program.

Dutton, Bertha P.

1938 Leyit Kin, a Small House Ruin, Chaco Canyon, New Mexico. School of American Research Monograph 7. Santa Fe.

Ford, Richard I.

1968 An Ecological Analysis Involving the Population of San Juan Pueblo, New Mexico. Unpublished Ph.D. Dissertation, Department of Anthropology, University of Michigan. University Microfilms, Ann Arbor.

1975 Re-excavation of Jemez Cave, New Mexico. Awanyu 3:13-27.

1980 Plant Remains. Volume IV, chapter 11, in Prehistory and History of the Ojo Amarillo, edited by David Kirkpatrick. Cultural Resources Management Division, New Mexico State University, Report 276.

1981 Gardening and Farming Before A.D. 1000: Patterns of Prehistoric Cultivation North of Mexico. Journal of Ethnobiology 1(1):6-27.

Gasser, Robert

1981 The Plant Remains from Walpi: Phase II. Analysis of Plant Remains in 37 Rooms and 11 Rodent Nests from Walpi, Hopi Indian Reservation, Navajo County, Arizona. Ms. on file, Heritage Conservation and Recreation Service, Interagency Archaeological Services, San Francisco.

Gasser, Robert E., and E. Charles Adams

1981 Aspects of Deterioration of Plant Remains in Archaeological Sites: The Walpi Archaeological Project. Journal of Ethnobiology 1(1): 182-192.

Graves, Henry S.

1919 The Uses of Wood for Fuel. U.S.D.A. Bulletin 753.

Harrington, H.D.
1964 Manual of the Plants of Colorado (second edition). Swallow Press, Chicago.

Hawley, Florence M.
1934 The Significance of the Dated Prehistory of Chetro Ketl, Chaco Canyon, New Mexico. Monographs of the School of American Research 2. Santa Fe.

Hill, James N.
1970 Broken K Pueblo: Prehistoric Social Organization in the American Southwest. Anthropological Papers, University of Arizona, no. 18.

Judd, Neil M.
1954 The Material Culture of Pueblo Bonito. Smithsonian Miscellaneous Collections no. 124. Washington.

1959 Pueblo del Arroyo, Chaco Canyon, New Mexico. Smithsonian Miscellaneous Collections no. 138(1). Washington.

Kaplan, Lawrence
n.d. Beans from Bc 288. Ms. on file, Division of Cultural Research, National Park Service, Albuquerque.

1956 The Cultivated Beans of the Prehistoric Southwest. Annals of the Missouri Botanical Garden 43:189-251.

1963 Archeoethnobotany of Cordova Cave, New Mexico. Economic Botany 17(4):350-359.

Kearney, Thomas H., and Robert H. Peebles
1960 Arizona Flora (second, revised edition). University of California Press, Berkeley.

Kluckhohn, Clyde, and Paul Reiter, (editors).
1939 Preliminary Report on the 1937 Excavations, Bc 50-51, Chaco Canyon, New Mexico. University of New Mexico Bulletin 345, Anthropological Series 3(2). Albuquerque.

Koeppen, R.C.
n.d. Unworked Wood from Bc 288. Ms. on file, Division of Cultural Research, National Park Service, Albuquerque.

Koschik, Wilma W.
1973 The Paleoethnobotany of the Arroyo Hondo Site: Preliminary Report on the Edible Plant Remains from 1972. Ms. on file, School of American Research, Santa Fe.

Lekson, Steven H. (editor)
1983 The Architecture and Dendrochronology of Cheto Ketl, Chaco Canyon, New Mexico. Reports of the Chaco Center no. 6. Division of Cultural Research, National Park Service, Albuquerque.

Lister, Robert H., and Florence C. Lister
Chaco Canyon: Archaeology and Archaeologists. University of New Mexico Press, Albuquerque.

Martin, Paul S., John B. Rinaldo, Elaine A. Bluhm, Hugh C. Cutler, and Roger Grange, Jr.
1952 *Mogollon Cultural Continuity and Change: The Stratigraphic Analysis of Tularosa and Cordova Caves*. Fieldiana, Anthropological Series 40.

Martin, William C., and C. Robert Hutchins
1981 *A Flora of New Mexico*. J. Cramer, Braunschweig, W. Germany.

McKenna, Peter J.
1985 *The Architecture and Material Culture of 29SJ1360, Chaco Canyon, New Mexico*. Reports of the Chaco Center no. 7. Division of Cultural Research, National Park Service, Albuquerque.

Minnis, Paul
1980 Wood Identifications. Appendix VI, in *Human Adaptations in a Marginal Environment: The UII Mitigation Project*, edited by James L. Moore and Joseph C. Winter, pp. 586-587. Office of Contract Archeology, University of New Mexico, Albuquerque.

1982 The Ethnobotanical Remains. In *Archeological Excavations near Lake Valley, San Juan County, New Mexico*, edited by Regge N. Wiseman, pp. 64-82. Museum of New Mexico, Research Section: Laboratory of Anthropology Note, 308.

Pepper, George H.
1920 *Pueblo Bonito*. Anthropological Papers of the American Museum of Natural History, vol 27. New York.

Potter, Loren D.
1974 Ecological Survey of Chaco Canyon. Ms. on file, Division of Cultural Research, National Park Service, Albuquerque.

Robins, J.S., and C.E. Domingo
1953 Some Effects of Severe Soil Moisture Deficits at Specific Growth Stages in Corn. *Agronomy Journal* 45:618-621.

Robinson, William J.
1979 Species Identification of Wood Submitted for Tree-ring Dating, 29SJ 389. Ms. on file, Division of Cultural Research, National Park Service, Albuquerque.

Schelberg, John
1982 *Economic and Social Development as an Adaptation to a Marginal Environment in Chaco Canyon, New Mexico*. Unpublished Ph.D. Dissertation, Northwestern University, Evanston.

Stiger, Mark A.
1977 Anasazi Diet: The Coprolite Evidence. Unpublished Master's Thesis, Department of Anthropology, University of Colorado, Boulder.

Struever, Mollie
1977 Relation of Flotation Analysis to Archeological Sites, Chaco Canyon, New Mexico. Final Report, Site 29SJ627. Ms. on file, Division of Cultural Research, National Park Service, Albuquerque.

Struever, Mollie S., and Paul J. Knight
1979 Analysis of Flotation Samples and Macro-botanical Remains: Block III Mitigation, Navajo Indian Irrigation Project. Ms. on file, Cultural Resources Management Program, Navajo Nation, Window Rock, Arizona. Castetter Laboratory for Ethnobotanical Studies, Technical Series 3.

Toll, Mollie S.
1981a Macro-botanical Remains Recovered from Chaco Canyon Coprolites. Ms. on file, Division of Cultural Research, National Park Service, Albuquerque. Castetter Laboratory for Ethnobotanical Studies, Technical Series 38.

1981b Flotation and Macro-botanical Analyses at 29SJ 629: A Pueblo I-II Village in Chaco Canyon. Ms. on file, Division of Cultural Research, National Park Service, Albuquerque, New Mexico. Castetter Laboratory for Ethnobotanical Studies, Technical Series 49.

1981c Vegetal Materials Recovered During Stabilization of Sliding Rock Ruin, Canyon de Chelly National Monument. Appendix G in Nondestructive Archeology at Sliding Rock Ruin: An Experiment in the Methodology of the Conservation Ethic, by Larry Nordby. Southwestern Cultural Resource Center, National Park Service, Santa Fe, New Mexico.

1985a Plant Utilization at a Chacoan Town Site: Pueblo Alto. Chaco Center, National Park Service, Albuquerque.

1985b Changing Patterns of Plant Utilization for Food and Fuel: Evidence from Flotation and Macro-botanical Remains. In Economy and Interaction Along the Lower Chaco River: the Navajo Mine Archeological Program, Mining Area III, edited by Patrick Hogan and Joseph C. Winter, pp. 331-350. Office of Contract Archeology, Albuquerque.

Vivian, R. Gordon, and Thomas W. Mathews
1965 Kin Kletso: A Pueblo III Community in Chaco Canyon, New Mexico. Southwestern Monuments Association Technical Series, vol. 6, part 1. Globe, Arizona.

Welsh, Stanley L.
1979 Charcoal Identifications from Excavations in Chaco Canyon National Monument, Parts I and II. Ms. on file, Chaco Center, National Park Service, Albuquerque.

Windes, Thomas C.
1977 Dwellers of the Wood. Ms. on file, Chaco Center, National Park Service, Albuquerque.

1980 The Absolute Boar: Test and Excavations at the Pueblo Alto Complex 1974-1979. Ms. on file, Division of Cultural Research, National Park Service, Albuquerque.

Winter, Joseph C.
1973 The Distribution and Development of Fremont Maize Agriculture: Some Preliminary Interpretations. *American Antiquity* 38(4):439-451.

Chapter Six

Baseline Biology of Birds and Mammals at Chaco Canyon National Monument New Mexico

by

Jack F. Cully, Jr.

Introduction

Bird and mammal species composition and population size at Chaco Canyon and throughout the San Juan Basin varies in both time and space. The temporal variation occurs seasonally and annually. Some species may occupy only one type of habitat or physiognomic association, while others are ubiquitous. In such spatially and temporally fluctuating environments, a simple cataloging of the species present at a habitat site yields very little information that can be used to verify broad environmental changes that are affecting the park, as a result of either extraneous factors such as mining outside of the park or intrinsic management practices.

This study has two major goals: (1) The first is to identify the population sizes of the species that occur in several different habitats at Chaco Canyon. These data provide a basis for comparing the results of future studies to determine what changes in the ecology are caused by human intervention, as well as for comparison with faunal remains from archeological sites. By knowing the faunal associations at the habitats in the park today, it should be possible to infer whether and how conditions differed at another time. (2) The second goal is to reduce the rather complicated population data to a simple index that will indicate changes in the ecological background, if such changes occurred. Unfortunately, the mass of data that must be assimilated to find meaningful differences, in often uncorrelated population changes among several habitats, may hide patterns that indicate underlying changes. I used two diversity indices for this purpose. For communities with numerous rare species, such as the bird community, Peet (1974) suggests that the Shannon-Weaver diversity index is most sensitive to change. For communities that are primarily composed of common species (as the mammal communities), he recommends Hill's (1973) modifications of the Simpson Index (Simpson 1949). In both indices, diversity has two major components, (1) the number of species present (richness), and (2) the relative numbers of individuals of each species (evenness). The value of using such a community measure, instead of a list of species, is that if the resource base remains the same through time, the consuming community should remain similar even though the species composition might change. Likewise, if the resource base is altered, a difference should be detectable through a change in subsequent diversity indices. This assumes that the organisms in the community are closely associated with specific resources.

The following analysis is divided into two sections, one for birds, the second for mammals. Since birds are highly mobile, changes in their communities may reflect large-scale changes that occur both within and around the park. Rodents do not migrate, and generally must react to more local conditions. Therefore, changes in the mammal community probably will reflect changes that are occurring within the park boundaries.

Baseline Biology of Birds: Communities of Four Habitats

For two years I have been gathering populations data on birds in four habitats at Chaco Canyon National Monument, San Juan County, New Mexico. Chaco Canyon is located in the center of the San Juan Basin (Figure 2.1). (See Chapter 2 for a description of the study areas.)

Bird species composition varies seasonally at Chaco Canyon as do population levels of the component species. Some species occupy only one habitat whereas others may occur in several. To compare bird communities of different habitats and to detect seasonal differences within communities, the Shannon-Weaver index of diversity was used: $H' = \Sigma P_i \ln P_i$ (Shannon and Weaver 1963). This index accounts for two factors: species number or richness, and the relative populations of the component species (evenness). Tramer (1969) found that diversity in breeding bird communities was highly correlated with richness. He suggests that the correlation occurred because the territorial behavior of most breeding species caused relative populations, and, therefore, evenness, to remain stable and high. He predicts that during the non-breeding season evenness will become a more important part of diversity since the birds' behavior is non-territorial, and the birds will tend to cluster around food resources.

At Chaco Canyon migrating birds constitute an important part of the bird community during most months. If Tramer's hypothesis, that evenness is dampened by territorial behavior, is correct, the diversity at Chaco Canyon should be affected more by fluctuations in evenness than are breeding populations where transient birds do not occur or are not considered by the observer.

Methods

Seventy-seven bird censuses were conducted along five transects in four habitat types at Chaco Canyon National Monument. The censuses cover the period 17 October 1978 to 31 July 1980. Censuses were conducted from March through November; no mid-winter censuses were run. Each study site consisted of a 1.6 km transect marked by numbered stakes at 31 m intervals. All birds observed on the ground or in trees or shrubs were counted. If birds were seen overhead or outside of the transect boundaries, they were noted, but their numbers were not included in this report. All censuses were begun within 30 minutes after sunrise and usually lasted

1.5 to 2 hours. Birds were counted as I walked along the transect with frequent stops (at least every 93 m) to listen and look for birds. Because birds sometimes flew ahead, special care was taken to avoid recounting the same birds. All birds seen within a transect were given equal importance, regardless of activity, i.e., breeding birds are not separated from non-breeding birds.

Migrating birds were an important part of the bird communities during all seasons that I worked at Chaco. Since I wanted to examine the bird use of the habitats, migrants were included in the analysis. Furthermore, the Shannon-Weaver index of diversity requires that all species present in the community be counted (Pielou 1974). Peet (1974) points out that the error due to missed species will be small in ecological studies. In this study $H' = -\Sigma P_i \ln P_i$ is used to describe the community found at each census. P_i is the proportion of the sample contributed by the i^{th} species. Evenness $(J) = H'/H_{max}$ where H_{max} = the natural log of the number of species encountered. Richness is simply the number of species encountered. Richness (R) and J were then compared by correlation with H' to see which contributed most of the variability of H' in each habitat. (Note that since R and J are not independent of H', statisically significance levels of r, the correlation coefficient, are not appropriate; r, nevertheless, provides a relative measure of how closely related these factors are to H'.)

When a diversity index is used to describe bird communities the following assumptions must hold: changes in species present in a habitat will be characterized by changes in relative populations of the component species. Likewise, if the habitat changes, a species' dispersion, and therefore, relative numbers, will change as well. These seem to be reasonable assumptions.

To determine whether there were differences among the bird communities of the five transects, the diversity indices calculated for each census were tested by a single factor analysis of variance and the Student-Newman-Keuls multiple range test (Zar 1974). Differences were considered significant where $p < .05$.

Results

The results of the bird censuses are shown in Tables 6.1-6.5. The Wash contains the greatest number of species (58) followed by the two floodplain sites, Casa Chiquita (45) and Pueblo Bonito (45), the Pinyon-juniper site (41) and finally the Bench (12) (Figure 2.1). In the Wash the diversity of birds dropped during the winter when most birds in the monument were granivorous. The Pinyon-juniper habitat exhibited a similar pattern of use; the greatest numbers of species occurred during seasons when insects were available. Seasonal use of the shrubby floodplain sites did not vary as much as the areas containing trees, a possible function of winter seed availability on the clay soils of the floodplain.

The high diversity of birds occurring in the wash during the breeding season was probably related to the cottonwood trees found there (Table

Table 6.1 Birds Observed on the Bench Transect

Common Name	Latin Name	B n=5	R n=6
Rock wren	Salpinctes obsoletus	9.00 (5)	3.83 (4)
House finch	Carpodacus mexicanus	0.40 (2)	0.67 (2)
Brown towhee	Pipilo fuscus		1.33 (4)
Black-throated sparrow	Amphispiza bilineata	6.00 (5)	2.00 (2)
Other Species		[3] 0.60	[8] 2.00

Note: The first number in each column is the mean number of birds seen during that season. The number in parentheses indicates the number of censuses in which the species was encountered. Only birds observed on more than one census are listed. The number of species encountered only once is shown in brackets followed by the mean number opf these individuals. The number of censuses during the season = n. B = breeding season, R = remaining.

Table 6.2 Birds Observed on the Casa Chiquita Transect

Common Name	Latin Name	B n=8	R n=10
American kestrel	Falco sparvarius	0.50 (3)	0.30 (2)
Mourning dove	Zenaida macroura	11.25 (5)	
Broad-tailed hummingbird	Selasphorus platycercus	0.25 (2)	
Cassin's kingbird	Tyrannus vociferans	0.63 (3)	
Say phoebe	Sayornis saya	3.63 (7)	0.80 (3)
Cliff swallow	Petrochelidon pyrrhonota	13.75 (2)	
Common raven	Corvus corax	2.25 (5)	0.40 (2)
Rock wren	Salpinctes obsoletus	9.13 (8)	2.90 (4)
Mockingbird	Mimus polyglottos	1.13 (5)	
Blue-grey gnatcatcher	Polioptila caerulea		0.20 (2)
Loggerhead shrike	Lanius ludovicianus	0.50 (4)	1.00 (6)
Yellow-rumped warbler	Dendroica coronata	1.63 (3)	
Western meadowlark	Sturnela neglecta	2.25 (4)	
Bullock's oriole	Icterus galbula	0.88 (3)	
Brown-headed cowbird	Molthrus ater	1.38 (3)	
Blue grosbeak	Guiraca caerulea	0.38 (2)	
House finch	Carpodacus mexicanus	1.13 (4)	0.70 (4)
Brown towhee	Pipilo fuscus	0.63 (2)	1.80 (6)
Lark sparrow	Chondestes gramacus	0.50 (3)	
Black-throated sparrow	Amphispiza bilineata	14.75 (8)	0.90 (4)
Sage sparrow	Amphispiza belli		2.10 (4)
Dark-eyed junco	Juncoi hyemalis		2.70 (5)
Grey-headed junco	Junco caniceps		0.20 (2)
Brewer's sparrow	Spizella breweri		0.80 (2)
White-crowned sparrow	Zonotrichia leucophrys		2.10 (4)
Other species		[12] 2.54	[14] 4.10

Table 6.3 Birds Observed on the Pueblo Bonito Transect

Common Name	Latin Name	B n=8	R n=11
American kestrel	*Falco sparvarius*	0.38 (3)	
Mourning dove	*Zenaida macroura*	0.88 (4)	
Ash-throated flycatcher	*Myiarchus cinerascens*	0.38 (2)	
Say phoebe	*Sayornis saya*	1.25 (6)	0.55 (2)
Cliff swallow	*Petrochelidon pyrrhonota*	16.25 (3)	
Common raven	*Corvus corax*	0.50 (2)	
Mountain chickadee	*Parus gambelii*		0.55 (2)
Bewick's wren	*Thryomanes bewickii*		0.18 (2)
Canyon wren	*Catherpes mexicanus*		0.55 (3)
Rock wren	*Salpinctes obsoletus*	13.12 (8)	4.73 (4)
Mockingbird	*Mimus polyglottos*	2.75 (8)	
Blue-grey gnatcatcher	*Polioptila caerulea*		1.55 (3)
Loggerhead shrike	*Lanius ludovicianus*	0.88 (2)	0.27 (3)
Yellow-rumped warbler	*Dendroica coronata*	0.63 (2)	
Western meadowlark	*Sturnella neglecta*	0.75 (3)	
Bullock's oriole	*Icterus glabula*	0.88 (2)	
Brown-headed cowbird	*Molothrus ater*	0.25 (2)	
House finch	*Carpodacus mexicanus*	1.00 (6)	4.27 (6)
Green-tailed towhee	*Pipilo chlorurus*		0.36 (3)
Rufous-sided towhee	*Pipilo erythrophthalmus*		0.18 (2)
Brown towhee	*Pipilo fuscus*	3.38 (8)	4.82 (11)
Black-throated sparrow	*Amphispiza bilineata*	17.00 (8)	4.82 (5)
Sage sparrow	*Amphispiza bellii*		5.27 (7)
Dark-eyed junco	*Junco hyemalis*		1.27 (5)
Chipping sparrow	*Spizella passerina*		0.45 (2)
Brewer's sparrow	*Spizella breweri*	1.75 (3)	
White-crowned sparrow	*Zonotrichia leucophrys*		31.36
Other species		[13] 2.67	[17] 2.34

Table 6.4 Birds Observed on the Pinyon-Juniper Transect

Common Name	Latin Name	B n=6	R n=7
Mourning dove	*Zenaida macroura*	2.17 (5)	0.43 (2)
Common nighthawk	*Chordeiles minor*	0.67 (3)	
Black-chinned hummingbird	*Archilochus alexandri*	0.33 (2)	
Broad-tailed hummingbird	*Selasphorus platycercus*	0.83 (2)	
Ash-throated flycatcher	*Myiarchus cinerascenes*	1.00 (2)	
Say phoebe	*Sayornis saya*	0.50 (3)	0.43 (2)
Grey flycatcher	*Empidonax wrightii*	0.67 (2)	0.71 (2)
Scrub jay	*Aphelocoma coerulescens*		0.71 (3)
Pinyon jay	*Gymnorhinnus cyanocephalus*	1.33 (3)	0.71 (2)
Plain titmouse	*Parus inoranatus*	2.33 (4)	3.29 (3)
House wren	*Troglodytes aedon*		0.43 (2)
Canyon wren	*Catherpes mexicanus*		0.29 (2)
Rock wren	*Salpinctes obsoletus*	4.33 (6)	3.00 (4)
Mockingbird	*Mimus polyglottos*	0.50 (3)	
Mountain bluebird	*Sialia curucoides*	1.00 (2)	
Blue-grey gnatcatcher	*Polioptila caerulea*	1.00 (2)	
Loggerhead shrike	*Lanius ludovicianus*		0.29 (2)
House finch	*Carpodacus mexicanus*	4.67 (4)	
Brown towhee	*Pipilo fuscus*		0.57 (2)
Black-throated sparrow	*Amphispiza bilineata*	4.17 (6)	1.86 (3)
Dark-eyed junco	*Junco hyemalis*		4.00 (3)
Chipping sparrow	*Spizella passerina*		2.14 (3)
Other species		[8] 1.52	[18] 4.70

Table 6.5 Birds Observed on the Wash Transect

Common Name	Latin Name	B n=8	R n=8
Turkey vulture	*Cathartes aura*	19.25 (8)	3.88 (4)
American kestrel	*Falco sparvarius*		0.25 (2)
Mourning dove	*Zenaida macroura*	23.63 (8)	3.63 (3)
Great-horned owl	*Bubo virginianus*	0.38 (2)	
Black-chinned hummingbird	*Archilochus alexandri*	0.50 (4)	
Flicker	*Colaptes cafer*		1.25 (4)
Downy woodpecker	*Picoides pubescens*		0.25 (4)
Western kingbird	*Tyrannus verticalis*	2.13 (6)	
Cassin's kingbird	*Tyrannuys vociferans*	2.75 (5)	
Ash-throated flycatcher	*Myiarchus cinerascens*	0.50 (3)	
Say phoebe	*Sayornis saya*	0.38 (2)	0.63 (2)
Grey flycatcher	*Empidonax wrightii*	0.25 (2)	
	Empidonax sp.		0.50 (2)
Western wood-pewee	*Contopus sordidulus*	0.38 (2)	
Mountain chickadee	*Parus gambelii*		2.25 (2)
House wren	*Troglodytes aedon*		1.13 (2)
Rock wren	*Salpinctes obsoletus*	3.63 (7)	1.63 (3)
Mockingbird	*Mimus polyglottos*	3.75 (7)	
Bendire thrasher	*Toxostoma bendirei*	0.25 (2)	
Robin	*Turdus migratorius*		0.38 (3)
Blue-grey gnatcatcher	*Polioptila caerulea*		0.88 (4)
Ruby-crowned kinglet	*Regulus calendula*		1.13 (2)
Loggerhead shrike	*Lanius ludovicianus*	1.00 (5)	0.25 (2)
Yellow-rumped warbler	*Dendroica coronata*	5.63 (3)	1.75 (4)
MacGillivary's warbler	*Oporonis tolmiei*		0.88 (2)
Wilson warbler	*Wilsonia pusilla*		1.63 (2)
Bullocks oriole	*Icterus galbula*	11.75 (6)	
Brown-headed cowbird	*Molothrus ater*	4.00 (7)	1.63 (2)
Western tanger	*Piranga ludovicianus*	1.25 (3)	
Black-headed grosbeak	*Pheucticus melanocephalus*	0.38 (2)	
Blue grosbeak	*Guiraca caerulea*	2.38 (6)	
House finch	*Carpodacus mexicanus*	8.00 (8)	24.00 (6)
Green-tailed towhee	*Pipilo chlorura*	0.38 (2)	1.13 (2)
Brown towhee	*Pipilo fuscus*	1.50 (2)	1.00 (2)
Pine siskin	*Carduelis pinus*		1.13 (2)
Black-throated sparrow	*Amphispiza bilineata*	2.88 (6)	
Dark-eyed junco	*Junco hyemalis*		9.25 (7)
White-crowned sparrow	*Zonotrichia leucophrys*		5.88 (4)
Song sparrow	*Melospiza melodia*		0.38 (2)
Other species		[21] 4.29	[13] 5.81

6.5). There were a number of species of birds that nest in the cottonwoods: mourning doves, western and Cassin's kingbirds, ash-throated flycatchers, Bullock's orioles, blue grosbeaks, and house finches. Because of the scarcity of cottonwoods in the San Juan Basin, these species were probably attracted from a large area and concentrated in the monument, particularly along the Wash. Many migrants, such as warblers, also concentrated there. Species that normally nest in cliffs were found nesting in the steep banks of the Wash.

The other woodland habitat, the Pinyon-juniper, exhibited the second highest diversity during the breeding season, but very low diversity and few birds during the winter months (Table 6.4). Many of the birds in the Wash were those usually confined to deciduous trees. Likewise, many of the birds found in the Pinyon-juniper are species (e.g., scrub jays, pinyon jays, and plain titmice) that are typical of and, to some extent, limited to, the Pinyon-juniper habitat.

The lowest bird diversity and populations occurred on the Bench during both summer and winter (Table 6.1). During the breeding season the Bench was inhabited by black-throated sparrows, rock wrens, and Say's phoebes. The other birds seen on the bench censuses were usually on the cliff tops singing. The cliffs provide the most conspicuous perches overlooking the floodplain and provide singing perches for house finches and mourning doves. Occasionally sparrow hawks and other birds that nest in the cliffs were seen on the cliff tops.

Patterns of bird diversity for Casa Chiquita (Table 6.2) and Pueblo Bonito (Table 6.3) were similar throughout this study. Bird diversity was somewhat higher during 1980 at Pueblo Bonito than at Casa Chiquita, perhaps due to the better vegetation conditions at the former.

At Casa Chiquita, diversity was highly correlated with richness and poorly correlated with evenness (Table 6.6). At Pueblo Bonito species number was correlated with diversity, but so was evenness. At the Wash, as at Pueblo Bonito, diversity was correlated with both species number and evenness. In the Pinyon-juniper habitat and on the Bench, diversity was correlated only with species numbers.

An analysis of variance test run on the diversity indices of the five transects (Figure 6.1) indicated that the diversity of the five transects was not equal. Results of a Student-Newman-Keuls multiple range test showed the Bench to be unique among the five habitats. Casa Chiquita, Pueblo Bonito, and the Pinyon-juniper transect are grouped together; the Wash is grouped with the Pinyon-juniper and Casa Chiquita, but not with Pueblo Bonito.

Discussion

The San Juan Basin is a large, homogeneous area predominantly of shrub grassland habitat. Most differences among habitats in the basin are small, allowing much overlap of habitat use by most species of birds. In addition to shrub grassland habitats, Chaco Canyon contains a riparian ha-

Table 6.6 Relationship of H' to Evenness and Richness

Habitat	n	r H:J	r H:R
Bench	11	-.0829	.8973
Casa Chiquita	18	.2806	.7420
Pueblo Bonito	19	.9254	.8106
Pinyon-Juniper	13	.1721	.8675
Wash	16	.8426	.8935

Note: r is a correlation coefficient; n represents the number of censuses run on each transect.

bitat characterized by at least two species of Populus, Salix sp. and Tamarisk sp. The cottonwoods and willows were planted in the wash during the 1930s and 1950s; the tamarisk is exotic. Cottonwoods and willows are found in other isolated spots in the basin south of the San Juan River, but nowhere else are they as abundant as at Chaco Canyon. If the bird species that are limited to this deciduous riparian habitat are discounted, the diversity of the Wash would probably be similar to that of Casa Chiquita and Pueblo Bonito. These habitats are similar to other wash-bottom habitats throughout the basin (Cully 1984).

During summer, most birds in the monument are insectivorous, and the foliage diversity in the Wash and Pinyon-juniper probably provides a greater variety of insects than do the other habitats. These habitats are characterized by lower populations and diversity of wintering birds than are the floodplain sites. Although foliage height diversity is lower at Casa Chiquita and Pueblo Bonito than at the wooded habitats, levels of annual production and grass cover are high. The lack of annuals on the Bench and in the Pinyon-juniper transect is probably reflected by the low numbers of wintering birds in those habitats. Seed production is also high in the wash and some juncos and white-crowned sparrows occur there during the winter. Their numbers are not generally as great as they are on the floodplains, however. Perhaps the sandier soils in the wash make finding seeds more difficult than do the loamy soils on the floodplain above.

There are two factors that can cause H' to vary: (1) richness, or the number of species present, and (2) evenness, or the relative populations of the component species. In every habitat at Chaco Canyon diversity was closely related to richness. At two of the transects, the Wash and Pueblo Bonito, evenness was also closely related to diversity. H' was able to distinguish three of the four habitats sampled at Chaco Canyon. The two closest in diversity were the two floodplain sites that occupy nearly identical habitat. Although the distinction between the Wash, Pinyon-juniper, and Casa Chiquita was not perfect, they were very nearly separated by the Student-Newman-Keuls multiple range test and a slightly larger sample size would probably complete this discrimination.

Tramer's (1969) suggestion that consistently high evenness caused by uniform spacing of breeding birds should leave richness to account for diversity seems to be supported in the three habitats where breeding birds are the major inhabitants. The Pueblo Bonito transect was the only one consistently high in winter populations of birds. The white-crowned sparrow, in loose winter flocks, was the most abundant species, accounting for more than half of the birds usually seen on that transect in late fall and early spring. The Wash contains few wintering species, none of which is numerous. At that time of year, richness and evenness are low. During migration, however, and during the breeding season, the cottonwoods in the Wash act as an oasis, both drawing large numbers of species and concentrating their numbers into a limited habitat. The result is that when diversity is high, so is evenness.

Rotenberry et al. (1979) found that during winter in the northern Great Basin, diversity was correlated with evenness rather than richness, whereas during the breeding season, the opposite was true. They concluded that during the breeding season diversity is controlled by resource-based interspecific competition, but that during winter birds are regulated by a harsh climate. In the Chaco study, there do not appear to be seasonal differences in the extent to which richness and evenness influence diversity. A possible cause of this might be related to the importance to diversity of migrating species in the San Juan Basin during all seasons studied. The two habitats at Chaco Canyon that received the most use by migrants exhibited the highest correlation between evenness and diversity. The other habitats are populated more by resident species, which have greater opportunities to achieve equilibrium than do migrants. This results in a consistently high level of evenness, which may be the result, of intraspecific rather than interspecific competition as proposed by Rotenberry et al. (1979). Transient species may not be present long enough at Chaco Canyon to develop stable interspecific or intraspecific relationships and, consequently, evenness can vary far more than in more stable communities.

At Pueblo Bonito and at the Wash, high summer diversity is accompanied by high evenness. During November and March, when diversity is lowest, so is evenness. In winter at Chaco Canyon, the most numerous birds are flocking granivorous species such as juncos and white-crowned sparrows The differences between summer and winter bird communities may be related to seasonal differences in resource availablility. Even dispersal is practical throughout the summer when insects are a widely available source of food. During the winter, however, birds have to rely on clumped resources such as seeds, or perhaps scale insects, with the result that flocking provides a more effective foraging strategy. Consequently, the most common species are found either in large numbers or not at all.

Considering the range of variability of diversity indices at each habitat, the Shannon-Weaver index provides a simple description of the bird communities at Chaco. In addition to showing whether communities are the same or different, this index might be able to provide clues about changes in the future. If evenness increases in certain habitats, it might be suggested that birds that formerly bred throughout the basin at low densities are being forced into more restricted habitat patches within the monument, a pattern that seems to occur now in the cottonwoods along the Wash. On the other hand, if an aggressive exotic species, such as the starling, becomes established in the monument, it could drive other species away, become more abundant itself, and cause the overall diversity to decline.

An Analysis of Small Mammal Communities

During the period October 1978 through August 1980, small mammal communities at Chaco Canyon National Monument were sampled. The primary goals of the study were: (1) to identify small mammal communities in the monument, and (2) to provide the National Park Service with baseline information that will allow NPS Managers to determine the effects of management practices on these communities. To meet these goals five trap grids were established in four habitat types; four of these trap grids were sampled five times each and the last was sampled four times. An attempt was also made to determine the effects of heavy visitor pressure on small mammal communities by placing one trap grid near Pueblo Bonito and another grid in comparable habitat but in an area of considerably less visitor use.

The field study covered 8,600 trap nights. I have trapped 14 species and seen an additional 11 mammal species at Chaco Canyon (Table 6.7). Bats were not included. A total of 1,385 individuals were captured on the grids, for an overall capture rate of 16%.

Methods

Mammals were trapped in 1 ha grids of 100 8 by 9 by 23 cm Sherman aluminum live traps baited with rolled oats. Trapping was conducted on four successive nights (weather permitting) at each trap grid during each sample period. Animals caught were identified to species, weighed, and sex, age, and, if obvious, sexual condition were noted. Each animal caught was individually marked (by toe clipping during the first year of the study) by use of numbered aluminum fingerling tags attached to their ears or, in the case of pocket mice, cheek pouches. The ear tags seemed to cause the mice no trouble and very few were removed.

During June 1980 a series of eight assessment lines were trapped around the trap grid at the Wash, Casa Chiquita, and the Bench (O'Farrel et al. 1978) to see how large an effective area was being trapped at each grid. The assessment lines radiated from each corner and the middle of each side of the grid; each line consisted of 12 Sherman live traps placed at 15 m intervals. The traps were run for two nights around each grid, resulting in an additional 576 trap nights.

The trapping results were analyzed using a multiple mark recapture technique. The Schnabel analysis formula is $\hat{N} = \frac{\Sigma (M_i C_i)}{\Sigma R_i}$ where M_i = the number of marked individuals in the populations at night i = (1-4). On the first night $M_i = 0$. C_i = the total number of individuals captured at night i and R_i = the number of previously marked animals in C_i. This analysis was performed for each species. If $\Sigma R_i = 0$ in this analysis was impossible, the number actually caught was used. Any animals found dead in the traps were subtracted from M_i for successive nights and animals marked in a previous trap session were treated the same as new animals, i.e., they were treated as if newly marked the first time they were captured during a given session. (For a complete discussion of the Schnabel analysis, see Tanner [1978].)

In order to compare the results of each trap sessions between communities, the results of each session were reduced to a diversity index $H = \frac{1}{\Sigma P_i^2}$ where P_i = the proportion of the community composed of the ith species (Simpson 1949; Peet 1974). This formula is most sensitive to

Table 6.7 Mammals Observed at Chaco Canyon National Monument

Common Name	Latin Name
Desert cottontail	Sylvilagus audubonì*
Black-tailed jack rabbit	Lepus californicus
Colorado chipmunk	Eutamias quadrivittatus*
White-tailed antelope squirrel	Ammospermophius leucrus*
Rock squirrel	Spermophilus variegatus
Gunnison's prairie dog	Cynomys gunnisoni
Botta's picket gopher	Thomomys bottae*
Silky pocket mouse	Perognathus flavus*
Plains pocket mouse	Perognathus flavescens*
Ord's kangaroo rat	Dipodomys ordii*
Banner-tailed kangaroo rat	Dipodomys spectabilis
Western harvest mouse	Reithrodontomys megalots*
Canyon mouse	Peromyscus crinitus*
Deer mouse	Peromyscus maniculatus*
Pinyon mouse	Peromyscus truei*
Northern grasshopper mouse	Onychomys leucogaster*
Stephen's woodrat	Neotoma stephensi*
Bushy-tailed woodrat	Neotoma cinerea*
Porcupine	Erethizon dorsatum
Coyote	Canis latrans
Kit fox	Vulpes macrotis
Grey fox	Urocyon cineroargenteus
Badger	Taxidea taxus
Bobcat	Lynx rufus
Mule deer	Odocoileus hemionus

*Species trapped in study, other seen only.

Common and Latin names from Findley et al. (1975).

changes in communities where most species are common. The greatest changes are in population levels of the component species. Two additional characteristics of the mammal communities were also calculated. These were richness (R) or the number of species captured and evenness (J) which is the ratio $H/_{H'}$ where $H' = \text{antilog} (- \Sigma P_i \log P_i)$ (Peet 1974). Both of indices provide an estimate of the numbers of species with equal population size that would have to be in a community to yield the same probability of predicting which species would be represented by the next capture.

The diversity indices from each area were compared using a single factor of analysis of variance (Socal and Rohlf 1969); significance is implied where $p < .05$.

Results

The trap results, based on the Schnabel analysis, are presented in Tables 6.8-6.12. The Bench generally had the fewest species as well as the lowest overall populations on the grid. The total figure for May 1980 was equal to that from Casa Chiquita during April 1980, but a series of assessment lines (O'Farrel et al. 1978) at these two grids during June 1980 indicated that while the Casa Chiquita grid and the Wash grid each sampled areas of approximately 2.3 ha, the Bench grid sampled more than 9 ha. In short, the Bench sample was at an even lower population density than the data indicate.

In numbers of species and diversity of mammals, the Pinyon-juniper woodland was consistently highest, although overall population levels were not as high as at Pueblo Bonito. The Pinyon-juniper transect was also outstanding in that it contained several species that were absent or uncommon in the other habitats. Colorado chipmunks, Stephens' woodrats, bushytail woodrats, and pinyon mice were most common in this habitat, although all but bushytail woodrats were caught at other locations as well. Grasshopper mice and silky pocket mice were missing altogether from this habitat; plains pocket mice, Ord kangaroo rats, and western harvest mice were uncommon in Pinyon-juniper.

The two floodplain sites, Casa Chiquita and Pueblo Bonito, had the most uniform population levels and species composition (with the exception of September 1979 at Pueblo Bonito where deer mouse numbers were very high). A paired-T test for differences between means on diversity indices at these two sites revealed no significant differences between the two areas ($T = -1.4698$, ns). The same test on overall mouse populations showed that Pueblo Bonito was significantly higher in total population ($T (.05,4) = -3.2906$ $.05 > \alpha > .02$), even though diversity was the same.

The differences in the species lists at these two areas may be somewhat misleading. The only species indicated at Pueblo Bonito and not at Casa Chiquita is the white-tailed antelope squirrel. This species, frequently seen at both areas, only entered traps on one occasion at Pueblo Bonito. Two species, pinyon mice and Stephens' woodrat, were encountered at Casa Chiquita but not at Pueblo Bonito. The pinyon mouse was captured

Table 6.8 Estimated Mammal Populations for the Bench Area

Species	Date				
	4/79	6/79	10/79	5/80	8/80
P. maniculatus	3.0	4.5	5.8	11.2	2.7
P. crinitus	7.3	4.0	9.0		1.0
R. megalotis					1.0
O. leucogaster				1.0	
N. stephensi			1.5		
D. ordii			1.0	1.0	5.5
P. flavus				11.6	3.0
A. leucurus				1.0	
E. quadrivittatus	2.0			1.0	
Total	12.3	8.5	17.3	26.8	14.2
Numbers of species	3	2	4	6	6

Table 6.9 Estimated Mammal Populations at Casa Chiquita

Species	Date				
	11/78	6/79	9/79	4/80	8/80
P. maniculatus	20.8	24.2	20.3	16.7	11.9
P. crinitus	1.0		1.0		
P. truei					1.0
R. megalotis	1.0				
O. leucogaster		1.0	2.0	2.0	2.0
N. stephensi					1.0
D. ordii	9.5	2.0	2.4	7.3	9.7
P. flavus					1.0
P. flavescens		1.0	1.0		1.0
Total	33.3	28.2	26.7	26.0	28.6
Number of species	4	4	5	3	7

Table 6.10 Estimated Mammal Populations at Pueblo Bonito

Species	Date				
	10/78	5/79	9/79	3/80	8/80
P. maniculatus	17.2	13.8	44.8	26.0	18.2
P. crinitus	6.0	1.0	2.0	2.0	
R. megalotis	2.0	2.0		2.0	3.0
O. leucogaster	2.0	4.0	3.0	4.0	1.0
D. ordii	3.8	9.3	5.5	7.7	7.3
P. flavescens	10.3	6.5	1.0		1.0
P. flavus	6.0		1.0	1.0	1.0
A. leucurus			7.0		
Total	47.3	36.6	64.3	42.7	31.5
Number of species	7	6	7	6	6

Table 6.11 Estimated Mammal Populations in the Pinyon-Juniper Woodland

Species	Date			
	5/79	8/79	11/79	4/80
P. maniculatus	15.2	19.0	12.6	18.0
P. crinitus	8.6	10.8	13.5	9.7
P. truei	5.0	4.8	2.0	2.0
R. megalotis	1.0			
N. stephensi	1.0	4.8	2.0	3.0
N. cinerea	1.0	2.0	1.0	
D. ordii		2.0	4.0	1.0
P. flavescens		1.0		1.0
A. leucurus		2.0		
E. quadrivittatus	1.0	3.0	2.0	16.2
Total	32.6	49.3	37.1	49.9
Number of species	7	9	7	7

Table 6.12 Estimated Mammal Populations in the Wash Area

Species	Date				
	4/79	7/79	10/79	5/80	7/80
P. maniculatus	21.8	16.2	39.9	18.5	16.5
P. crinitus	1.0		1.0		
R. megalotis	3.0		4.0	4.0	3.0
O. leucogaster			2.0		2.0
N. stephensi		1.0			1.0
D. ordii	1.0	4.0	6.8	10.0	9.3
P. flavescens			5.0		9.0
P. flavus					1.0
Total	26.8	21.2	58.7	32.5	41.8
Number of species	4	3	5	3	7

once, during late summer, and was probably a dispersing individual from a nearby area containing juniper trees. The woodrat also appeared during August 1980, but was caught several times, and appeared to be a resident. The common species were common in both areas. At the Pueblo Bonito grid there was an open area of grassland (without an equivalent at Casa Chiquita), which was regularly occupied by silky and plains pocket mice. These species were probably more abundant near Casa Chiquita in open habitat than they were on the more brushy trap grid.

The Wash was occupied by a mammal community very similar to that of the floodplain sites. The Wash was probably the most interesting site during the study, due to the fact that it was subjected to flooding during January 1979, followed by a period of severe cold which appears to have killed most of the small mammals from this habitat. When I trapped the Wash transect the first time in April 1979, the grid area was devoid of grasses and many of the shrubs that are typically abundant. The mouse community consisted of one Ord's kangaroo rat, three western harvest mice, one canyon mouse (on the floodplain), and 22 deer mice. Following this session I trapped assessment lines around the grid and found that many of the deer mice and the one Ord's kangaroo rat previously caught on the grid had home ranges that extended well outside the Wash onto the floodplain. This implies, that by the time I trapped there, recolonization was in progress albeit at an early stage. In July 1979 there were fewer deer mice, four new Ord's kangaroo rats, and a Stephens' woodrat; the harvest mice were missing. By October it appeared that the full complement of important species had returned, although the community was dominated by deer mice that accounted for nearly 70% of the individuals captured. During this session an early blizzard struck and many mice were killed in traps. This may at least partially account for the again depauperate community found in the Wash during May 1980. Conditions had returned to a high level of diversity by July 1980.

All five grids were tested for differences among diversity indices, which are graphed for each area in Figure 2.1, by a single factor analysis of variance (Socal and Rohlf 1969). There were no significant differences between areas ($F = 2.6524$, $0.10 > p > .05$) although p is very close to significance. The sample size was very small however, $n_j = 5$ and 4 and $n_i = 5$. With a larger sample it is likely that discernible differences between areas will appear.

Discussion

The population patterns for each species at the five study sites are shown in Figures 6.2-6.4. The distribution of the mammal species suggests that there are three mammal communities at Chaco Canyon: Pinyon-juniper woodland, rock grassland, and the Wash complex (including floodplain). The rock grassland community on the Bench appears to act as a sink for excess production at other areas in the monument. There was little evidence of reproduction in this habitat and population increases seem to follow increases in other habitats. Furthermore, the sex ratio in this habitat is heavily biased toward males when a particular species becomes abundant. Third, in most cases there has been very low survivorship from

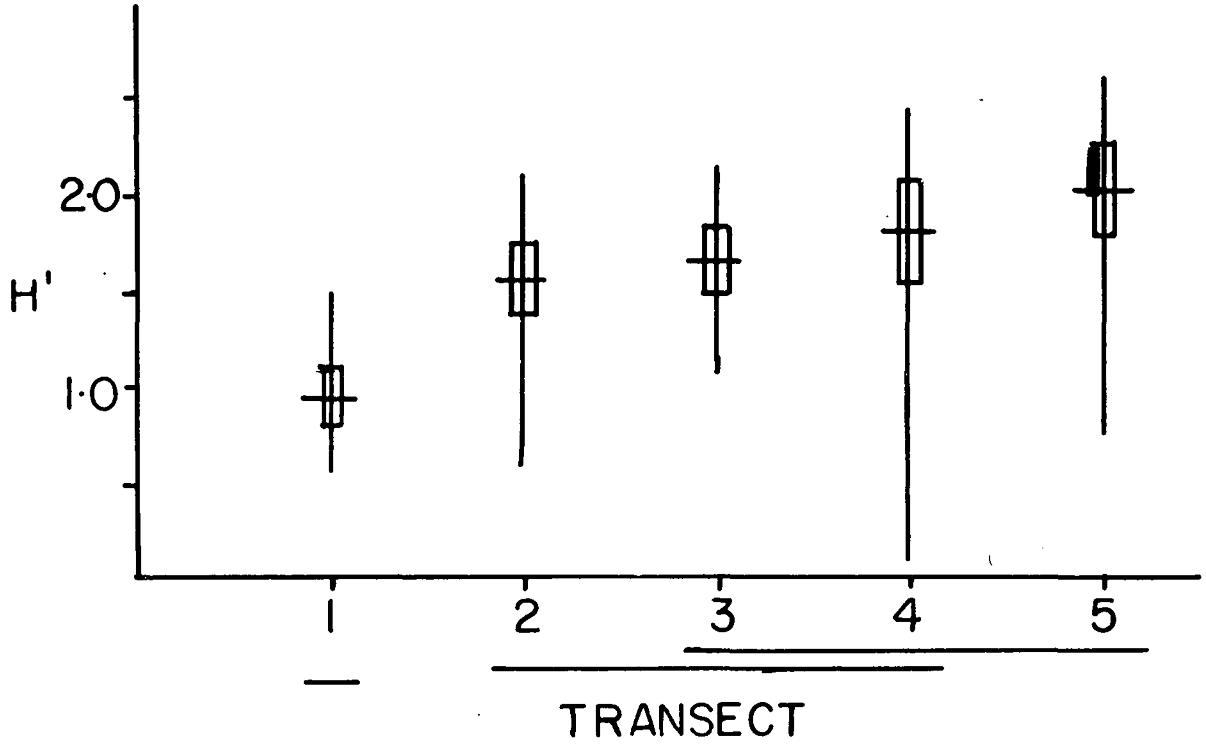


Figure 6.1 Diversity (H') of birds at the five transects at Chaco Canyon. The vertical line represents the range; the rectangle is the mean ± one standard deviation, and the horizontal line is the mean. The transect number and the number of censuses were: (1) Bench n = 11; (2) Pueblo Bonito n = 19; (3) Casa Chiquita n = 18; (4) Pinyon-juniper n = 13; (5) Wash n = 16.

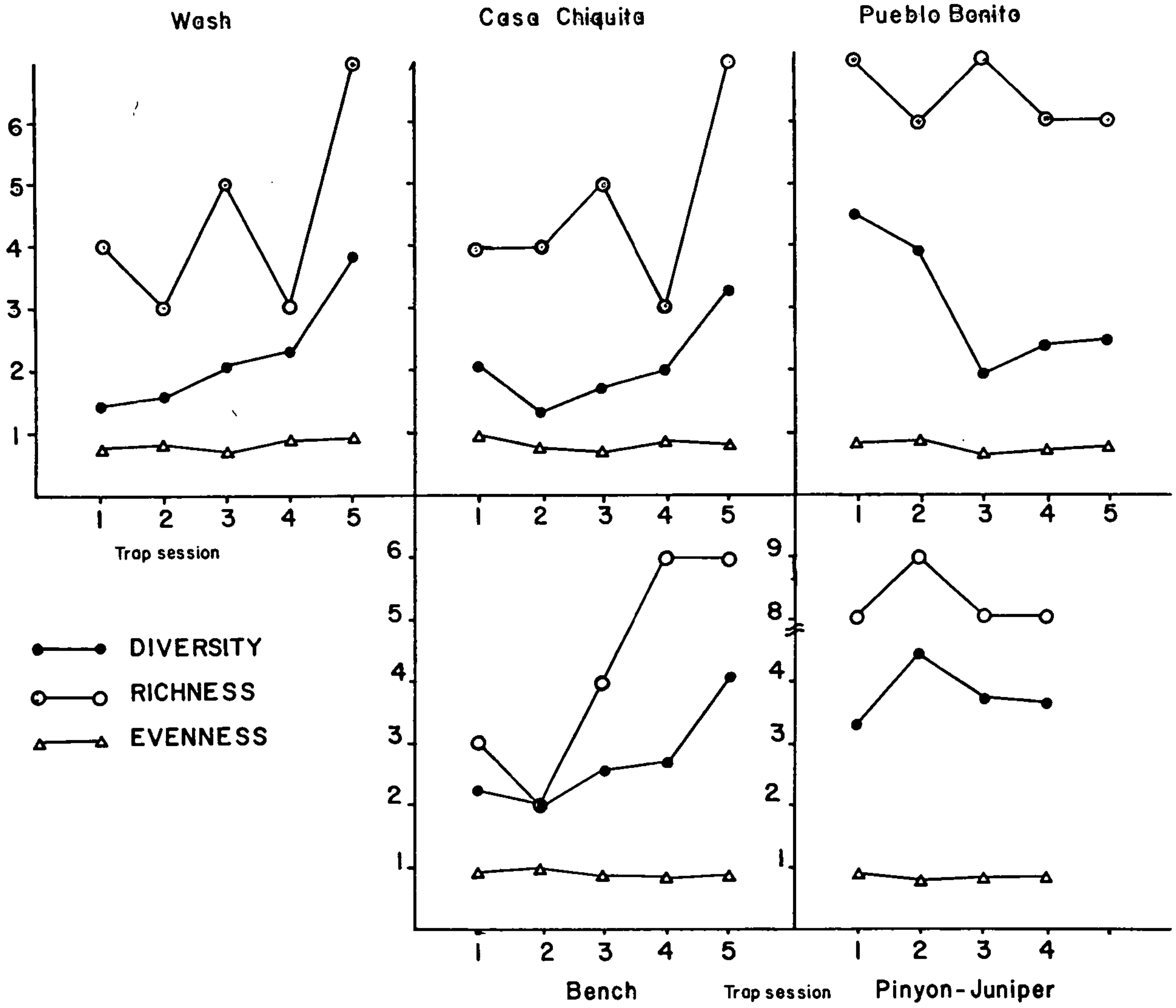


Figure 6.2 Diversity indices of each site showing the relationship of diversity to richness and evenness

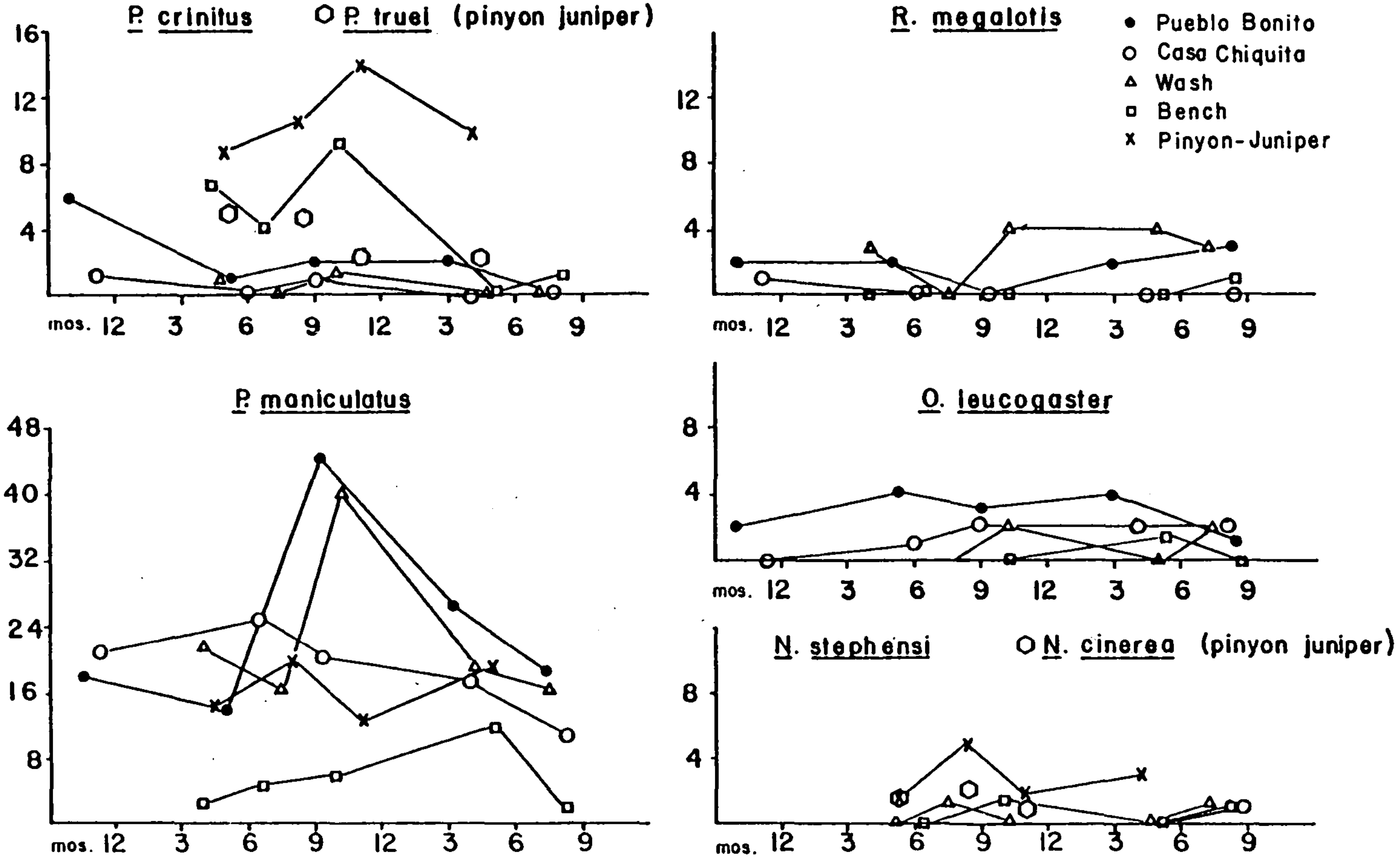


Figure 6.3 Populations of cricetine rodents at the five trap sites

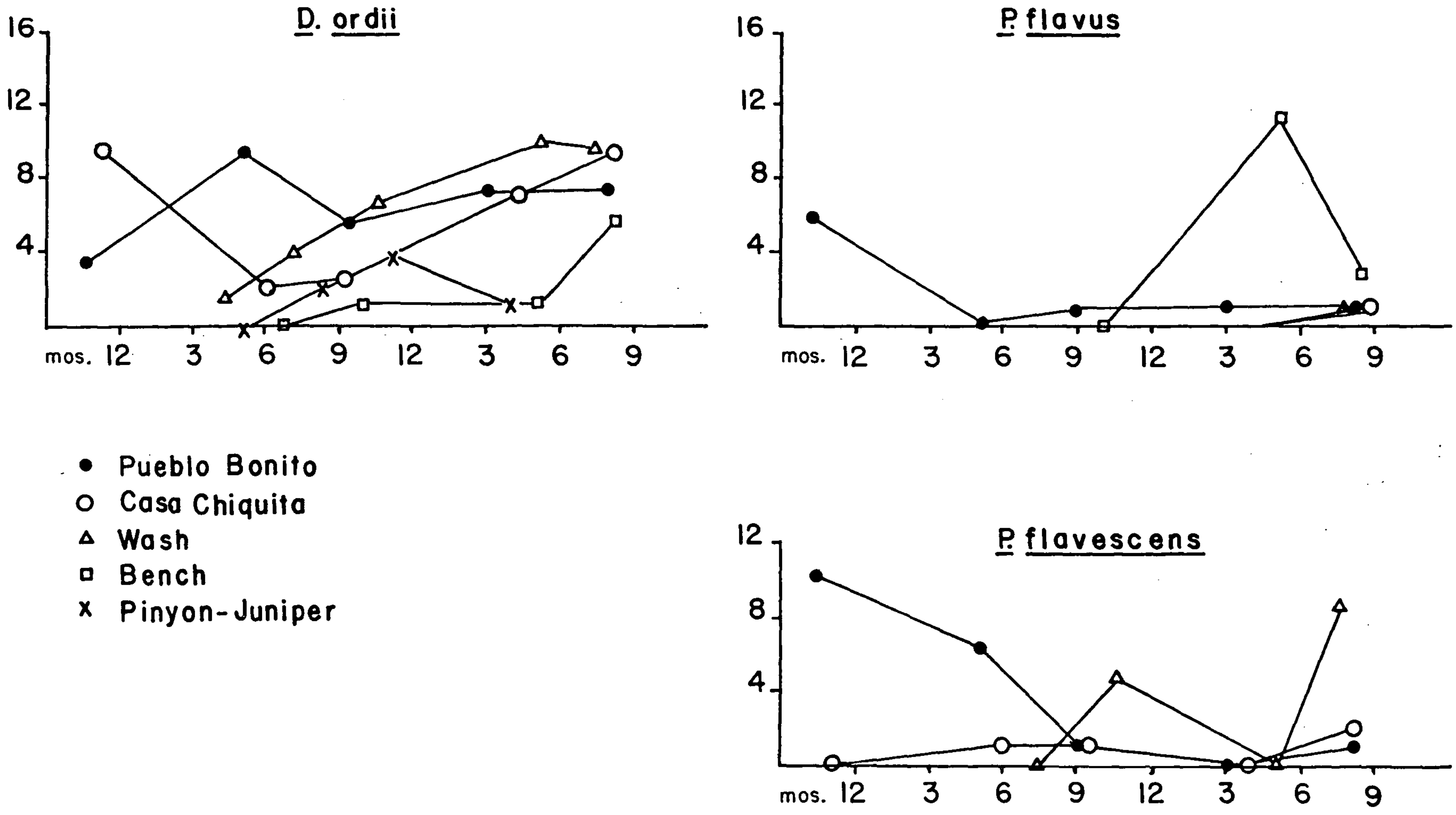


Figure 6.4 Populations of heteromyid rodents at the five trap sites

one trap session to the next compared to survivorship rates at the other trap areas.

The Pinyon-juniper woodland community supports predominantly cricetines and sciurids. Population densities in this habitat are generally intermediate between the Wash complex and the rock grassland. The low numbers of heteromyids probably reflect the limited soil depth in this area. Much of the surface is exposed sandstone.

The Wash complex is characterized by a mix of heteromyid, cricetine, and sciurid rodents. Deer mice and western harvest mice reach their highest numbers in this habitat as do Ord's kangaroo rats and grasshopper mice. The latter two species are grassland types, however, as are silky and plains pocket mice both of which do well outside of shrub communities. I have not sampled the shrub grassland communities outside of the canyon, so it is possible that grasshopper mice and heteromyids reach higher densities there than in the Wash complex.

The diversity index was a useful tool for describing bird communities at Chaco Canyon, and with a larger sample size it might be a useful for mammals as well. Mammal communities are far simpler at Chaco than are bird communities, at least in terms of species number. If the assumption made in the preceding sections of this report holds, i.e., that the diversity index represents an underlying resource base, it should be possible to be even more precise in detecting changes in mammal than the bird communities.

Birds are highly mobile and occur at densities one tenth as great as mammal densities. They also have considerably lower reproductive potential than mammals and probably experience high mortality rates during migration. These considerations may hamper a bird's ability to track environmental changes. Mammals cannot leave when conditions are bad, and some, at least, have the capacity to reproduce very quickly when conditions are favorable. The period of the study has been characterized by tremendous climatic variability. In 1979 the spring was very wet and annual plant production was tremendous in all habitats (Cully and Cully, this volume). The next year was extremely dry and there was almost no annual plant growth. Mammal populations responded to the climatic changes with very fast population and diversity adjustments of their own. Inter-habitat differences are not shown by the diversity indices because the temporal variance within zones resulting from these climatic gyrations is great enough to hide any inter-habitat differences that exist. In a period of less extreme climatic fluctuation, mammal diversity should provide a more accurate measure of ecological conditions than does bird diversity.

Conclusions

The sampling of birds and rodents at Chaco Canyon suggests that there are three major habitat related communities: (1) the Wash-floodplain complex, (2) the Pinyon-juniper woodland; and (3) the rock-grassland of the Bench. The analysis of variance of diversity indices at the five study sites was significant for birds but not for mammals. The lack of significant differences among habitats for mammals is a result of the within-habitat population change that followed tremendous annual plant productivity in 1979. With an additional one or two years of sampling, these differences would probably become significant. Bird diversity did vary among habitats despite the changes in annual plant productivity. Bird populations were considerably lower than mammal populations, and since birds do not possess the capacity to track environmental variation to the same degree as mammals, their within-habitat variance was low compared to the between habitat variance; consequently, the differences in bird diversity among habitats were significant.

The high temporal variance in populations of both birds and mammals suggests that there are no easy ways to monitor underlying changes in the ecology of a diverse area. The fact that the communities in different habitats are shown by differences in the diversity indices, after only two years with highly variable rainfall and plant productivity, suggests that a diversity index may be a useful tool for detecting basic ecological changes. Studies of three years or longer will probably be required to be able to see such changes.

References Cited

Cully, J.F., Jr.
1981 Baseline Biology of Birds at Chaco Canyon National Monument, New Mexico: Communities of Four Habitats.

1984 A Multivariate Analysis of Niche Relationships Within a Nocturnal Rodent Community in Northwestern New Mexico. Unpublished Ph.D. Dissertation, Department of Biology, University of New Mexico, Albuquerque.

Findley, J.S., A.H. Harris, D.E. Wilson, and C. Jones
1975 Mammals of New Mexico. University of New Mexico Press. Albuquerque.

Hill, M.O.
1973 Diversity and Evenness - A Unifying Notation and Its Consequences. Ecology 54(2):427-432.

Hubbard, J.P.
1978 Revised Checklist of the Birds of New Mexico. New Mexico Ornithological Society Publication 6. Albuquerque.

Kelley, E., and L.D. Potter
1974 Preliminary Vegetation Type Map of Chaco Canyon. Ms. on file, Division Cultural Research, National Park Service, Albuquerque.

O'Farrel, M.J., D.W. Kaughman, and D. Landahl
1977 Use of Live Trapping with the Assessment Line Method for Density Estimation. Journal of Mammalology 58:575-582.

Peet, R.K.
1974 The Measure of Species Diversity. Annual Review of Ecological Systems 5:285-307.

Pielou, E.C.
1974 Population and Community Ecology. Gordon and Breach, New York.

Rotenberry, J.T., R.E. Fitzner, and W.H. Rickard
1979 Seasonal Variation in Avian Community Structure. The Auk 96:499-505.

Schmidt, C.G.
1976 Summer Birds of the San Juan Valley, New Mexico. New Mexico Ornothological Society Publication 4. Albuquerque.

Shannon, C.E., and W. Weaver
1963 The Mathematical Theory of Communication. University of Illinois Press, Urbana.

Simpson, E.H.
1949 Measurement of Diversity. Nature 163-688.

Socal, R.P., and F.J. Rohlf
1969 Biometry. W.H. Freeman and Company, San Francisco.

Tanner, J.T.
1978 Guide to the Study of Animal Population. University of Tennessee Press, Knoxville.

Tramer, E.J.
1969 Bird Species Diversity: Components of Shannon's Formula. Ecology 50:927-929.

Zar, J.H.
1974 Biostatistical Analysis. Prentice Hall, Englewood Cliffs.

Chapter Seven

Prehistoric Faunal Utilization in Chaco Canyon Basketmaker III Through Pueblo III

by

Nancy J. Akins

Introduction

Animal procurement involves a number of scheduling and decision-making processes as well as detailed knowledge of the surrounding environment. Understanding these processes and how they relate to other aspects of a system can be obtained only through detailed studies.

While the preservation of faunal remains at Chaco Canyon is generally good to excellent, the range and quality of faunal reporting has varied. Pepper (1920) mentioned a few exotic species in room by room descriptions of his finds at Pueblo Bonito. Judd (1954 and 1959) provided lists of the species identified and ethnographic observations on the use of some taxa. The trend of reporting lists of species continued with few exceptions through the 1960s. Quantification of any kind was almost totally absent including a general idea of the sample size involved. Dutton (1938) recovered "a considerable amount" of bone from Leyit Kin and Hibben "several thousand" from Bc 50 (1937).

The stabilization efforts of the National Park Service in the 1950s and 1960s (and even today) are no better. The reports are largely unpublished and when faunal identifications were made these often did not appear in the final report (Vivian and Mathews 1965; Voll et al. n.d.). Although L. Hargrave made a valiant attempt to identify all of the bird remains recovered, his efforts rarely resulted in even a species list. An exception is the unpublished report on the bone and feathers from Bc 288 (McKusick 1971a) which not only included counts by provenience but notes on the taxa recovered and some comparisons with other Chacoan sites.

With the present focus on adaptation and subsistence in archeology, the Chaco Project recognized the importance of complete analysis of the faunal remains. The excavation of a number of small sites dating from Basketmaker III through Pueblo III and portions of two greathouses provides the data necessary to look at adaptations through time and differences in subsistence between large and small sites in Chaco Canyon.

This report begins with a short description of each excavated site that is considered followed by a section on methodology. The taxa recovered, their availability, uses, and habits precede a section on processing and, finally, the changes in distributions and regional comparisons.

The Sample

Thirteen of the sites tested or excavated by the Chaco Project are considered in this overview. While most of these tend to be Basketmaker III and Pueblo II there is a range both spatially and chronologically. The next section will briefly describe the work done at the site and present observation on factors that may have affected the faunal sample. Detailed reports on the faunal remains from each site are on file at the National Park Service, Albuquerque office, and some may appear as appendices to site reports (Akins 1981a, 1981b, 1981c, 1981d, 1981e, 1981f, 1981g, and 1982b; Gillespie 1979, 1981a, 1981b, 1981c).

Basketmaker III - Pueblo I Sites

29SJ 423. This site is the furthest west of the sites and contains the earliest excavated Basketmaker III deposits in the canyon. Three "pithouses", three cists, and a Basketmaker great kiva were tested or excavated, but little screening was done. The fill was generally shallow and rested on bedrock resulting in the worst preservation of any tested site. The poorly preserved site yielded a large number of unidentifiable fragments and more burned bone than most of the other sites since burning tends to preserve bone. A total of 1,946 bones were analyzed.

29SJ 299. Located near Fajada Butte, 29SJ 299 is predominately a Basketmaker III site, but also contains a Pueblo I component and an intrusive Pueblo II kiva. The Basketmaker excavations included three pithouses with associated storage structures; those of the Pueblo I component revealed a pithouse, four surface rooms, and a ramada. Screening was not done. Only 318 bones were recovered, of which a fair number were rodent species. The lack of trash excavated at the site may be partially responsible for the small amount of bone.

29SJ 628. The best sample from a Basketmaker III site comes from one located in Marcia's Rincon. Six pithouses, most of which were trash-filled, a series of surface cists, and trash deposits were excavated. A sample of 4,997 bones was recovered and analyzed. Although screening was not carried out, some elements from small rodents were recovered.

29SJ 721. Located just east of Werito's Rincon, excavation at this site included two pithouses, six cists, a Pueblo I room, and a Pueblo III kiva. Screening was not done at the site; only 26 bones were recovered.

Shabik'eshchee Village. This was the furthest east of the tested sites. A pithouse was mostly excavated and another trenched. The trash fill produced a fair sample (339) of bone for a limited excavation. Preservation was good, but screening was not done, which appears to have biased the sample in favor of large mammals.

29SJ 724. Excavation at this Pueblo I site, located near 29SJ 721, included a pit structure, ten surface rooms, a trash area, and exterior features. Although screening was not carried out, several small taxa were recovered in the sample of 470 bones.

Pueblo II - Pueblo III Sites

29SJ 627. Another Marcia's Rincon site, this was the largest of the small sites excavated. Seven pit structures, 25 rooms, an extensive trash mound, and numerous exterior features were encountered. Occupation dates range from the late A.D. 700s into the early 1100s. The first season's excavations were not screened, but the second's were. A good sample of bone was recovered (6,752) and analyzed.

29SJ 629. Also located in Marcia's Rincon, excavation at this site included two pithouses, nine rooms, a kiva, a trash midden, and exterior features. The site material was screened, some even fine screened, and resulted in the recovery of 2,818 bones.

29SJ 1360. Located near Fajada Butte, this Pueblo II site was not screened and produced few bones for the amount of work. Two kivas, approximately nine rooms, a test through the trash, and numerous plaza features were excavated. The relative abundance of large mammal versus small mammal bones in this sample of 708 bones suggests that the collection strategy had a greater effect on this sample than any other site.

29SJ 633. The only late Pueblo III site tested is this one located in Marcia's Rincon. One and a half rooms were excavated and screened producing a sample of 3,912 bones.

Una Vida. This greathouse site was subjected to an unusual sampling procedure. Portions were originally excavated by Gordon Vivian in the early 1960s, but little information was recorded. Before backfilling, the floors of the rooms were recleared to note the features. In doing this, a number of unexcavated features and lower floors were investigated (Akins and Gillespie 1979) resulting in a sample of bones from the earliest portion of the site. A total of 3,374 were recovered and analyzed. Screening and fine screening was done.

Pueblo Alto. Extensive excavations were carried out at Pueblo Alto. Approximately 10% of the site was excavated or tested, resulting in the recovery of approximately 50,000 bones of which 30,509 were identified and reported. Pueblo Alto was the only site where all of the bone recovered was not analyzed. The trash mound and Kiva 10 were sampled and an exterior trench was not examined. The sample from the trash mound included only the "booths" which were carefully excavated columns. Material from the main trench and slump were not identified.

The Pueblo Alto deposits range in time from before construction of the greathouse to the latest occupation. Preservation was excellent and screening or fine screening was done throughout the site.

29SJ 390. The walls at this small ruin, located near Pueblo Alto, were outlined to determine the plan. These activities resulted in the recovery of a small number of bones (33) which were identified. No screening was done.

Several factors contribute to the faunal samples above. The location of the site has an effect on preservation as well as its post-occupational use by animals and humans in historic times. The density of the site occupation, site size, and length of occupation affected the rate of deposition as would changes in depositional practices through time. Excavation techniques, particularly screening and excavation limited to architectural features, may have a significant effect on some samples. The recovery of a fair number of rodent bones in some of the unscreened sites suggest care was taken.

Methodology

A computer format was developed to utilize the information generated by the faunal analysis. All but four of the sites (29SJ 390, 29SJ 629, 29SJ 633, and 29SJ 721) were computerized to provide a detailed permanent record of each bone.

Mammal and turkey identifications were made at the National Park Service, Albuquerque office, using skeletons recovered from the excavated sites, road kills, or other collected specimens for comparison. Those elements that were not identifiable with this collection were taken to the Museum of Southwestern Biology (University of New Mexico Biology Department) where the identifications were completed using comparative specimens from as close to Chaco as possible. Bear and wolf elements were compared with specimens at the Field Museum of Natural History in Chicago when local examples were not available.

Birds, other than mature turkeys, were identified by Charmion McKusick (most of 29SJ 628) and Steve Emslie (Museum of Northern Arizona - all other sites). Dr. John Applegarth (University of New Mexico) identified the herpetological materials and Dr. William Koster (University of New Mexico emeritus) the two fish bones.

The Coding Format

A number of variables were recorded and used to analyze the sites.

Provenience Coding. The format for the provenience coding is a condensed version of the project's inventory recording system. It includes a site code; the general provenience unit (for example, Room 3); the general level category (fill, floor fill, roof fill, etc.); a floor indicator (floor 3); the layer-level number; the level characteristic (aeolian, trash, occupational surface, etc.); the feature category (test pit, firepit, etc.) the feature number; and the feature level category (fill, floor, etc.). The format allows fine or broad comparisons within a site.

Classification. A hierarchical recording system, with a four-digit number indicating an identification to the species level, three to the generic level, and two to the order, was developed. If none of these could be assigned, an unknown category was chosen. The alternatives for the unknowns were small to medium mammal, rodent, medium mammal, artiodactyl, medium to large mammal, bird, or unknown.

Skeletal Element. Skeletal element identifications were detailed. Those that could not be exactly determined were classified as precisely as possible (i.e. vertebra, longbone, etc.). Articulated skeletons were recorded as one element and articulated body parts (feet, vertebrae, etc.) were recorded by skeletal element and the articulation noted in a separate variable.

The Portion Represented. To ensure that the MNI (minimum number of individuals) counts generated by the computer were accurate, the portion represented was specific. Alternatives ranged from complete or mostly complete to a variety of fragmentations designed for either paired or axial elements.

Side. Axial was used to record the skull and vertebral elements. All others were sided if possible (left, right, or unknown).

Age. Five age groups were considered: fetal or very immature, immature, young adult, adult, and older adult. The first was composed of elements from animals that had not yet reached 1/3 of mature size, immature as elements 1/3 to 2/3 of adult size, young adults as elements that were almost or adult in size, but which did not yet have their epiphyses fused. Older adults were recorded when recognized, usually on the basis of extreme tooth wear. Few prey species live long enough to become arthritic. The few arthritic elements were recorded as pathologies. An isolated bone with such evidence could also be traumatic in origin and not an indication of age.

These definitions undoubtedly lead to some difference in the aging of body parts from a single individual since epiphyseal union is not uniform.

Method for Assessing Age. This variable was recorded for the nonadult options. The best and the most commonly used were size and epiphyseal union. Immature animals often have lighter and more porous bones, so this criterion was applied to elements with no epiphyses and those too incomplete to be sized.

Butchering. The kind and location of butchering were recorded. Variables for the former include the portion removed by a diagonal cut and the portion removed by a straight cut, chopping, light cuts or scratches, and heavy cuts or scratches. The location was abbreviated to proximal, distal, midshaft, and combinations of these. Little butchering was noted from the sites.

Checking. Bones exposed for a period of time exhibit small cracks and flaking called checking. The degree was recorded to acquire information on the rapidity and origin of refuse deposition. At Pueblo Alto evidence of checking was found most often in the plaza (24.7% of the bones were checked) and the wall clearing proveniences (28.1%) as compared to structures (5.6%) and trash deposits (7.2%). The trash mound had slightly more (8.2%) than the trash-filled structures (5.2%). When the body size of the animal was considered the amount increased with the size of the animal: rodents 2.0%, small mammals 5.0%, medium mammals 15.7%, large mammals 24.5%, small birds 3.8%, raptors 4.6%, and turkey 10.1%.

Burning. The extent of burning and color of the burn were noted. The amount was recorded as complete, partial, very slight, and calcinated and the degree or color as white, black, gray, brown, or "cooking brown."

Bone can become burned through cooking, from discard into a firepit, or from boiling; at some sites it may also be due to depositional conditions. The latter will affect all bones of a certain size within a unit, while the former results in only some bone discoloration.

At Pueblo Alto the occupational fill (ashy) of firepits contained 44.4% unburned, 41.2% completely burned, 2.8% partially burned, 2.5% slightly burned, and 9.5% "cooking brown" bone (n=284). Heating pits or baking pits yielded 40.0% unburned, 28.3% completely burned, 1.2% partially burned, 1.6% very slightly burned, and 28.3% "cooking brown" bone (n=191). The firepits at 29SJ 627 had a pattern very similar to the firepits at Pueblo Alto (50.0%, 36.0%, 0.7%, 0.0%, and 13.2% respectively; [n=136]). The heating pits, however, contained almost no bone (n=3) and none was burned. The burned bone found in the firepits and heating pits features has implications for other kinds of deposits. Proveniences with large amounts of burning may suggest firepit or feature dumping while those with far less would indicate a mixture of activities.

Animal Activity. Rodent and carnivore gnawing were monitored to determine whether either kind of disturbance had taken place at a site.

Evidence of Use. Bones were occasionally used without modification. This activity was recorded here rather than treating each as a tool.

Miscellaneous Observation. Several infrequently occurring conditions were recorded as present or absent, e.g., purple staining, pigment stains, and rounding. The former is a condition of deposition. The latter can result from the movement of bone in soils, cooking, or from passing through the digestive tracts of humans, carnivores, or turkeys.

The final variables recorded pathologies, articulations, the number of fragments with that identification (allowing for more than one bone to be recorded per line), the field specimen number, and the individual specimen number.

Analytic Technique

The method of analysis varied from site to site and according to the analyst. In general, the site excavator was asked to divide the site into logical units for comparison and from which the MNIs were calculated. Several provenience units (i.e., levels within a structure, adjacent grids from a plaza or trash midden, etc.) were often lumped to keep the distinction from being so fine that the number of bones in any one unit was very small. The computerized sites were tabulated using SAS utility progress (Helwig and Council 1979) to make detailed comparisons of such variables as burning, checking, and animal activity on a provenience and taxon basis.

The MNIs for small sites were determined using a SAS SORT procedure or the bones themselves. For larger samples MNIs were calculated by the computer. A program written by Alan Rogers (then of the University of New Mexico) tabulated the number of proximal, distal, and shaft portions for each side and age of all longbones plus various fragmentations of the skull, mandibles, scapulae, and innominates. Each combination of skeletal element, fragmentation, and side was compared to determine which contributed the largest MNI for that taxon. The immature elements and complete skeletons were taken into account. An accurate MNI for the artiodactyl and carnivore species was considered so important that taxa were always hand-checked by comparing and matching elements.

The three sites analyzed by Gillespie (29SJ 629, 29SJ 633 and 29SJ 721) were not computerized. The same information was recorded, but it was not always included in the reports.

Definition of Some Commonly Used Terms

The term "element" is used to indicate a single item whether it is a complete bone, a fragment of bone, or an articulated skeleton. Skeletal element is used to denote a particular part of the body (radius, ulna, etc.).

The NISP is the number of identified specimens per taxon. The total NISP or total elements is the sum of the taxa (i.e., the entire sample). A taxon (plural taxa) is a taxonomic unit and may refer to a species, a genera, a family, or even an unknown category depending upon the context.

In this report, MNI generally refers to the site MNI. This figure results from taking the entire site sample as one unit to calculate a MNI. By definition the site MNI is the absolute minimum MNI for a site. Presumably, the actual number of individuals for a taxon lies between the site MNI and the NISP. Any other MNI calculation using provenience units or other aggregates is an estimate falling between these two. Thus, the estimated MNI refers to an estimate based on a particular set of provenience units or aggregates. An important point regarding the estimated MNI is that changes in the aggregates used can alter even an ordinal ranking of taxa (Grayson 1981; Lyman 1982).

The Taxa

A large number of taxa have been recovered from excavations in Chaco Canyon. The mechanisms by which many of these came to be deposited in archeological sites are often as important as the presence. Many have arrived by natural processes such as burrowing into abandoned sites or were left by raptors or carnivores. When these are human in origin, the relative frequency, use, distance of transport, and processing are the important factors. Information on these mechanisms is not obtainable through species lists.

For ease of presentation the discussion has been divided into mammalian, avian, and herpetological taxa. Included with each are tables that give the presence/absence distributions culled from the reports, archives, and notes listed in Table 7.1 and the Chaco Project reports on file at the National Park Service, Albuquerque office. A short section on each taxon will give the distributions, availability, and possible use as well as comments regarding how some came to be found in archeological contexts.

Mammals

Table 7.2 shows that at least 43 species of mammals have been recovered from archeological sites in Chaco Canyon. Many are rodent species that were only occasionally exploited as food animals. The most consistently reported species--rabbits, prairie dogs, deer, antelope, and mountain sheep are those which contributed the most to subsistence.

Bats

Myotis californicus. Bats are rarely recovered from archeological sites. The California myotis specimens from Pueblo Alto were found articulated just above the floor of an interior room. These were presumably roosting when either the roofing timbers were removed or their means of entry was blocked. It is a crevice and cave dwelling species that is locally common in grasslands and deserts through the ponderosa pine zone (Findley et al. 1975).

Antrozous pallidus. The pallid bat is a desert species common to areas where desert terrain meets rock outcroppings (Findley et al. 1975). They are most frequently observed from May through September and their presence in a deposit could be an indicator of spring to early fall deposition. The single element from this species was found in a pithouse posthole at Site 29SJ 724.

Rabbits

Sylvilagus auduboni. The majority of the cottontail rabbits represented in archeological collections from Chaco Canyon are of this species which is found in the canyon area today (Cully, this volume; Findley et al. 1975). Species determination for cottontails is difficult and best determined by plotting the mandibular cheek tooth row against the depth of the dentary (Findley et al. 1975). This was done for most of the recently excavated sites and nearly all those measured were in the range of *S. auduboni*. The postcranial elements have been assumed to represent this species. Cottontail bones were the most numerous of the identifiable elements at many of the recently excavated sites. Burning was often higher for this taxon than any other.

Sylvilagus nuttalli. Nuttal's cottontail does not occur in the immediate area today and it is unlikely that it did prehistorically. It

Table 7.1 Source Information for the Earlier Excavated Sites

Site	Excavation Date	Excavation By	Report	Information	Mammal ids.	Bird ids.	n=	Comment
Pueblo Bonito	1896-1899	AMNH Pepper	1920 Pepper	occasional comment by room				exotics only
Pueblo Bonito	1921-1927	USNM Judd	1954 Judd	species list	Miller, Kellog, Shamel, Johnson	Wetmore -------		good ethnographic comments
			1962b Hargrave	MNI, el., p.		Hargrave		
Pueblo del Arroyo	1923-1926	USNM Ruppert	1959 Judd	species list	Johnson, Setzer	Wetmore, Friedman		species form "local trash"
Shabik 'eshchee	1926-1927	USNM Roberts	1929 Roberts	species list	Wetmore, Shamel	Wetmore, Shamel		artifacts only
			n.d. McKusick	species, el. count				artifacts only
Chetro Ketl	1920-21	SAR-UNM	1960a Hargrave	ids, el., p.		Hargrave	13	bird only
	1929-34	Hewitt	1939 Kluckhohn and Reiter	presence	unknown			
(in	1934-1936	SAR-UNM Dutton	1938 Dutton	species list	Wetmore	Wetmore		"a considerable amount"
			1962 Hargrave and Dodgen			Hargrave reexamined	48+	5 new species added
Bc 50	1936	UNM Brand	1937 Hibben	# of bones, p. *	Wetmore	Wetmore -------		"several thousand" * for 935 ided. specimens
			1960b Hargrave			Hargrave		previously unidentified
			n.d. McKusick	species, counts				
Bc 51	1937	UNM Brand	1939 Kluckhohn and Reiter	additions to the Bc 50 species list*	Allen	Allen -------	3,824	percentages were so similar to Bc 50 that they are not given
			1960c Hargrave	species, el., p.		Hargrave	15	artifacts only
Bc 53	1940 1941	UNM Roberts	1965 Vivian and Mathews	species list		Hargrave		birds only
			n.d. McKusick	species list			14	
Bc 54	1941	UNM	1941 Bullen	species, percentages			@ 146	mammals only
Half House	1947	UNM Reiter	1951 Adams	species, el.-	Burt	Hargrave	33m 6b	
Bc 59	1947	UNM Mathews						herps only-ided. by J. Applegarth
THE FOLLOWING ARE FROM NPS SALVAGE OR STABILIZATION PROJECTS								
Pueblo del Arroyo	1950	Vivian	n.d Hargrave	species, el. p.		Hargrave		bird only
Bc 51	1950	Vivian, Rixey	1960c Hargrave	species, el. p.		Hargrave		bird only
			n.d. McKusick	species, count			50b	
Kin Kletso	1950-1952	Vivian, Rixey,	1965 Vivian and Mathews	presence/absence	Mathews ?	Hargrave		fish by R. Gehlbach
		Mathews, Breternitz,	1963 Hargrave	species, el. p.				
		Rickert	n.d. McKusick	mammal presence/absence bird counts			60+	
Bc 236	1958	Bradley	n.d. Bradley	species, counts	Turney	Hargrave	57b 268m	counts were omited from later versions
			1959a Hargrave	species, el. p.				
Talus Unit	1959	Shiner	1959b Hargrave	species, el., p.		Hargrave	98+	bird only, some turkey was not kept
Bc 192	1960	Maxon	n.d. Maxon	species, el.	Turney	Turney	590	some mistakes in ides. were noted and corrected (NJA 1981)
Una Vida	1960	Vivian	1961a Hargrave	species, el., p.		Hargrave	73+	bird only
Bc 362	1962	Voll,	n.d. Voll	species list		Hargrave		bird only
		Richert	n.d. McKusick	species, counts			53+	
Chetro Ketl	1964	Voll	1964a Hargrave	species el., p.		Hargrave	15	bird only
			n.d. McKusick	feathers		McKusick	36b,	14 feathers
Casa Chiquita	1964	Voll	1964a Hargrave	species, el.		Hargrave	3	birds only
Bc 288	1966 1967	Morris Abel, Mayer, Buckingham	1971a McKusick	species, el. p, notes on the collection	McKusick	McKusick	2226 feathers 27 b 301 m	includes artifacts

el = element
p = provenience
b = bird
m = mammal
ided = identified

Table 7.2 Distribution of Mammal Taxa from Chacoan Sites

												I------Chaco Project Excavations------I														
	BONITO	d ARROYO	CHETRO K	K KLETSO	LEYIT K	HALF H	SHABIK V	Bc 50	Bc 51	Bc 54	Bc 192	Bc 236	Bc 288	UNA VIDA	P ALTO	SHABIK V	299	390	423	627	628	629	633	721	724	1360
Bats																										
Myotis californicus (California myotis)															X											
Antrozous pallidas (pallid bat)																									X	
Rabbits																										
Sylvilagus auduboni (desert cottontail)	X	X	X	X	X		A	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Sylvilagus nuttalli (Nutall's cottontail)					X			X	X						X											
Lepus californicus (black-tailed jack rabbit)	X	X		X	X	X	A	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Lepus americanus (snowshoe hare)															X											
Rodents																										
scurid (squirrel)					X				X			X		X	X					X	X		X			
Ammospermophilus leucurus (antelope ground squirrel)															X							X				
Spermophilus variegatus (rock squirrel)				X		X							X		X						X	X				
Cynomys gunnisoni (Gunnison's prairie dog)				X	X			X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Sciurus aberti (Abert's squirrel)														X	X											
Thomomys sp. (pocket gophers)					X							X														
Thomomys bottae (Botta's pocket gopher)				X				X	X		X			X	X	X	X			X	X	X	X		X	X
Perognathus sp. (pocket mice)														X	X		X		X	X	X	X			X	
Perognathus favensis (plains pocket mouse)																	X					X	X		X	
Perognathus flavus (silky pocket mouse)																						X				
Dipodomys ordii (Ord's kangaroo rat)				X								X		X	X	X	X		X	X	X	X	X		X	
Dipodomys spectabilis (banner-tailed kangaroo rat)															X		X			X	X	X	X			
Castor canadensis (beaver)	X	X																								
Reithrodontomys megalotis (western harvest mouse)															X								X			
Peromyscus sp.												X	X	X	X	X	X		X	X					X	
Peromyscus maniculatus (deer mouse)								X	X													X				
Peromyscus boylii (brush mouse)													X													
Onychomys leucogaster (northern grasshopper mouse)														X	X							X	X			
Neotoma sp. (woodrats)			X	X									X	X	X	X	X		X	X	X	X	X		X	
Neotoma cinerea (bushy-tailed woodrat)				X									X	X	X	X	X		X	X	X	X			X	
Neotoma stephensi (Stephen's woodrat)															X						X	X				
Neotoma albigula (white-throated woodrat)													X		X											
Neotoma mexicana (Colorado woodrat)					X			X	X																	
Microtus sp. (voles)													X													
Microtus mexicanus (Mexican vole)															X											
Erethizon dorsatum (porcupine)	X			X											X							X				
Carnivores																										
Canis sp.				X		X				X	X	X	X		X	X	X		X	X	X	X	X		X	X
Canis latrans (coyote)	X	X		X										X	X		X		X	X	X	X	X		X	X
Canus lupus (wolf)															X					X		X				
Canis familiarus (domestic dog)	X	X			X			X	X		X				X	X	X		X	X	X	X				X
Vulpes vulpes (red fox)	X																			X						
Urocyon cinereoargenteus (gray fox)	X				X		A								X				X	X	X			A	X	
Ursus sp.			X																							
Ursus americanus (black bear)	X																				X					
Ursus arctos (grizzly bear)	X								[X]						X	X			X							
Taxidea taxus (badger)	X	X		X			A	X	X						X		X			X	X	X	X			X
Felis concolor (mountain lion)	X																					A				
Felis rufus (bobcat)	X	X		X			A	X	X			X	X	X	X	X	A		X	X	X	A	X		X	
Artiodactyls																										
Cervus elaphus (elk)	X	X			X		A		X						X				X	X	X	X				
Odocoileus hemionus (mule deer)	X	X		X	X		A	X	X	X	X	X	X	X	X	X	A		X	X	X	X	X		A	X
Antilocapra americana (pronghorn)	X	X		X	X		A	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X		X	X
Bison bison (American bison)			X																							
Bos taurus (domestic cow)				X									X													
Ovis canadensis (mountain sheep)	X	X						X	X			X	X	X	X	X	X		X	X	X	X	X			X
Ovis/Capra (domestic sheep or goat)															X		X	X								

A = artifacts only
[ ] previously unreported

is an upland species that reaches its lower limits in well developed pinyon-juniper woodlands and in mesic, well vegetated valleys (Harris 1963). Those found at Chaco were probably imported. The closest area of procurement, assuming a range similar to that today, would have been the Chuska Mountains (Findley et al. 1975).

A single specimen from Pueblo Alto was suggested by plotting the mandibles from that site. Others have been reported from Bc 50, Bc 51, and Leyit Kin. The criterion used to determine the species for these is unknown, however, reexamination of those from Bc 50 (Gillespie, personal communication 1979) suggest that they were predominately all adults or juveniles that are S. auduboni.

Lepus californicus. The black-tailed jack rabbit occurs throughout the San Juan Basin and has been reported within the park area by Cully (this volume). It is most common in open shrub and shrub-grasslands with a tendency to concentrate in areas where local rains have resulted in lush vegetative growth (Findley et al. 1975). Another of the commonly utilized taxa, it had a high rate of burning in the recently excavated sites.

According to McKusick (n.d.), Lepus townsendi has been identified from Kin Kletso. Slightly larger and heavier that the black-tailed jack rabbit (Bailey 1931), it occurs in sage plains of the upper Rio Grande Valley from Taos north as well as in the open parkland on top of the San Juan Mountains (Findley et al. 1975). Considering the present range of this species it more likely represents a large Lepus californicus.

Lepus americanus. The snowshoe hare is a mountain forest rabbit that is definitely not local to Chaco Canyon. Bailey (1931) gives the New Mexico range as along the Sangre de Cristo Mountains on both sides of the Pecos River down to Santa Fe, and down the San Juan and Jemez ranges west of the Rio Grande. It inhabits dense spruce-fir forests and is seldom seen.

This species is between a cottontail and jack rabbit in size and was recognized by a single mandible from Pueblo Alto. Harris (1963) found several elements from snowshoe hares in the Navajo Reservoir District archeological collections and noted that they were probably long distance imports from higher elevations. Both finds suggest that the snowshoe hare was circulated among the Anasazi, probably as a curiosity.

Squirrels

The squirrels are difficult to distinguish and it is usually possible to identify species only from the mandibular and maxillary elements. There can be problems when an analyst is located far from where the collection was made. Comparative specimens should be from the same area as the collection. Identification made on the basis of size may be in error if specimens from another environmental zone are used.

Ammospermophilus lecurus. The antelope ground squirrel is common in the canyon today. Cully (this volume) trapped it in bench, pinyon-juniper woodlands, and Pueblo Bonito. The small size makes it an unlikely food source. They may have been attracted to the Anasazi fields and gardens where considerable damage could be done to planted and ripening grains. Procurement may have been by trapping as part of a pest removal process. Two Chacoan sites contained this species. Both were recently excavated and screening may be the chief factor in recovering the small bones.

Spermophilus variegatus. Rock squirrels are found in the canyon today (Cully, this volume), especially in broken terrain and rock areas (Findley et al. 1975). Bailey (1931) suggests that these, too, are agricultural pests in areas where fields are in close proximity to the preferred habitat. The larger size of this squirrel would make them a more worthwhile food source.

Unfortunately only the mandibular and maxillary elements are readily identified to the species level. The post-cranial skeleton is so similar to Cynomys and the other squirrels that separation is difficult and rock squirrels are quite likely under-represented in the site totals.

Cynomys gunnisoni. Gunnison's prairie dog is the third most common small mammal found in the Chaco Canyon archeological collections. It is present in the area today and has been found articulated in some sites. In general, the use of this species by the Anasazi increased steadily throughout the occupation of the canyon. This may have been the result of an increase in field areas that provided more habitat or a human response to decrease in local populations of cottontail and jack rabbits. Its frequent appearance in sites and the fact that it is a hibernating species make it a valuable indicator of seasonality.

Sciurus aberti. The Abert's tassel-eared squirrel is confined to ponderosa or mixed conifer forests containing ponderosa pine (Findley et al. 1975). The closest available to Chaco are in the Chuska Mountains, the Zuni Mountains, Mt. Taylor, or the San Juan Mountains and would have required transport from a fair distance. It has been reported from only two sites, Pueblo Alto and Una Vida.

Scurids. Other species of squirrels present in the canyon today, including Eutamias quadrivittatus (the Colorado chipmunk) and Spermophilus spilosoma (the spotted ground squirrel), have not been positively identified in the archeological collections. This may be partially due to the similarity of the post-cranial elements to those of the antelope ground squirrel. In the recently excavated sites, these were generally recorded as scurid.

Spermophilus tridecemlineatus was reported in the Leyit Kin collections (Dutton 1938). The thirteen-lined ground squirrel is common only in the shortgrass plains of the northeastern portion of the state. They are not found in the San Juan-Chaco drainage or anywhere north of the Datil Mountains (Findley et al. 1975). Their limited range and the fact that squirrel species are difficult to distinguish suggest that the identification (made at the U. S. National Museum) is possibly an error.

Other imported squirrels that were not identifiable to the species level may be present in the collections.

Rodents

Thomomys bottae. Botta's pocket gopher is probably the only *Thomomys* represented in the archeological collections. None of the others occurs in the area. (Cully this volume) has trapped this taxon within the park. Bailey (1931) noted that they are generally valley dwellers partial to sandy soil and can be particularly destructive to agricultural crops. The small size of this rodent and its preference for underground living (Harris 1963) make it unlikely that it was routinely hunted. Trapping to protect fields is a more reasonable alternative. It has been found in most of the sites where rodent recovery is reported and has occurred as complete or nearly complete post-occupational burrowers.

Perognathus. *Perognathus flaveacens* and *Perognathus flavus* are present in Chaco Canyon today and have been trapped near Pueblo Bonito (Cully this volume). Weed seeds are the principal components of their diet and they were probably of little consequence as an agricultural pest (Bailey 1931). A large number have been found as articulated post-occupational burrowers in sites. Burned bones of this species are very uncommon.

Dipodomys ordii. Ord's kangaroo rat, one of the most common and widespread desert rodents in New Mexico (Findley et al. 1975), is partial to friable soils such as those found in archeological sites. Examples have been recovered in the majority of the the sites where collection procedures were such that rodents were collected. Their principal food is wild seeds, but they may do minor damage to crops (Bailey 1931). Even though a few have been burned, their small size makes it unlikely that they were pursued as a food item.

Dopodomys spectabilis. The banner-tailed kangaroo rat is larger and would have been a more reasonable food source. Few bones of this species are found in archeological sites even though they are present today (Cully, this volume). It is a strictly nocturnal species (Bailey 1931) which may be one reason it was seldom utilized.

Castor canadensis. The beaver has been reported from only two Chacoan sites, Pueblo Bonito, and Pueblo del Arroyo. At one time beaver lived along most permanent streams in the state (Bailey 1931) and the archeological specimens are most likely from the San Juan River or its tributaries. These animals may have been prized for pelts, a commodity that would rarely leave faunal remains since they were most likely processed near where they were obtained.

Reithrodontomys megalotis. The western harvest mouse is found in most habitats throughout New Mexico (Cully, this volume). They are seed eaters and ground dwellers and are often found in the grassy or weedy borders of fields. Few have been recovered in the Chaco sites but some of this could be attributed to the close similarity between this species and *Peromyscus*.

Peromyscus. Peromyscus crinitus (the canyon mouse), Peromyscus maniculatus (the deer mouse), and Peromyscus truei (the pinyon mouse) are present in the canyon today (Cully, this volume). Their food consists mainly of seeds, grain, berries, insects, and even fresh meat. Bailey observed that possession is quickly taken of any available cover. "The scattered grain and bits of food about camp apparently deceived them into thinking they had found a permanent food supply" (1931:145).

Large numbers of articulated skeletons were recovered in the more carefully excavated sites. The distribution at Pueblo Alto suggests they inhabitated the site with humans and chose to live in areas where food was stored, processed, or consumed. Complete or nearly complete articulated skeletons were found in floor fill proveniences 34.6% of the time and in features 46.7% (n=67). Over half were associated with the upper or latest floors of structures. The small size and nocturnal habits of these mice further suggest that their presence in sites was incidental.

Peromyscus elements were generally not identified to the species level.

Onychomys leucogaster. The northern grasshopper mouse is also widespread in the state. It was trapped by Cully in all but the pinyon-juniper woodland locales in the canyon (this volume). The diet of this nocturnal mouse is insectivorous and carnivorous. Again, their presence at a site is most likely incidental. Skeletally they are very similar to Peromyscus and are probably more common than Table 7.2 would indicate.

Neotoma cinerea. The bushy-tailed woodrat is the largest of the woodrats and the only one that is readily identifiable. Cully trapped these in pinyon-juniper locales (this volume) and Bailey (1931) captured one at Pueblo Bonito. Bailey believed they were probably a serious pest for the food-storing aborigines. Many of those found in archeological contexts may have been disposed of as pests but were occasionally eaten.

Neotoma stephensi. Both Bailey (1931) and Findley et al. (1975) note Stephen's woodrats' preference for rock accumulations in the pinyon-juniper zone. It is present in the canyon today (Cully, this volume), but has been specifically identified in a few sites. Because it is similar in size to the following two woodrats, all but the dental elements were recorded as Neotoma sp.

Neotoma albiqula. The white-throated woodrat was not sighted or trapped in Chaco Canyon by Cully (this volume). Findley et al. (1975) found them to the northeast and 15 miles east of Crownpoint. They inhabit open areas from desert to mixed conifer forests and coexist with Neotoma stephensi. Archeologically they were found in only two sites, Pueblo Alto and Bc 288.

Neotoma mexicana. The Colorado woodrat is primarily a montane species that is most abundant in mixed conifer forests or in mesic locations at lower elevations (Findley et al. 1975). The three sites for which this species was identified were all analyzed by Wetmore at the U. S. National Museum and are possible misidentifications.

Microtus mexicanus. The Mexican vole is one of the more unusual finds. The habitat of this vole is said to be montane grasslands in ponderosa and mixed conifer forests, occasionally descending to pinyon-juniper woodlands (Findley et al. 1975). The closest recorded presences are around Thoreau and Cottonwood Gulch (Findley et al. 1975). An articulated skeleton and a partial skull were recovered outlining walls at Pueblo Alto and an unspecified Microtus was found at Bc 288. It is clearly out of place according to the descriptions, however shallowly buried and multiple specimens suggest it may have been present in the canyon or was deposited by wide ranging carnivores or raptors.

Erethizon dorsatum. Although they are present in the area today (Cully, this volume), porcupine bones are relatively uncommon in the Chaco sites occurring only at Pueblo Bonito, Kin Kletso, Pueblo Alto, and 29SJ 629. The sparse distribution suggests a use other than food.

Carnivores

Canis letrans. Coyotes are present in the canyon today and have been recovered from most of the archeological sites studied. They are most numerous in the earlier sites and are occasionally burned.

Canis lupus. Wolf elements have been reported in only three archeological collections, all from recent excavations. Although Bailey (1931) shows the 1917 distribution for this species as extending quite close to Chaco, it was either seldom utilized or the elements were deposited outside the site.

Canis familiarus. Domestic dog remains were found at many of the sites. The articulated skeletons and larger numbers are found mainly in Pueblo II village sites. Few elements were recovered from Pueblo Alto, and the majority of those came from wall clearing activities.

The distribution suggests that the purpose served by these animals changed. If their main function had been to aid hunters, then a reduced reliance on the species hunted with dogs may have limited their usefulness. On the other hand, if it was primarily to drive other carnivores away and warn the populace of the approach of visitors, changes in architectural plans, such as enclosing of plazas many have reduced the need.

Vulpes vulpes. The red fox has been reported for a few Chacoan sites. According to Bailey (1931) this species was trapped in the Farmington to Shiprock area in the early 1900s; however, Findley et al. (1975) note that a mountainous habitat is generally preferred suggesting that the elements found were probably imported.

Urocyn cineroargenteus. The gray fox is present in Chaco today (Cully, this volume) and occurs in a fair number of archeological sites. Fox skins are used in Pueblo ceremonies (Bradfield 1973); this species was the most readily available of the foxes.

Ursus americans. Although not native to the immediate area, the black bear could have been found in any of the mountain regions ringing the San Juan Basin. It is not as common as the grizzly bear in Chacoan archeological collections. The elements recovered are generally parts that indicate the use of the pelts and claws, possibly for ceremonial occasions. Judd (1954) reports finding the claws secreted in the wall of a kiva at Pueblo Bonito. A complete mandible was found at Bc 51 during the stabilization of Room 147 in 1950.

Ursus arctos. The range of the grizzly bear is similar to that of the black bear including many of the mountain areas surrounding the San Juan Basin. The distribution in Chaco sites is interesting. It includes two greathouses (Pueblo Bonito and Pueblo Alto) and two Basketmaker sites (29SJ 423 and Shabik'eshchee Village). Both of the latter have great kivas suggesting that more ceremonialism may have taken place.

The distribution of elements, broader for grizzly bears than for black bears, includes a distal humerus from Pueblo Alto, a metapodial from 29SJ 423, and a tibia and possibly a rib from Shabik'eshchee. The same niche at Pueblo Bonito that contained claws from a black bear also had a "considerable number" of grizzly claws and phalanges.

Taxidea taxus. Badgers are found throughout the state in all climates and physiographic regions. Their numbers are greatest where prairie dogs and other burrowing rodents are plentiful. They have a rank odor and put up a fight when cornered (Bailey 1931), yet are one of the more common carnivores and the only mustelid found in archeological sites.

The Hopis claim that badgers raid cornfields, and if the damage becomes too bad, they are killed. They are regarded as a medicine animal because of their digging habits and are associated with "below" (Bradfield 1973).

Felis concolor. Although mountain lions are generally found in forested mountains or rock-rimmed canyons and cliffs, they wander considerable distances and have been recorded well out on the plains and in open valleys. Their range primarily depends upon a supply of game (Bailey 1931). The distribution in Chaco includes only two sites, Pueblo Bonito and 29SJ 629. The element from the latter (a claw) was an artifact. Those from Pueblo Bonito were claws found in the same kiva niche that also contained claws from the black bear and the grizzly bear.

Felis rufus. Bobcats are still common in Chaco (Cully, this volume) and are one of the more frequently recovered carnivores in the archeological sites. The distribution tends to follow that of the coyote and domestic dog, with more occurrences in the earlier sites.

Artiodactyls

Cervus elaphus. The range for elk or wapiti includes montane grasslands in most of the montains surrounding the San Juan Basin (Findley et al. 1975). Considering the distance that had to be traveled to collect this species, it is relatively common and consistent in its presence.

Odocoileus hemionus. Mule deer can be found in Chaco Canyon as well as throughout the San Juan Basin. Deer were utilized as a food source throughout the time sequence and most intensely during late Pueblo II (Gallup Black-on-white ceramic associations). A single element from *Odocoileus virginianus* (the white-tailed deer) was reported for Bc 288 (McKusick 1971b). Examination of the specimen suggests that it was in the size range of mule deer and a misidentification.

Antilocapra americana. The preferred habitat of pronghorn is open grassland basins and plateaus with adjacent rolling hills (Buechner 1950). Bailey (1931) has stated that they were abundant over the great arid plains of northwestern New Mexico as late as 1883. The distribution is limited by the availability of standing water (Haley 1965). Pronghorn remains are found in as many archeological sites as are mule deer. There appears to have been a greater use of this species in the earlier sites.

Bison bison. The only mention of bison from Anasazi sites in Chaco comes from Brand (1937:64) who states that a few bones have been reported from Chetro Ketl. Where these were found and by whom is not known, so given that the range of bison is a considerable distance from Chaco and that only one report exists, it may be an error in identification. Reports of bison bones in the Four Corners area include Spruce Tree House (Reed 1955), Badger House, and sites 1644 and 1676 (Hayes and Lancaster 1975) at Mesa Verde, and Morris Site 41 along the La Plata River (Reed 1955). The Zuni obtained bison products from the Plains by way of Pecos Pueblo (Reed 1955), leaving open the possibility of long distance transport.

Bos tarus. One element of a domestic cow was recovered from Bc 288. McKusick (1971b) notes that it was apparently deposited subsequent to the main occupation.

Ovis canadensis. Although mountain sheep are now confined to high rugged mountains, their range was probably much greater prehistorically (Manville 1980). They have been found in almost every recently analyzed Chaco site suggesting that they were readily available within the Basin and probably not far from Chaco. By the end of the time sequence its importance as a food item overtook that of pronghorn.

Ovis/Capra. Intrusive domestic sheep or goat bones were found at three of the recently excavated sites. These were generally in the upper fill of structures.

The most obvious differences in species distribution that can be seen in Table 7.2 are the result of sampling. Rodents occur far less frequently in the earlier excavated sites. Ten of the 26 rodent taxa do not appear at all, and 10 others are found in one or two of the 13 sites. These were simply not recovered with the excavation methods common before the 1960s. Otherwise the difference on a presence/absence basis can be accounted for by sample size and, to some extent, identification methodology. It has been demonstrated time and again that the larger the sample size the more species are present (Grayson 1981; Wing and Brown 1979). Since the greathouse sites have had larger excavations and presumably larger samples it is not surprising that they have more species identified and appear to be more diverse.

Birds

The number of bird taxa recovered from the Chaco collections is almost as large as that of the mammals. Table 7.3 lists the occurrences and the common names. The information from the earlier excavated sites is of a much better quality than that for mammals. Lyndon Hargrave made an effort to locate and identify all bird remains taken from Chaco, even the small numbers recovered in stabilization activities. Memos reporting the identifications and an archeo-ornithology file have survived and give complete and accurate identifications for a large number of sites.

The uses of birds by the Anasazi fall into three categories: food, feathers for utilitarian purposes, and parts for ceremonial use. There are few specific references to the eating of birds in the Pueblo ethnographic literature, and it is quite likely that most of those from Chaco result from other uses. This is also suggested by the small number found. Compared to most mammals the frequencies and percentages are quite low (see Appendix 2); however, the Santa Clara (Hill 1982) ate ducks, geese, grouse, quail, and wild turkey. Feathers were a necessary ingredient for most offerings, and hunting was done with that in mind. With the exception of raptors, most birds were probably in direct competition with humans for wild and cultivated crops and may have been trapped or killed in that context. The use of feathers and bird skins for ceremonial purposes presents some problems. Curation and the possibility of trade make it difficult to infer seasonality even though many bird species are present in Chaco for a limited amount of time during the year.

The following descriptions rely heavily on Cully's (this volume) annotated list of birds from Chaco Canyon. He classifies these as resident (present year-round), a migrant (present for short periods during spring and/or fall), and summer or winter residents. Regular species are found every year and irregular every other year. Occasional species show up every three to five years and casual even less often.

Ducks and Geese

Anas platyrhnchos. The mallard is a casual migrant in Chaco Canyon (Cully, this volume) but a common migrant in the San Juan Basin. It migrates and winters throughout the state in suitable habitats (Hubbard 1978). Since it has been reported at only two sites, it may have been a trade item.

Anas acuta. The pintail is not listed by Cully (this volume) or in a checklist compiled at the park (Scurlock n.d.). It is the most widely distributed of the North American ducks and is abundant in the west. The

Table 7.3 Distribution of Bird Taxa for Chaco Canyon

																	I----Chaco Project Excavations----I											
	BONITO	dARROYO	CHETROK	TUNIT	UVIDA	KKLETSO	CCHIQ	LEYITK	HALFH	Bc50	Bc51	Bc53	Bc192	Bc236	Bc288	Bc362	UVIDA	PALTO	SHABIK	299	390	423	627	628	629	633	724	1360
Anatidai																										X		
Anas sp. (unidentified duck)																						X						
Anas platyrhynchos (mallard)							X											X										
Anas acuta (pintail)																X												
Anas americana (American widgeon)			X																									
Aythya americana (redhead)	X																											
Branta canadensis (Canada goose)																		X					A					
FALCONIFORMES																											X	
Accipitridae																		X										
Accipiter gentilis (goshawk)						X					X					A												
Accipiter cooperii (Cooper's hawk)				X																								
Buteo sp.							X				A				X			X				X	X	X	X	X	X	X
Buteo lagopus (rough-legged hawk)					X					A	X					A		X										
Buteo regalis (ferruginous hawk)	X		X	X	X			X			X	X				X		X					X	X			X	
Buteo jamaicensis (red-tailed hawk)	X	X	X	X	X			X		X	X				F	X		X						X	X		X	
Buteo swainsoni (Swainson's hawk)	X		X															X										
Aquila or *Haliaeetus* (eagle)																	X											
Aquila chrysaetos (golden eagle)	X		X	X	X	X		X		X	X	X			F	X	X	X					X		X	X	X	
Haliaeetus leucocephalus (bald eagle)																											X	
Circus cyaneus (marsh hawk)				X		X						X												X				
Falconidae																												
Falco sp.																						X						
Falco mexicanus (prairie falcon)	X	X	X			X					X			X	X									A				X
Falco sparvarius (American Kestrel)				X							X							X										
Meleagrididae																												
Meleagris gallopavo (turkey)	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X
Phasianidae																												
quail species												X		X				X				X				X		
Callipepla squamata (scaled quail)			X	X	X			X						X	X			X								X		
Gruidae																												
Grus canadensis (sandhill crane)	X				X	A					A	X						X		A			A	X	X			
Columbidae																												
Zenaida macroura (mourning dove)				X		X										X		X										
Ectopistes migratorius (passenger pigeon)					X																							
Tytonidae																												
Tyto alba (barn owl)					X																							
Strigidae																												
Otus asio (screech owl)	X														X			X										
Bubo virginianus (great horned owl)	X		X		X	X		X		X	X			X					A*				X			X		
Asio otus (long-eared owl)											X																	
Trochilidae (hummingbirds)																		X										
Psittacidae																												
Rhynchopsitta pachrhyncha (thick-billed parrot)	X				X																							
Ara sp.	X	X																										
Ara macao (scarlet macaw)	X	X	F			X																						X
Picidae																												
Colaptes auratus (common flicker)			F	X											F			X										
PASSERIFORMES (unidentified passeriform)				X		X											X	X										
Alaudidae																												
Eremophila alpestris (horned lark)				X										X			X	X	X				X			X		
Hirundinidae																												
Hirundinidae sp. (swallows)																		X										
Corvidae																		X										
Gymnorhinus cyanocephalus (pinyon jay)	X							X										X										
Pica pica (black-billed magpie)	X		X			X		X			X							X										
Corvus corax (common raven)	X	X	X			X		X			X	X	X					X	X	X			X	X	X	X		X
Icteridae (blackbirds and allies)																	X	X										
Turdidae																												
Turdus migratorius (American robin)					X																							
Sialia sp.																		X									X	
Sialia mexicana (western bluebird)																		X										
Sialia currucoides (mountain bluebird)																		X										
Laniidae																		X										
Lanis ludovicianus (loggerhead shrike)																		X										
Fringillidae																	X	X										
Junco hyemalis (slate-colored junco)																		X										
Pipilo erythrophthalmus (rufous-sided towee)																		X										
Pipilo chlorurus (green-tailed towee)																		X								X		

F = feathers only
A = artifacts only
*   identification by McKusick from Roberts collection

preferred habitat is marshes and winter freshwater marshes and lakes (Udvardy 1977). It migrates and winters mainly at lower and middle elevations statewide. Known breeding grounds close to Chaco include the Chuska Mountains and the Jicarilla Reservation. They have been recorded in the San Juan Valley in June (Hubbard 1978). This species was present at only one site.

Anas americana. The American wigeon inhabits marshy areas, tundra, and prairies. It winters mainly in tidal and valley marshes along the east, west, and gulf coasts (Udvardy 1977), but also migrates and winters statewide (Hubbard 1978). It has been identified only at Chetro Ketl by McKusick (n.d.) and is not listed in either of the available lists for Chaco Canyon (Cully, this volume; Scurlock n.d.).

Anas sp. A partial element of a teal duck was identified from 29SJ 423. Emslie (n.d.) notes that it falls within the size range of the green-winged teal (*Anas carolinensis*), the blue-winged teal (*Anas discors*), and the cinnamon teal (*Anas cyanoptera*). None of these has been observed in Chaco, but all migrate and summer almost statewide (Hubbard 1978).

Aythya americana. The redhead has not been observed in the canyon and is reported only from Pueblo Bonito (Judd 1954). Hargrave was unable to acquire the element(s) to confirm the identifications. Hubbard (1978) calls this species irregular on the Jicarilla Reservation in summer and occasional in the Chuska Mountains.

Branta canadensis. The Canadian goose is the only goose observed in the archeological collections. Cully (this volume) considers this species as a casual migrant. It migrates and winters almost statewide and a major population is found in the San Juan River Valley (Hubbard 1978). Elements were found at Pueblo Alto and in tool form at 29SJ 627.

Hawks and Eagles

Accipiter gentilis. The goshawk inhabits the Rocky Mountains into New Mexico. It migrates and winters in lowlands as far south as northern Mexico (Udvardy 1977). Although it is not listed in either Chaco list (Cully, this volume; Scurlock n.d.), it is a winter migrant to the San Juan Valley (Hubbard 1978).

Accipiter cooperii. Cully (this volume) lists the sharp-shinned hawk as an irregular migrant. It is resident in mountainous areas and migrates and winters statewide (Hubbard 1978). Elements of this taxon have been found only at Talus Unit.

Buteo lagopus. The rough-legged hawk is not mentioned by (Cully, this volume) but it migrates and winters almost statewide (Hubbard 1978). It is locally common in grasslands and open habitats mainly at lower and middle elevations. Today they are most numerous in the northeastern plains of the state. Some of the the archeological occurrences may have been as trade items.

Buteo regalis. Ferruginous hawks are regular to irregular residents of Chaco (Cully, this volume). They migrate and winter statewide and may breed within the canyon. It is the second most commonly recorded hawk in the archeological collections occurring throughout the time spectrum.

Buteo jamaicensis. The red-tailed hawk is the only species of hawk reported to be a regular year-round resident of the park (Cully, this volume); therefore, it is not surprising that this taxon is recovered more than any of the other hawks. They are quite numerous in sites dating from Basketmaker III through Pueblo III. An articulated skeleton was found on the floor of a room at Pueblo Bonito (Judd 1954).

Buteo swainsoni. Cully (this volume) does not list the Swainson's hawk, but Hubbard (1978) notes that it migrates and summers statewide. It was found in Pueblo Bonito, Chetro Ketl, and Pueblo Alto.

Aquila chrysaetos. The golden eagle is a regular, uncommon migrant to Chaco Canyon (Cully 1981). It is the most common of the raptors found in archeological sites and according to Vivian and Mathews (1965) they were the most popular of the wild birds among the Pueblos who kept them for their feathers.

The Zunis caught young eagles and kept them caged. The feathers were used in dances. The Hopis hunted and kept eagles for ceremonial purposes. Clans in each village owned the buttes on which they nested, some of which were 40 miles or more from the village. Adult eagles were captured and fleglings were robbed from the nest. Both were tethered on roofs and fed crushed meat. The feathers were plucked and used ceremonially. These were killed in late July, skinned, and the corpses were tossed into a fission in the rock or placed in a special graveyard (Beaglehole 1936); Bradfield 1973). John Bourke (around 1880) observed eagles kept at Zia, Santa Ana, San Felipe, Jemez, Taos, Picuris, and San Ildefonso. The Santa Clara buried the feathers in fields (Schroeder 1968).

At Pueblo Alto eagle bones were more numerous in the Early Pueblo II deposits (Red Mesa Black-on-white ceramic associations) than at any other site or time but still constituted a very small percent of the assemblage (1.5%).

Haliaeetus leucocephalus. The bald eagle is a rare migrant that probably occurs only occasionally (Cully, this volume). It migrates and winters almost statewide, mainly near water (Hubbard 1978). The single archeological occurrence was a talon found on the surface at 29SJ 724.

Circus cyaneus. Marsh hawks are regular, uncommon migrants and winter residents of Chaco Canyon (Cully, this volume). Four sites contained elements of this species.

Falco mexicanus. The prairie falcon is a regular, uncommon year-round resident of Chaco (Cully, this volume). While they have been recorded at a number of past excavations, very few have been found in the more recent ones. A partial skeleton was found in a kiva at Pueblo del Arroyo (Judd 1959).

Falco sparvarius. The sparrow hawk or American kestrel is a regular common summer resident (Cully, this volume). Much less common in archeological sites than the prairie falcon, it has been found in only three.

Turkeys

Meleagris gallopavo. The turkey is by far the most commonly recovered species of bird at Chaco. This has often led to the assumption that they were primarily of dietary importance. Ethnographic accounts left by the early Spanish visits to the Pueblos indicate that turkeys were kept mainly for their feathers (Bradfield 1973; Henderson and Harrington 1914; Schorger 1966). An economic argument can be made for Chaco. The native habitat of the turkey in New Mexico is along wooded streams in the mountains at elevations of 2286 m to 2926 m (7,500 to 9,600 ft), suggesting that those found in Chaco Canyon were domestic. Turkeys can be destructive to crops. It would have been necessary to contain them during the portion of the year when crops were raised, yet turkey pens are not a common feature of Chacoan sites. If turned out to forage for the remainder of the year, few could have been supported by the local vegetation and would have been in direct competition with human foraging. They also need water twice a day and cannot depend on dew and food as a source of water (Schorger 1966). Corn and water would have to have been provided to keep them alive. If turkeys were to be eaten, it would be more economical to import mature birds than it would be to raise them and feed them. There is some evidence of change in the utilization of this species, which will be detailed in a later section.

Quail

Callipepla squamata. Scaled quail are uncommon to common residents of the area. Cully (this volume) observed them most often in greasewood and saltbrush environs along the floodplain. They appear in numerous archeological sites but always in low numbers (one or two elements). If they were used as a food source it was only sporadically.

Cranes

Grus canadensis. The sandhill crane migrates almost statewide and is casual in the northwest part of the state (Hubbard 1978). Both the greater and lesser varieties have been identified in the archeological collections. They have been found in a fair number of sites and often only in the form of artifacts. The relative unlikelihood of occurrence in Chaco and the artifactual forms suggest these were imported.

Doves and Pigeons

Zenaida macroura. The mourning dove is a regular and abundant summer resident that nests in all habitats of Chaco Canyon (Cully, this volume). It is not common in archeological sites possibly because the gray and brown feathers were not particularly prized by the Anasazi. Henderson and Harrington (1914) note that mourning doves were used as food by the Tewas.

Ectopistes migratorius. The passenger pigeon has been identified from Una Vida by Hargrave (1964b) and confirmed by Wetmore. Now extinct, its former range was eastern North America (Bent 1932; Goodwin 1967). If correct, this may be one of the greatest long-distance transports yet recorded for Chaco. Elements from this species have also been recovered from Picuris Pueblo (Emslie 1983).

Owls

Tyto alba. The barn owl has been occasionally reported in the San Juan Valley, but is easily overlooked and may be resident almost statewide (Hubbard 1978). It has been found only at Una Vida.

Otus asio. Screech owls are resident in the south and northward to San Juan Valley and occur almost statewide. There is some suggestion of migration but no long distance movement (Hubbard 1978). A partial articulated specimen from Bc 288 (McKusick 1971a) suggests that it may have inhabited the canyon. Screech owl remains were found at Pueblo Alto and Pueblo Bonito also.

Bubo virginianus. The great horned owl is a regular uncommon year-round resident of the canyon (Cully, this volume) and the most common of the owls found archeologically. It occurred at eleven sites.

Asio otus. Long-eared owls, regular uncommon summer residents, are occasionally flushed from densely vegetated rincons or cottonwoods along the wash (Cully, this volume). They migrate and winter statewide and are known to breed near Farmington (Hubbard 1978). They have been found only at Bc 51.

Hummingbirds

A mandible from a hummingbird was found at Pueblo Alto. Three species are found at Chaco today: the black-chinned (*Archilochus alexandri*), a regular summer resident; the broad-tailed (*Selasphorus platycercus*), a common summer resident; and the rufous (*Selasphorus platycercus*), a regular uncommon fall migrant (Cully, this volume).

Parrots and Macaws

Rhynchopsitta pachyrhyncha. Remains of thick-billed parrots have been reported from Pueblo Bonito and Una Vida. The range for this species is the pine belt in the mountains of middle and northern Mexico (Judd 1954). They occur in far fewer numbers (three individuals) than the macaw and presumably were not as important. One articulated skeleton was buried at Pueblo Bonito (Judd 1954).

Ara macao and Ara sp. The scarlet macaw is a red, blue, and yellow bird that ranges from the hot tropical lowlands of southern Tamaulipas on the east coast of Mexico down through Central America to Brazil (Judd 1954).

Although Judd (1954) reports the presence of both the scarlet macaw and the military macaw (Ara migratorius), Hargrave's (1970) reexamination of the collections from Pueblo Bonito and Pueblo del Arroyo determined that only the scarlet macaw and undetermined macaw are present. The sole military macaw confirmed was from the southwest cave from the Mimbres area.

Hargrave (1970) reports 30 scarlet macaws and one undetermined macaw from Pueblo Bonito, three scarlet macaws from Pueblo del Arroyo, and one scarlet macaw from Kin Kletso. Scarlet macaw feathers were found at Chetro Ketl (McKusick n.d.). Recent excavations can add five elements of a macaw from 29SJ 1360, the first small site yielding macaw remains.

The majority of the macaws examined by Hargrave were either fledglings (11 or 12 months) or adolescents (1 to 3 years). One individual of advanced age was found at Pueblo Bonito. Apparently, these tropical birds did not fare well in the cold climate of Chaco. Constant plucking of feathers for ceremonies probably did not help the situation.

Woodpeckers

Colaptes auratus. The flicker is a regular uncommon migrant and winter resident of Chaco (Cully, this volume). It is represented by feathers only at Chetro Ketl and Bc 288 and by bones at Talus Unit and Pueblo Alto. The elements are from wings (three), and one from a leg suggesting the possibility that all were important for their feathers.

Passeriformes (small perching birds)

Eremophila alpestris. The horned lark is a regular abundant year-round resident of Chaco, living in the shrub-grasslands on top of the mesas and surrounding the canyon but rarely seen in the canyon itself (Cully, this volume). This small brown bird may have been considered a field pest and trapped in that context. It was recovered from a fair number of sites, mostly recent excavations.

Hirundinidae sp. A single element from a swallow was recovered from Pueblo Alto. Cully (this volume) found five species of swallow in Chaco today: the barn swallow (Hirundo rustiea), a regular spring migrant; the cliff swallow (Petrochelidon pyrrohonota), a regular abundant summer resident; the tree swallow (Iridoprocne bicolor), a regular spring migrant; the violet-green swallow (Tachycineta thalassins), an occasional spring migrant; and the bank swallow (Riparia riparia), an occasional migrant.

Gymnorhinus cyanocephalus. The pinyon jay is a year-round resident that occurs most abundantly in pinyon-juniper woodlands (Cully, this volume). Few elements of this locally available jay have been found in the archeological collections, although remains have been confirmed at Pueblo Bonito, Leyit Kin, and Pueblo Alto.

Corvidae. An element from a jay other than the pinyon jay was recovered at Pueblo Alto. It could represent Steller's jay (*Cyanocitta stelleri*), a casual winter resident or the scrub jay (*Aphelocoma coerulescens*), an uncommon resident that is most common in the pinyon-juniper areas on top of Chacra Mesa (Cully, this volume). Pepper (1920) found skeletons of Steller's jay among a mass of macaws and ceremonial objects at Pueblo Bonito.

Pica pica. Black-billed magpies are casual winter residents of Chaco (Cully, this volume). Recovery was much more common in the earlier excavations. Pueblo Alto is the only recently excavated site to contain this species. Ceremonial use of magpies is suggested at Pueblo Bonito where four mandibles and a premaxilla that had been cut off and bound together and a phalanx were found in Room 38 with 13 macaw skeletons (Hargrave n.d.). They appear in the mythology of the Tewa (Henderson and Harrington 1914) and were used by the Hopi for the headdresses of warriors (Bradfield 1973).

Corvus corax. The common raven is a common year-round resident of Chaco (Cully, this volume) and one of the most common species reported archeologically.

Icteridae. Included in this family are blackbirds and orioles. These have been reported only from the recent excavations at Una Vida and from Pueblo Alto. The Pueblo Alto specimens are probably orioles and those from Una Vida blackbirds. Blackbirds may have been used as food by the Tewa (Henderson and Harrington 1914), but the circumstances of their deposition at Pueblo Alto suggest a ceremonial use. Thirteen fragments of bird beaks (seven oriole, two turkey, three Passeriformes, and one Aves) were found associated with one surface of the East Plaza.

Cully (this volume) lists several species of this family. The yellow-headed blackbird (*Xanthocephalus zanthocephalus*) is an occasional spring migrant; the red-wing blackbird (*Agelaius phoeniceus*), an occasional to casual spring migrant; Scott's oriole (*Icterus parisorus*), a casual fall migrant; Bullock's oriole (*Icterus galbula*), a common summer breeding resident in the cottonwoods along the wash; and Brewer's blackbird (*Euphagus cyanocephalus*), an irregular uncommon migrant.

Turdus migratus. The American robin occurs regularly during migration, but is uncommon in Chaco (Cully, this volume). They migrate and winter statewide, typically in wooded areas (Hubbard 1978). The only archeological occurrence of this species is from Una Vida.

Sialia sp. Two species of bluebird are present in Chaco today, the western bluebird (*Sialia mexicana*), an occasional rare resident, and the mountain bluebird (*Sialia currucoides*), a common winter resident and uncommon summer resident (Cully, this volume). Both species were found at Pueblo Alto, as well as an undetermined element from 29SJ 724.

Lanius ludovicianus. The logger-headed shrike is a common resident along the floodplain of the canyon (Cully, this volume). It has been identified only from Pueblo Alto where two articulated skeletons were found. The birds had apparently been trapped in a room and died.

Fringillidae. Three species belonging to this family, as well as undetermined elements, have been found at Chaco. All were represented at Pueblo Alto and one at 29SJ 633. The slate-colored junco (Junco hyemalis) is a common winter resident; the rufous-sided towhee (Pipilo erythrophtalmus) a regular uncommon migrant and possibly a winter resident; and the green-tailed towhee (Pipilo chlorurus) a regular uncommon migrant (Cully, this volume).

The presence of birds in an archeological site is a little more complex than for the mammals. Like the rodents, smaller birds are found more often at the recently excavated sites. Because birds were not primarily a food item and were of such ceremonial importance, they were probably widely traded. An examination of the body part distribution may help to clarify which taxa were traded and which collected locally.

There may also be some difference resulting from the analysts. Of the 27 sites in Table 7.3, 7 are greathouses and 20 are small sites or villages. Hargrave made or confirmed the identification of 11 and Emslie 12. Table 7.4 gives the breakdown for several taxa. Some of the differences may be methodological. For example, the cards accompanying the identifications (Emslie n.d.) often state the Buteo regalis identifications were made on the basis of size. Hargrave may have used other criteria. It does seem unusual that all of the goshawk and marsh hawk and most of the rough-legged hawk, great horned owl, and magpie identifications were by Hargrave. In general he worked with the smaller sample sizes.

Amphibians, Reptiles, and Fish

A small number of amphibian, reptile, and fish bones have been recovered in archeological sites at Chaco. The majority are probably post-occupational residents of the site area. Because of the small and fragile nature of the bones, few were found in the earlier excavations in the canyon. Table 7.5 gives the distribution by site.

Toads

Spea sp. Two species of spadefood toads are present in Chaco today and have been recovered in a number of archeological sites. The plains spadefoot (Spea bombifrons formerly Scaphiopus bombifrons) and the western spadefoot (Spea multiplicata formerly Scaphiopus hammondi) are occasionally present in the same site and have been captured by Jones (1970) in the same localities at Chaco. They are commonly found in the canyon bottom but sometimes occur on sandy mesas (J. Applegarth, personal communication 1978). This seems to be confirmed by the distribution of

Table 7.4 Comparison of Some Emslie and Hargrave Bird Species Identifications

	Hargrave		Emslie	
	greathouse	village	greathouse	village
number of sites	5	6	2	10
taxon				
ducks and geese	1	1	1	3
goshawk	1	2	0	0
rough-legged hawk	1	3	1	0
ferruginous hawk	1	4	1	3
red-tailed hawk	1	4	1	2
golden eagle	3	5	2	4
marsh hawk	2	1	0	0
prairie falcon	2	2	0	2
scaled quail	2	3	1	1
sandhill crane	1	1	1	3
mourning dove	1	2	1	0
great horned owl	3	4	0	2
black-billed magpie	2	2	1	0
common raven	2	3	1	6

(Emslie n.d.; Hargrave n.d., 1959a, 1959b, 1960a, 1960b, 1960c, 1961a 1962, 1963, 1964a, 1964b)

Table 7.5 Distribution of Amphibian, Reptile, and Fish Bones for Chaco Canyon

						Chaco Project Excavations							
	Pueblo Bonito	del Arroyo	Kin Kletso	Leyit Kin	Bc 59	Una Vida	Pueblo Alto	29SJ 299	29SJ 423	29SJ 627	29SJ 628	29SJ 629	29SJ 633
AMPHIBIANS													
Pelobatidae													
Spea sp. (spadefoot toads)					X	X	X	X		X	X	X	
Spea bombifrons (plain spadefoot)								X		X		X	
Spea multiplicata (western spadefoot)						X				X		X	
Bufonidae (true toads)													
Bufo sp.										X			
Bufo woodhousei (Woodhouse's toad)										X			
REPTILES													
Iguanidae (iguanids)							X						
Sceloporus undulatus (north plateau lizard)							X		X			X	
Sceloporus graciosus (sagebrush lizard)												X	
Phrynosoma douglassi (mountain short-horned lizard)							X			X			
Teidae													
Cnemidophorus velox (plateau whiptail lizard)							X						
Colubridae													
Pituophus melanoleucus (gopher snake)					X		X						X
Crotalidae													
Crotalus viridis (prairie rattlesnake)						X							
unidentified snake						X	X						
Testudinidae (turtle)	X												
FISH													
Osteichthyes	X												
Cyprinidae													
Gila sp. (bonytail)							X						
Lepisosteidae													
Lepisosteus sp. (gar pike)		X	X										
Lepisosteus osseus (long nosed gar)			X				X						
Lamnidae (mackerel shark)				X									

spadefoot remains in the sites, e.g., they are more common in the canyon bottom sites than those higher up, such as Pueblo Alto.

Bufo sp. and *Bufo woodhousei*. True toads were not found by Jones (1970) in his survey of the canyon, but he noted that Harris collected this species no closer than 20 miles from the canyon. Those recovered from 29SJ 627 were partial skeletons found in kivas suggesting that they do (or did) occur in the canyon but rarely.

Lizards

Sceloporus undulatus. Bones of the northern plateau lizard were the most common of any lizard found at Pueblo Alto. It was also found at 29SJ 423 and 29SJ 629. This species, the second most common lizard in Chaco Canyon today, favors a habitat of cliff faces, large boulders, and ruin walls (Jones 1970). Most of those from Pueblo Alto were found in the wall niches of one room.

Sceloporus graciosus. Jones (1970) found the sagebrush lizard to be confined to areas of sandy soils, usually in association with small mammal burrows at the base of large shrubs. It was recovered only at 29SJ 629.

Phrynosoma douglassi. The mountain short-horned lizard is found primarily in mixed grassland associations, although quite to his surprise, Jones (1970) did find a juvenile of this species on top of Fajada Butte. It has been recovered from Pueblo Alto and 29SJ 627.

Cnemidophorus velox. The plateau whiptail lizard is most commonly found in the alluvial canyon bottom often in and near ruins and in close association with tumbleweed, greasewood, rabbitbrush, and fourwing saltbush. More common on flat areas but also found on slopes (Jones 1970), it has been seen at Pueblo Alto.

Snakes

Pituophus melanoleucus. The gopher snake is the most common snake in the canyon today and occurs in all habitats and plant associations (Jones 1970). It has been found at Bc 59 (six vertebrae) and 29SJ 633 (an articulated skeleton); a vertebra was recovered from the Pueblo Alto trash mound. The latter was a cultural rather than accidental deposition and suggests that some use many have been made of this species.

Crotalus viridis. The prairie rattlesnake is generally found on slopes and in ruins (Jones 1970). A rib and a precaudal vertebra were found in a wall niche at Una Vida and are probably post-occupational remains.

Turtles

Testudinidae. There are no turtles living in Chaco today. The only archeological occurrence was a turtle carcass found by Pepper at Pueblo Bonito (Judd 1954). It was most likely ceremonial paraphernalia and probably imported. The Hopis made expeditions to obtain turtle shells for use as dance rattles (Beaglehole 1936).

Fish

Fish remains are quite rare in Chaco Canyon archeological sites. There are no permanent streams and any that are found represent transported items.

Osteichthyes. An unidentified fish bone was recovered at Pueblo Bonito by Pepper (1920).

Gila sp. A vertebra representing a bonytail (either *Gila elegans* or *Gila robusta*) was recovered at Pueblo Alto. Both are large minnows that were formerly common in the San Juan River. Two *Gila* sp. vertebrae were recovered from the Mesa Verde occupation of Aztec Ruin (Gehlback and Miller 1961).

Lepisosteus sp. Gar pike remains have been found in a number of sites at Chaco. Parts of the lower dentary of a long-nosed gar (*Lepisosteus osseus*) and 25 scales from the same genera were recovered at Kin Kletso (Vivian and Mathews 1965). Judd (1959) reported scales from Pueblo del Arroyo. A fragment of another long-nosed gar dentary was found in an unanalyzed provenience at Pueblo Alto.

Remains of gar are not an uncommon find. A section of 52 interlocking scales were found at the outlier site of Escalante in Southwestern Colorado (Nemetz 1977) and two bones of this taxon were found at the outlier Guadalupe Ruin (Pippin 1979).

The nearest gar are in the lower Pecos River and adjacent waters in New Mexico. They may also have occurred in the Rio Grande (Vivian and Mathews 1965), but either way they were transported quite a distance.

Lamnidae. Dutton (1938) reported a non-fossil mackerel shark tooth from Leyit Kin. She noted that these sharks are known to occur from Cape Cod to the West Indies, but are not common except in the Gulf of Mexico. The teeth of this genera range from broadly triangular with serrated edges to long and smooth (Castro 1983) and could be quite similar to those found in fossil form at Chaco.

Nearly all of the herpetological remains are intrusive or naturally deposited. The turtle and the infrequently occurring fish remains probably served a ceremonial function.

Use and Processing

The primary aim of this report is to consider faunal subsistence practices, and how these changed through time. In order to make comparisons it was necessary to choose the most appropriate measure of abundance. The NISP and the percent of the identified elements or percent of the total NISP are used in most cases. For the straight comparisons in this chapter the NISP is the best alternative available. No matter how the proveniences in a site are divided, the total NISP will always be the same. When MNIs are used the total is largely a function of the number of units into which the sample has been divided. The Chaco Anasazi sites contain a number of different provenience types. Any division is going to be arbitrary to an extent. There is nothing to guarantee that the elements from Taxon A in one room are not from the same individual as those from any other room. Equating the 30 or more elements of a species representing one MNI in a pithouse sample of 1,000 elements with the one MNI generated by a single bone in a layer of trash from one grid with a sample size of 12 is unrealistic but often done.

While there may be interdependence between fragments of bones, it is of a lesser magnitude than the possible error from arbitrary site divisions in a complex site. A bone will break into only so many identifiable fragments, while each element and fragmentation of an individual (one MNI) may become widely scattered and end up in a number of proveniences.

MNIs have been used for a number of the comparisons made in this section. Rather than listing each skeletal element and fragmentation (i.e., proximal, distal, process, etc.) major portions of the body are compared with the site MNI to determine the distribution of body parts for a taxon. The most numerous skeletal element in that body part was compared with the MNI. For example, if 8 left femurs were found in a taxon with a site MNI of 10, 80% of the rear legs were considered to be represented in the sample (the artiodactlys were recorded in halves of individuals). The percentage does not imply that all skeletal elements composing that body portion were present in equal numbers. There are often considerable differences in the abundance of the first and second most common skeletal element in a body portion. MNIs have also been used when age distribution are given.

How an animal was used, its availability, and transport can be addressed through the distribution of body parts, butchering practices, articulations, and burning. The processing variables will be examined by groupings of taxa that are similar in size, use, and collection within a site. The commonly utilized or "economic small mammals" (rabbits and prairie dogs) will form the first group. The remainder of the rodents will then be examined. The carnivores are considered as a group followed by the artiodactyls. Turkeys, because of their unique role, are treated alone. The wild birds are examined as a group to determine whether any patterns appear that may be related to different uses. The same dated proveniences (Appendix 1) are used throughout this chapter for the numerical comparison. The other variables presented are site totals.

The Small Economic Mammals

The presence of large numbers of rabbit and sometimes prairie dog bones in archeological sites suggests that these small mammals were of considerable importance to the Anasazi. Although small in size, they occur in fair numbers and reproduce rapidly making them a readily available resource. Modern range management studies (Fagerstone et al. 1980; Flinders and Hansen 1975) have shown that populations of both jack rabbits and cottontails increase dramatically in and around agricultural fields.

Communal hunts were common occurrences among modern Pueblo groups. Beaglehole (1936) and Bradfield (1973) note that the Hopis held communal hunts most often in early summer and autumn when fields had to be protected and there were eagles to be fed. Others took place following the gathering of pinyon nuts (October and November) to provide meat for the fall festivals. Throwing sticks and dogs were used.

We might expect that hunts designed to protect crop areas would result in a combination of the two rabbits while drives might favor one over another depending on where the hunt took place. Either way deposits resulting from such hunts would be difficult to distinguish from day to day procurement activities.

Prairie dogs are formidable field pests that could have been trapped throughout the crop season or their localized burrows. In Chaco, where their hibernation lasts from November into March, the burrows may have been raided during winter. Such raids would net full-sized animals. If a range of ages, especially very immature individuals, occur in an assemblage this can be ruled out.

Relative Numbers

There are differences in the prevalence, and by extension, the relative use of these three taxa (Table 7.6 and Figures 7.1 and 7.2). Cottontail frequencies are high in the Basketmaker III and Pueblo I assemblages, decrease, and finally increase again late in the time sequence. While it is tempting to suggest that there is an inverse relationship with the human population in the canyon, percentages are relative and suggest only that other taxa are making up more of the total. The increased use of other taxa could have been by choice or forced by decreases in the cottontail population. The curves for jack rabbits differ slightly depending on whether the percentage of total elements or of NISP is considered. This taxon seems to fluctuate but tends toward an inverse of the cottontail rabbits, except for a block of time from about A.D. 1080 to 1150 when it is equal and parallel to the curve for prairie dogs.

Prairie dog percentages are rarely higher than either of the rabbits, but it does occur late in the time sequence. Because prairie dogs hibernate, the highs and lows could conceivably be the result of seasonal deposition at a site. For example, the large amount at 29SJ 629 (A.D. 974 to 1040) could reflect a larger population of selective deposition during the spring and summer, while the other extreme at 29SJ 627 (A.D. 1050 to 1080) may have resulted primarily from winter deposition. Within a single site it may be due to seasonal depositional patterns, i.e., household trash was carried farther during the warm months than in the colder ones. Increases in prairie dog availability, possibly brought about by an extension of the field areas or decreases in the other locally available small mammals, might have caused more reliance on prairie dogs.

Table 7.6 Frequencies and Percentages of Cottontail Rabbits, Jack Rabbits, and Prairie Dogs

	Cottontail Rabbits			Jack Rabbits			Prairie Dogs				
Site/date	NISP	% ided	% total	NISP	% ided	% total	NISP	% ided	% total	Total ided	Total Elements
A.D.											
Una Vida											
950-1050	523	29.9	18.9	405	23.2	14.6	213	12.2	7.7	1746	2771
1050-1220	106	24.0	17.6	138	31.3	22.9	53	12.0	8.8	441	603
Pueblo Alto											
920-1020	1006	41.3	20.7	697	28.6	14.3	178	7.3	3.7	2436	4864
1020-1120	3235	40.4	21.5	2418	30.2	16.1	992	12.4	6.6	8013	15037
1120-1220	1435	24.6	14.8	1471	25.2	15.2	1379	23.7	14.3	5826	9666
Shabik'eshchee											
600-750	103	46.8	30.4	36	16.4	10.6	4	1.8	1.2	220	339
29SJ 299											
600-700	37	43.0	22.3	27	31.4	16.3	6	7.0	3.6	86	166
780-820	36	35.3	32.4	40	39.2	36.0	10	9.8	9.0	102	111
920-1020	3	8.8	7.5	7	20.6	17.5	1	2.9	2.5	34	40
29SJ 423											
500-600	589	77.1	30.0	97	12.7	4.9	6	.8	.3	764	1964
29SJ 627 (samples)											
1000-1050	432	40.1	21.4	415	38.5	20.6	48	4.4	2.4	1077	2018
1050-1080	54	16.9	10.8	183	57.2	36.4	2	.6	.4	320	502
1130-1200	54	11.0	4.7	153	31.1	13.3	152	30.9	13.2	492	1148
29SJ 628											
700-820	2042	46.0	40.9	1717	38.7	34.4	175	3.9	3.5	4438	4997
29SJ 629											
850-950	272	35.9	18.2	199	26.2	13.3	72	9.5	4.8	758	1494
975-1040	39	12.9	7.1	117	38.7	21.3	60	19.9	10.9	302	548
1100-1150	18	13.2	6.5	26	19.1	9.4	29	21.3	10.5	136	275
29SJ 633											
1020-1120	89	41.6	25.7	23	10.7	6.6	14	6.5	4.0	214	346
1220-1250	963	41.9	28.3	319	13.9	9.4	132	5.7	3.9	2299	3407
29SJ 721											
650-850	8	61.5	30.8	4	30.8	15.4	1	7.7	3.8	13	26
29SJ 724											
780-820	133	34.4	28.3	178	46.0	37.9	18	4.6	3.8	387	470
29SJ 1360											
920-1020	39	9.7	5.5	145	36.2	20.5	25	6.2	3.5	400	708

Note: The site proveniences used in this and all following taxa abundance tables can be found in Appendix 1.

NISP = the number of identified specimens
ided = the total identified elements (the unknown categories are not included)
total elements = the entire sample including the unknown categories

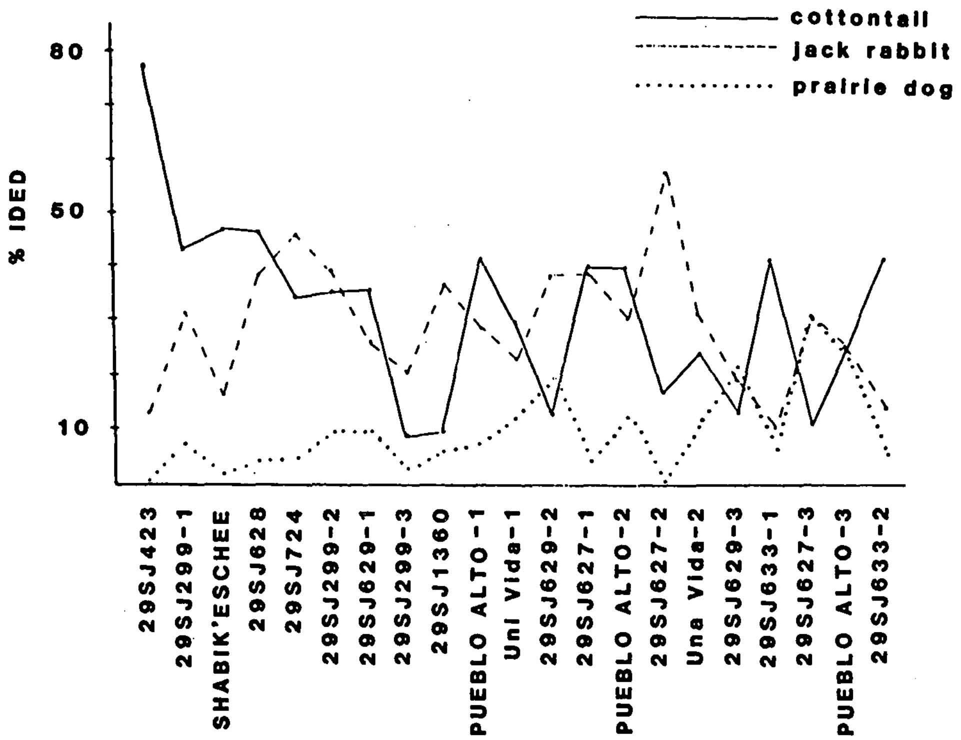


Figure 7.1 Cottontail, Jack Rabbit, and Prairie Dog Percent of the Identified Elements

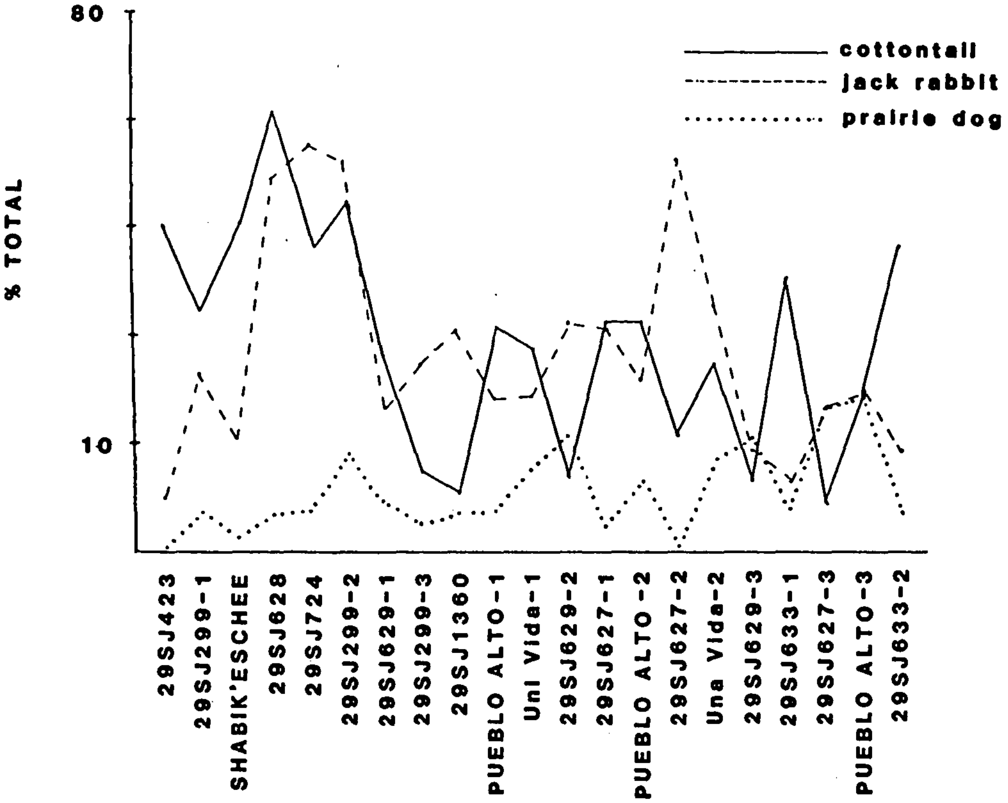


Figure 7.2 Cottontail, Jack Rabbit, and Prairie Dog Percent of the Total Sample

Processing

Processing of these three taxa was probably quite similar. Little disarticulation is necessary to cook animals of this size and, indeed butchering was seldom noted. They could have been pulled apart or cooked whole by boiling or roasting. The butchering observations that were recorded suggest that occasionally front legs were removed; marks on the pelvis and proximal femur suggest that rear legs were sometimes removed (9 cases); partial rear legs were removed (15 cases); and that feet were often removed (52 cases). The articulations show similar patterns. Many were feet (45), with some front (12) and rear (5) legs. Vertebrae were also found (18) articulated suggesting that parts of the spinal column may have been discarded.

Burning (Table 7.7) is high for the small economic mammals compared to the rodents, carnivores, artiodactyls, or birds. Most was "cooking brown," a discoloration that may result from cooking. Actual charring is not high, though a few methods of cooking result in complete or even partially burned bone. Discard in a firepit is a more likely explanation for charred bones from these animals.

Body Part Distribution

Small mammals were probably returned to the site complete with little or no in-field preparation. The distribution of body parts is more a function of excavation techniques, breakage, and potential for identification than "meat packages." Table 7.8 gives this information. In brief, it suggests that the smaller the element the less likely its recovery--especially in the unscreened sites. The limbs and mandibles or innominates contributed the most toward the MNI total. Jack rabbits, because they are larger, have the best representation for the smaller elements (compare the front feet). Prairie dog mandibles are denser and have better recovery than those of rabbits. The combination of low mandibles and innominates at 29SJ 423 is probably the result of poor preservation.

Summary

Rabbits, probably hunted year round both on a communal and individual basis, were returned to the site complete or almost complete. Prairie dogs were most likely taken as field pests, primarily during spring and summer when they could do the most damage to crops. The relative use of these three taxa fluctuates considerably. From A.D. 1080 to 1150 the curves for prairie dogs and jack rabbits are almost identical.

Rodents

A fairly large number of rodent species live in Chaco Canyon today and most show up in the archeological record. Generally these are either post-occupational burrowers (pocket gophers, pocket mice, or kangaroo rats) or opportunistic household pests (*Peromyscus* sp.). The household pest variety is the more numerous in the well-sampled sites.

Table 7.7 Amount of Burning for Cottontail Rabbits, Jack Rabbits, and Prairie Dogs by Site

	Cottontail Rabbit						Jack Rabbit						Prairie Dog					
site	n=	no burn	c.b.	1	2	3	n=	no burn	c.b.	1	2	3	n=	no burn	c.b.	1	2	3
Una Vida	629	78.2	19.8	.3	.2	1.4	543	86.7	10.7	.7	.4	1.5	266	89.5	9.8		.4	.4
Pueblo Alto	5910	79.7	12.4	.7	.3	6.9	4799	82.3	11.8	1.0	.5	4.3	2616	87.8	10.5	.3	.3	1.0
Shabik. Vil.	103	91.3	7.8			1.0	36	88.9	8.3			2.8	4	75.0	25.0			
29SJ 299	76	94.7			3.9	1.3	74	95.9	1.3			2.7	17	100.0				
29SJ 423	589	52.1	44.1	.3		3.4	97	42.3	47.4	2.1		8.2	6	50.0	50.0			
29SJ 627	992	68.1	26.7	2.4	.4	2.3	1345	75.0	17.6	2.4	.4	4.5	335	76.3	17.5	1.7	.6	3.9
29SJ 628	2042	92.6	4.7	.7	.2	1.7	1717	91.1	4.1	.9	.1	3.8	175	92.0	5.1	1.7		1.1
29SJ 629	381	---96.6---		--------3.4------			395	---95.9---		-----4.0------			225	---92.0---		----8.0-----		
29SJ 633	1101	---84.1---		------15.9------			351	---91.5---		-----8.5------			160	---91.9---		----8.1-----		
29SJ 724	133	77.4	19.5	.7	.7	.7	178	68.5	29.2			2.2	18	100.0				
29SJ 1360	39	84.6	10.2		5.1		145	86.9	11.0			2.1	25	92.0	8.0			

1 = very slight burn 2 = partially burned 3 = completely burned

Table 7.8 Percentage of the Site MNI That Can Be Accounted For by Body Part (Cottontail Rabbit, Jack Rabbit, and Prairie Dog)

	Cottontail		Jack Rabbit		Prairie Dog	
	MNI	%	MNI	%	MNI	%
Una Vida						
total MNI	22		10		9	
mandible	5	22.7	4	40.0	9	66.7
front leg	17	77.3	8	80.0	8	88.9
front foot	7	31.8	6	60.0	3	33.3
innominate	9	40.9	5	50.0	2	22.2
rear leg	19	86.4	5	50.0	5	55.5
rear foot	10	45.4	3	30.0	3	33.3
Pueblo Alto						
total MNI	107		65		102	
mandible	76	71.0	34	52.3	97	95.1
front leg	105	98.1	65	100.0	73	71.6
front foot	22	20.5	41	63.1	5	4.9
innominate	83	77.6	48	73.8	45	44.1
rear leg	87	81.3	36	55.4	62	60.8
rear foot	74	69.2	29	44.6	13	12.7
29SJ 299						
total MNI	6		4		3	
mandible	1	16.7	2	50.0	2	66.7
front leg	2	33.3	3	75.0	3	100.0
front foot	0	0.0	1	25.0	0	0.0
innominate	4	66.7	2	50.0	0	0.0
rear leg	6	100.0	3	75.0	2	66.7
rear foot	2	33.3	1	25.0	0	0.0
29SJ 423						
total MNI	11		4		1	
mandible	2	18.2	1	25.0	0	0.0
front leg	11	100.0	3	75.0	1	100.0
front foot	5	45.4	2	50.0	0	0.0
innominate	5	45.4	1	25.0	0	0.0
rear leg	9	81.8	2	50.0	1	100.0
rear foot	11	100.0	4	100.0	0	0.0
29SJ 627						
total MNI	36		32		18	
mandible	29	80.5	14	43.7	15	83.3
front leg	30	83.3	31	96.9	18	100.0
front foot	2	5.5	9	28.1	1	5.5
innominate	36	100.0	12	37.5	12	66.6
rear leg	34	94.4	30	93.7	8	44.4
rear foot	18	50.0	21	65.6	1	5.5

Table 7.8 continued

	Cottontail		Jack Rabbit		Prairie Dog	
	MNI	%	MNI	%	MNI	%
29SJ 628						
total MNI	86		35		17	
mandible	46	50.0	18	51.4	17	100.0
front leg	40	46.5	31	88.6	9	52.9
front foot	3	3.5	6	17.1	1	5.9
innominate	84	97.7	26	74.3	3	17.6
rear leg	73	84.9	35	100.0	7	41.2
rear foot	25	29.1	21	60.0	1	5.9
29SJ 633						
total MNI	27.5		8.5		8.5	
mandible	27.5	100.0	4.5	52.9	8.5	100.0
front leg	25	90.9	6	70.6	6.5	76.5
front foot						
innominate	22	80.0	8.5	100.0	2	23.5
rear leg	27.5	100.0	8	94.1	5.5	64.7
rear foot	18.5	67.3	6	70.6	1.5	17.6
29SJ 724						
total MNI	9		6		2	
mandible	7	77.8	3	50.0	2	100.0
front leg	4	44.4	3	50.0	1	50.0
front foot	1	11.1	3	33.3	0	0.0
innominate	7	77.8	2	33.3	2	100.0
rear leg	5	55.5	4	66.7	2	100.0
rear foot	3	33.3	5	83.3	0	0.0
29SJ 1360						
total MNI	4		7		8	
mandible	3	75.0	2	28.6	0	100.0
front leg	1	25.0	4	57.1	1	12.5
front foot	0	0.0	1	14.3	0	0.0
innominate	3	75.0	5	71.4	0	0.0
rear leg	3	75.0	7	100.0	2	25.0
rear foot	1	25.0	2	28.6	0	0.0

Note: Articulated skeletons are not included in the total MNI, immature individuals are taken into account, sites with very low MNI counts are not presented, and this information is not available for 29SJ 629.

In an experiment using a series of nested screen sizes (1/4, 1/8, and 1/16 in), Thomas (1969) found that 94 to 100% of the bones from pocket gopher and smaller-sized rodents and 85 to 100% of the squirrel-sized mammals were lost in 1/4 in screen. This size was used at Chaco when screening was done. Given this finding it is likely that the vast majority of rodent bones were lost from even the screened sites, thus it is even more amazing that any were recovered from those that were not screened.

Table 7.9 gives the NISP and percentages for the rodents and Table 7.10 the burning observed. The low numbers and percentages are predictable given the collection practices and are probably more a reflection of carefully excavated floors and the tenacity of certain screeners than relative abundance or use. The very high percentages at certain sites, e.g., Una Vida, result from fine screening (1/16 in) trash filled features or are from careful floor excavations (29SJ 299 [A.D. 920-1020] and 29SJ 629 [A.D. 1100-1150]).

Aside from the recovery problem, rodents were occasionally used as food items, especially those that may have been trapped as field pests. Table 7.10 shows that the most consistently utilized may have been the pocket gopher, kangaroo rats, and woodrats.

Carnivores

Carnivore remains are not abundant in the Chacoan faunal collections. Those that are more numerous in the area today (bobcats and coyotes) are also the ones most often found in sites. With the exception of the imports (wolf, mountain lion, and bear) and the domesticate (dog), the archeological distribution may reflect the relative densities prehistorically.

Uses for these animals may include food items, clothing and bedding (hides or pelts), and ceremonial paraphernalia. Ethnographic references to ceremonial use are best for the bear whose hide was used in curing ceremonies and for fighting witches by the Keresans (White 1943). The Santa Claras also ate the meat, used the hides for robes, bedding, and rugs, and wore the claws to acquire power (Hill 1982). Fox skins are used in modern Pueblo ceremonies (Bradfield 1973). Archeologically, bear and mountain lion claws were found sealed in a kiva niche at Pueblo Bonito and Pepper recovered the hair, jaw, and two claw fragments from bear in one room (Judd 1954). A highly polished wolf tooth that had split in half was found in two widely separated proveniences at 29SJ 627. The polish suggests that one portion continued to be used after the break.

Relative Numbers

Table 7.11 gives the carnivore distribution for the dated proveniences of the recently excavated sites. These are converted to percentages of the medium to large mammals, the identified elements, and the total sample for comparison. In general, except for a few cases with small

Table 7.9 Rodent NISP, Percent of the Identified Elements, and Percent of the Total Elements

	Squirrels			Pocket Gopher			Pocket Mouse			Kangaroo Rats		
Site/date A.D.	NISP	% ided	% total	NISP	% ided	% total	NISP	% ided	% total	NISP	% ided	% total
Una Vida												
950-1050	3	.2	.1	16	.9	.6	5	.3	.2	44	2.5	1.6
1050-1220	10	2.3	1.7	17	3.8	2.8	2	.4	.3	3	.7	.5
Pueblo Alto												
920-1020	3	.1	.1	10	.4	.2				15	.6	.3
1020-1120	10	.1	.1	21	.3	.1	5	.1		75	.9	.5
1120-1220	9	.1	.1	83	1.4	.9	9	.1	.1	57	1.0	.6
Shabik'eshchee												
600-750				16	7.3	4.7				1	.4	.3
29SJ 299												
600-700				1	1.2	.6	4	4.6	2.4	1	1.2	.6
780-820							2	2.0	1.8	3	2.9	2.7
920-1020										11	32.3	27.5
29SJ 423												
500-600							1	.1		5	.6	.2
29SJ 627 (samples)												
1000-1050				5	.5	.2	2	.2	.1	5	.5	.2
1050-1080				1	.3	.2				10	3.1	2.0
1130-1200				2	.4	.2				2	.4	.2
29SJ 628												
700-820	4	.1	.1	33	.7	.7	4	.1	.1	16	.4	.3
29SJ 629												
850-950	15	2.0	1.0	38	5.0	2.5	9	1.2	.6	11	1.4	.7
975-1040				11	3.6	2.0	14	4.6	2.5	5	1.6	.9
1100-1150							31	22.8	11.3	19	14.0	6.9
29SJ 633												
1020-1120				1	.5	.3	3	1.4	.9	9	4.2	2.6
1220-1250	1	-	-	8	.3	.2	3	.1	.1	13	.4	.5
29SJ 721												
650-850												
29SJ 724												
780-820				4	1.0	.8	2	.5	.4	2	.5	.4
29SJ 1360												
920-1020				1	.2	.1				4	1.0	.6

Note: NISP = the number of identified specimens
ided = the total identified elements (the unknown categories are not included)
total elements = the entire sample including the unknown catergories

Table 7.9 continued

	Harvest deer, and Grasshopper Mice			Bushy-tailed Woodrat			Wood Rats			Porcupine				
Site/date	NISP	% ided	% total	NISP	% ided	% total	NISP	% ided	% total	NISP	% ided	% total	total ided	total elements
A.D.														
Una Vida														
950-1050	429	24.6	15.5	2	.1	.1	4	.2	.1				1746	2771
1050-1220	73	16.5	12.1	3	.7	.5							441	603
Pueblo Alto														
920-1020	51	2.1	1.0	1	-	-							2436	4864
1020-1120	596	7.4	4.0	4	-	-	29	.4	.2				8013	15037
1120-1220	94	1.6	1.0	6	.1	.1	26	.4	.3				5826	9666
Shabik'eshchee														
600-750	1	.4	.3	5	2.3	1.5	2	.9	.6				220	339
29SJ 299														
600-700	1	1.2	.6				1	1.2	.6				86	166
780-820	1	1.0	.9	1	1.0	.9							102	111
920-1020													34	40
29SJ 423														
500-600	6	.8	.3	1	.1	-	6	.8	.3				764	1964
29SJ 627 (samples)														
1000-1050	5	.5	.2	3	.3	.1	4	.4	.2				1077	2018
1050-1080													320	502
1130-1200	1	.2	.1				1	.2	.1				492	1148
29SJ 628														
700-820				7	.2	.1	9	.2	.2				4438	4997
29SJ 629														
850-950	9	1.2	.6				12	1.6	.8	1	.1	.1	758	1494
975-1040	12	4.0	2.2				1	.3	.2	2	.7	.4	302	548
1100-1150	2	1.5	.7										136	275
29SJ 633														
1020-1120	39	18.2	11.3				7	3.3	2.0				214	346
1220-1250	31	1.3	.9				29	1.3	.8				2299	3407
29SJ 721														
650-850														
29SJ 724														
780-820	5	1.3	1.1	1	.3	.2	2	.5	.4				387	470
29SJ 1360														
920-1020													400	708

Table 7.10 Burning Observations for Rodents (Percent of That Taxa for Those Sites at Which It Was Found)

	n=	Unburned	Cooking Brown	Slight Burn	Partial Burn	Complete Burn
SQUIRRELS						
Una Vida	10	90.0				10.0
POCKET GOPHER (*T. bottae*)						
Una Vida	33	87.9	12.1			
Pueblo Alto	118	90.7	3.4	1.7		4.2
29SJ 627	24	87.5	4.2	4.2		4.2
29SJ 628	33	88.0	9.0	3.0		
POCKET MOUSE (*Perognathus* sp.)						
29SJ 699	54	-----98.2-----		------------1.8----------		
KANGAROO RAT (*D. ordii*)						
Una Vida	47	91.5	2.1	6.4		
Pueblo Alto	134	94.7	3.0			2.3
29SJ 423	5	80.0				20.0
29SJ 628	10	90.0		10.0		
29SJ 629	37	-----97.3-----		------------2.7----------		
DEER MOUSE (*Peromyscus* sp.)						
Una Vida	500	94.4	4.6	.6	.2	.2
Pueblo Alto	739	99.4	.4			.1
WOODRATS (*Neotoma* sp.)						
Pueblo Alto	55	87.3	5.4			7.3
29SJ 423	6	66.7	33.3			
29SJ 633	36	----94.5------		------------5.5-----------		
BUSHY-TAILED WOODRAT (*N. cinerea*)						
Pueblo Alto	12	83.3	16.7			
29SJ 628	7	85.7	14.3			

Table 7.11 Carnivore NISP and Percentages of Medium to Large Mammals, Identified Elements, and Total Elements

	Unknown Canid				Dog				Coyote				Wolf				Foxes			
	NISP	% m-l	% ided	% total	NISP	% m-l	% ided	% total	NISP	% m-l	% ided	% total	NISP	% m-l	% ided	% total	NISP	% m-l	% ided	% total
A.D.																				
Una Vida																				
950-1050	3	.7	.2	.1					13	3.0	.7	.5								
1050-1220	3	4.1	.7	.5																
Pueblo Alto																				
920-1020	11	1.3	.4	.2					13	1.5	.5	.3	1	.1	-	-				
1020-1120	6	.2	.1	-	1	-	-	-					1	-	-	-	1	-	-	-
1120-1220	19	1.4	.4	.2	1	.1	-	-	1	.1										
Shabik'eshchee																				
600-750	4	3.1	1.8	1.2	2	1.5	.9	.6												
29SJ 299																				
600-700	1	4.5	1.2	.6	1	4.5	1.2	.6												
780-820									1	100.0	1.0	.9								
920-1020					3	37.5	8.8	7.5												
29SJ 423																				
500-600	9	2.9	1.2	.5	2	.6	.3	.1	10	3.2	1.3	.5					2	.6	.3	.1
29SJ 627 (samples)																				
1000-1050	9	1.7	.8	.4	8	1.5	.7	.4	14	2.6	1.3	.7	1	.2	.1	-	1	.2	.1	-
1050-1080	1	.6	.3	.2	1	.6	.3	.2	1	.6	.3	.2								
1130-1200	1	.2	.2	.1	13	2.6	2.6	1.1	2	.4	.4	.2					1	.2	.2	.1
29SJ 628																				
700-820	60	9.6	1.3	1.2	15	2.4	.3	.3	35	5.6	.8	.7					5	.8	.1	.1
29SJ 629																				
850-950	22	7.9	2.9	1.5	54	19.5	7.1	3.6	23	8.3	3.0	1.5	2	.7	.3	.1				
975-1040	7	4.9	2.3	1.3	6	4.2	2.0	1.1	1	.7	.3	.2								
1100-1150	1	2.8	.7	.4	1	2.8	.7	.4												
29SJ 633																				
1020-1120	3	6.1	1.4	.9																
1220-1250																				
29SJ 721																				
650-850																				
29SJ 724																				
780-820	1	6.7	.3	.2					4	26.7	1.0	.8					1	6.7	.3	.2
29SJ 1360																				
920-1020	12	3.0	3.0	1.7	60	15.2	15.0	8.5	13	3.3	3.2	1.8								

Note: NISP = the number of identified specimens
ided = the total identified elements (the unknown categories are not included)
total elements = the entire sample including the unknown categories

Table 7.11 continued

	Bob Cat				Mountain Lion				Badger				Bear				Total counts		
	NISP	% m-l	% ided	% total	NISP	% m-l	% ided	% total	NISP	% m-l	% ided	% total	NISP	% m-l	% ided	% total	med-lrg	ided	total
A.D.																			
Una Vida																			
950-1050	9	2.1	.5	.3													429	1746	2771
1050-1220																	73	441	603
Pueblo Alto																			
920-1020	9	1.0	.4	.2													874*	2436	4864
1020-1120	2	-	-	-					1	-	-	-					3670*	8013	15037
1120-1220	1	.1	-	-					7	.5	.1	.1					1383*	5826	9666
Shabik'eshchee																			
600-750	4	3.1	1.8	1.2									1	.8	.4	.3	129	220	339
29SJ 299																			
600-700									1	4.5	1.2	.6					22	86	166
780-820																	1	102	111
920-1020									1	12.5	2.9	2.5					8	34	40
29SJ 423																			
500-600	3	1.0	.4	.1									1	.3	.1	-	310	764	1964
29SJ 627 (samples)																			
1000-1050	4	.7	.4	.2													535	1077	2018
1050-1080	2	1.2	.6	.4													166	320	502
1130-1200																	502	492	1148
29SJ 628																			
700-820	7	1.1	.2	.1					31	5.0	.7	.6	1	.2	-	-	625	4438	4997
29SJ 629																			
850-950					1	.4	.1	.1	1	.4	.1	.1					277	758	1494
975-1040																	143	302	548
1100-1150																	36	136	275
29SJ 633																			
1020-1120	1	2.0	.5	.3													49	214	346
1220-1250	1	9.1	-	-					2	18.2	.1	.1					11	2299	3407
29SJ 721																			
650-850																	1	13	26
29SJ 724																			
780-820	1	6.7	.3	.2													15	387	470
29SJ 1360																			
920-1020									1	.2	.2	.1					394	400	708

Note: Medium to large includes the carnivores, artiodactyls, medium mammals, medium to large mammals, and unknown artiodactyl mammals

*estimated: The medium to large totals for Pueblo Alto were calculated from the percentages found in a large sample and applied to the entire assemblage. A.D. 920-1020 n=3150; A.D. 1020-1120 n=8893; A.D. 1120-1220 n=6095.

sample sizes, the percentages are very small. The canids were more common in the assemblages dating between A.D. 700 and 1020 and in the village sites. The bobcat has a similar distribution. Bear remains are all early (A.D. 500 to 800) with the exception of an element found during the wall clearing activities at Pueblo Alto that is not reflected in the table.

Processing

The butchering marks and articulate elements that would suggest skinning or butchering were uncommon (Table 7.12) and tend to suggest skinning rather than definite evidence of butchering. The burning (Table 7.13) implies that some may have been roasted or were accidentally or deliberately burned. Coyote and wolf elements are the most frequently burned followed by bobcat. Dog has one of the lowest percentages and was found burned at only one site. Canis sp., coyote, and bobcat are the most consistently burned.

Body Part Distribution

Table 7.14 takes each taxon and shows how the individuals from a site were represented in body parts. It tends to suggest that the number of elements found at a site, and the potential for identification and preservation determine the distribution rather than special uses that would result in the presence of only certain elements. Special treatment of carnivore bodies would not result in the scattered spatial distributions characteristic of most sites.

Clusters of carnivore bones and articulated skeletons have been found. Judd (1954) found the detached skulls of a bobcat, a gray fox, two red foxes, a dog, and three coyotes as well as a few leg bones from bobcats and other fox and coyote bones in one room of Pueblo Bonito. A kiva at the same site contained two incomplete skeletons of dogs and a coyote. An almost complete bobcat skeleton and a dog burial were found in a kiva at Bc 50 (Hibben 1937).

This suggests that carnivore use was varied. Some carnivores (especially the rarer taxa) may have been taken strictly for ceremonial purposes, but most were occasionally burned and may have been eaten.

Dogs

Articulated skeletons and the remains of domestic dogs were found at some of the recently excavated sites and evidence of their presence at almost all. They were most likely used for hunting, to warn of the approach of strangers, to watch fields, and to chase off other carnivores. They may also have helped to keep the site clear of human refuse. Dog burials and the two immature dogs found in a pithouse at 29SJ 1360 (McKenna 1984) suggest they were held in some esteem or affection.

Dog burials and articulated skeletons are most common in Pueblo II sites. Two dog skeletons were found at 29SJ 299. A mature dog with quite worn teeth was placed in the vent shaft of a kiva and an immature dog skeleton was found in the fill of an incomplete pit structure. Two

Table 7.12 Evidence of Butchering and Articulated Parts of Carnivores

Site	Taxon	Butchering, etc.	Articulation
Una Vida	coyote	distal humerus; light cuts from tool manufacture, butchering, or skinning	3 cervical vertebrae 1 front foot
	bobcat		5 thoracic vertebrae
Pueblo Alto	*Canis* sp.		5 phalanges
	wolf	metatarsal; beveled cut midshaft for ornament manufacture	
	bear	distal humerus; cut off from skinning or butchering	
29SJ 423	bear	disal metapodial; beveled cut midshaft for ornament manufacture	
29SJ 627	dog		thoracic vertebrae
	coyote		front foot
29SJ 628	*Canis* sp.	distal femur; heavy cuts probably from butchering	
29SJ 628	dog	distal humerus; light cuts from tool manufacture, butchering, or skinning	
	bobcat	distal ulna; light cuts from tool manufacture, butchering, or skinning	
	badger	carpal; light cuts from skinning	front foot
29SJ 629		[not available]	
	dog		12 thoracic and 1st lumbar vertebrae
29SJ 633	bobcat	skull; deep cuts on frontals from skinning	
	badger		hind foot
29SJ 1360	dog		skull and mandibles
	coyote		atlas and axis vertebrae front foot

Table 7.13 Burned Carnivore Percentages for those Sites and Taxa in Which They Occurred

<table>
<tr><th>Site</th><th>n=</th><th>Unburned</th><th>Cooking Brown</th><th>Slight Burn</th><th>Partial Burn</th><th>Complete Burn</th></tr>
<tr><td>Canis sp.</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Pueblo Alto</td><td>37</td><td>97.1</td><td></td><td></td><td>2.9</td><td></td></tr>
<tr><td>29SJ 423</td><td>9</td><td>77.8</td><td>22.2</td><td></td><td></td><td></td></tr>
<tr><td>29SJ 627</td><td>33</td><td>97.0</td><td></td><td></td><td></td><td>3.0</td></tr>
<tr><td>29SJ 628</td><td>60</td><td>98.3</td><td></td><td></td><td></td><td>1.7</td></tr>
<tr><td>29SJ 629</td><td>32</td><td colspan="2">96.9</td><td colspan="3">3.1</td></tr>
<tr><td>29SJ 724</td><td>1</td><td></td><td></td><td></td><td></td><td>100.0</td></tr>
<tr><td>dog</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>29SJ 627</td><td>89</td><td>96.7</td><td>1.1</td><td>1.1</td><td></td><td>1.1</td></tr>
<tr><td>coyote</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Pueblo Alto</td><td>16</td><td>68.7</td><td></td><td>25.0</td><td></td><td>6.2</td></tr>
<tr><td>29SJ 627</td><td>53</td><td>84.9</td><td>11.3</td><td></td><td></td><td>3.8</td></tr>
<tr><td>29SJ 628</td><td>35</td><td>85.7</td><td></td><td>14.3</td><td></td><td></td></tr>
<tr><td>29SJ 629</td><td>28</td><td colspan="2">60.7</td><td colspan="3">39.3</td></tr>
<tr><td>wolf</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Pueblo Alto</td><td>2</td><td>50.0</td><td></td><td></td><td></td><td>50.0</td></tr>
<tr><td>29SJ 629</td><td>2</td><td colspan="2">50.0</td><td colspan="3">50.0</td></tr>
<tr><td>bobcat</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Una Vida</td><td>9</td><td>33.3</td><td>55.6</td><td></td><td></td><td>11.1</td></tr>
<tr><td>Pueblo Alto</td><td>13</td><td>85.3</td><td></td><td></td><td></td><td>7.7</td></tr>
<tr><td>29SJ 423</td><td>3</td><td>66.7</td><td></td><td></td><td></td><td>33.3</td></tr>
<tr><td>29SJ 628</td><td>7</td><td>85.7</td><td></td><td>14.3</td><td></td><td></td></tr>
<tr><td>29SJ 633</td><td>2</td><td colspan="2">50.0</td><td colspan="2">50.0</td><td></td></tr>
<tr><td>bear</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>29SJ 423</td><td>1</td><td></td><td></td><td></td><td></td><td>100.0</td></tr>
<tr><td>summary*</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Canis sp.</td><td>199</td><td>96.5</td><td>1.0</td><td></td><td>.5</td><td>2.0</td></tr>
<tr><td>dog</td><td>250</td><td>98.9</td><td>.4</td><td>.4</td><td></td><td>.4</td></tr>
<tr><td>coyote</td><td>173</td><td>83.2</td><td>3.5</td><td>5.2</td><td></td><td>8.1</td></tr>
<tr><td>wolf</td><td>7</td><td>71.4</td><td></td><td></td><td></td><td>28.6</td></tr>
<tr><td>fox</td><td>12</td><td>100.0</td><td></td><td></td><td></td><td></td></tr>
<tr><td>bobcat</td><td>52</td><td>80.8</td><td>9.6</td><td>1.9</td><td></td><td>7.7</td></tr>
<tr><td>mountain lion</td><td>1</td><td>100.0</td><td></td><td></td><td></td><td></td></tr>
<tr><td>badger</td><td>48</td><td>100.0</td><td></td><td></td><td></td><td></td></tr>
<tr><td>bear</td><td>4</td><td>75.0</td><td></td><td></td><td></td><td>25.0</td></tr>
</table>

* Note: The burning for 29SJ 629 and 29SJ 633 are assumed to be not or completely burned

Table 7.14 Carnivore Element Distribution. Percent of Elements for Canis sp. and Percent of the Site NMI for all Others

	Canis sp. (% of elements)										Dog						
body part	Una Vida	Pueblo Alto	Shabik.	29SJ 299	29SJ 423	29SJ 627	29SJ 628	29SJ 633	29SJ 724	29SJ 1360	Pueblo Alto	Shabik.	29SJ 299	29SJ 423	29SJ 627	29SJ 628	29SJ 1360
skull	33.3	16.2				45.4	10.0	25.0	100.0	8.3					50	100	37
mandible		18.9	50.0	100.0	11.1	15.1	8.3			25.0		100		100	75	50	100
c. vert.		2.7			22.2	3.0	1.7	50.0		8.3	50	100			75		12
t. vert.						3.0	5.0			8.3	50				50		25
l. vert/sacrum		5.4				3.0	3.3								25		12
unknown vert.		5.4					36.7										
innominate						3.0	1.7								50		25
ribs		2.7				9.1	20.0	25.0							25		25
front leg	16.7	13.5			22.2	12.1	5.0			33.3			100		75	100	12
front foot		2.7									100				75	50	
rear leg		10.8				3.0	8.3			8.3	50				75	50	37
rear foot		5.4									50			100	75		12
unident, foot	50.0	10.8	50.0		44.4					8.3							12
unknown		5.4				3.0											
n=	6	37	4	1	9	33	60	4	1	12	11	2	2	2	87	15	58
MNI*											2	1	1	1	4	2	8

* articulated skeletons are not included in the MNI

	Coyote								Wolf			Fox				
	Una Vida	Pueblo Alto	29SJ 299	29SJ 423	29SJ 627	29SJ 628	29SJ 724	29SJ 1360	Pueblo Alto	29SJ 627	29SJ 629	Pueblo Alto	29SJ 423	29SJ 627	29SJ 628	29SJ 724
skull		100		33	50	100							100		100	
mandible				100	50	50						100			100	
c. vert.	100	50		33	100	100		50		100					100	
t. vert.		50			100									50		
l. vert/sacrum					50	100										
innominate				33											100	
ribs					50											
front leg	100	50	100	33	100	100	100	100	100					100	100	100
front foot	100				50	50		50	100						100	
rear leg	100	50			50						100				100	
rear foot		50			50	100				100	100		100			
unident. foot				33												
n=	13	16	1	10	53	35	4	13	2	3	2	1	2	3	5	1
MNI	1	2	1	3	2	2	2	2	1	1	1	1	2	1	1	1

	Bobcat								/Mt. Lion/		Badger							/ Bear			
	Una Vida	Pueblo Alto	Shabik.	29SJ 423	29SJ 627	29SJ 628	29SJ 629	29SJ 633	29SJ 724	29SJ 629	Pueblo Alto	29SJ 299	29SJ 627	29SJ 628	29SJ 629	29SJ 633	29SJ 1360	Pueblo Alto	Shabik.	29SJ 423	29SJ 628
skull		50				50		100			50			50							
mandible		100		100										50		100					
c. vert.											50		100								
t. vert.	50														100						
l. vert/sacrum	50	50	100																		
innominate														50							
ribs		50			50						50	100	100								
front leg		50	100	100	100	100								50				100			
front foot														50							
rear leg	100				50		100	100			100			100							
rear foot			100		50	50						100				100			100		
unident. foot	50	50		100					100	100							100			100	100
n=	9	13	4	3	12	7	1	2	1	1	8	2	3	31	1	2	1	1	1	1	1
MNI	2	2	1	1	2	2	1	1	1	1	2	1	1	2	1	1	1	1	1	1	1

immature dogs were found articulated at 29SJ 627. Both were less than one month old and were found in the same kiva, one near the floor and the other in the fill. As mentioned before, two dogs, one four to five months old and one six to seven months old, were found in a pithouse at 29SJ 1360 with the human inhabitants. Apparently, all had died of asphyxiation. Finally, at 29SJ 629, an immature dog was found on the floor of a pithouse.

Judd (1954) notes that five articulated and reasonably complete dog skeletons were found in his excavations. These were from two kivas at Pueblo del Arroyo. Altogether only 12 dogs and 30 coyotes were represented in his collections suggesting that dogs were not numerous at either Pueblo Bonito or Pueblo del Arroyo. One burial from Bc 50 was of an immature dog placed in a cist and sealed. It was slightly flexed with the head to the south--like most of the human burials at that site (Hibben 1937). Another was found along with four turkey skeletons and a dog skull just above the floor of a kiva (Senter 1939).

The presence of dog skeletons in kivas and pit structures may suggest that some were placed there as part of closing ceremonies; however, the association and conditions are not consistent enough to merit further attention.

Most sites contained the remains of mature and immature dogs. Table 7.15 gives the age distribution for the minimum or site MNI. Considering that the elements were usually scattered these figures are probably underestimations.

Table 7.16 presents the amount of carnivore gnawing and numbers of tooth punctures recorded for each site as well as the gnawing rank and rank of the dog and Canis sp. found at a site. There is some correspondence between the two, although 29SJ 628 has the largest difference in the ranks.

The gnawing and punctures suggest that dog chewing was varied. Table 7.17 gives the species percentages for the sites with the two largest samples--Pueblo Alto and 29SJ 627. In the Pueblo Alto sample more small mammals have gnawing or punctures than in that from 29SJ 627. Many of the isolated human bones found at these sites have also been gnawed, probably by dogs, suggesting that much of their diet may have come from scavenging in midden deposits.

Whatever function was fulfilled by dogs, it apparently changed. Dog remains and evidence of their presence is least common late in time. A similar situation has been noted in southwest Colorado by Emslie (1978) where the highest number of dogs is recorded for Pueblo II sites; only a few have been found in the excavated Pueblo III sites.

Summary

Carnivore bones are scant in Chacoan archeological sites throughout the time spectrum, but are more common beween A.D. 700 and 1020. While

Table 7.15 Age Distribution of Dogs (Site MNI)
(Based on Cornwall 1956)

	n=	< 1 mo.	4-5 mos.	< 6 mos.	6-7 mos.	< 1 yr.	adult	old adult
Pueblo Alto	2			(1)		(1)	2	
Shabik. V.	1						1	
29SJ 299	3					1* (1)		1*
29SJ 423	1						1	
29SJ 627	6	2**	1-2	1			2+	
29SJ 628	2		1				1-3	
29SJ 629	14					3*	10	1
29SJ 1360	10		1*	2	1*		6	

( ) *Canis* sp. probably a dog
* an articulated skeleton

Table 7.16 Comparison of Carnivore Gnawing and Tooth Punctures

site	n=	%	Gnawing rank	Dog/candid % rank
Una Vida	10	.3	5	6
Pueblo Alto	68	.2	6	6
Shabik'eshchee	17	5.0	1	2
29SJ 299	11	3.5	2	3
29SJ 423	7	.3	5	5
29SJ 627	88	1.3	3	2
29SJ 628	8	.1	7	4
29SJ 629	several			
29SJ 633	not available			
29SJ 721	not available			
29SJ 724	5	1.1	4	6
29SJ 1360	8	1.1	4	1

Table 7.17 Percent Gnawed and Punctured Bones

Taxon	Pueblo Alto	29SJ 627
cottontail rabbit	19.1	4.5
jack rabbit	30.9	35.2
rodent	10.3	1.1
canid		4.5
other carnivore	2.9	
deer	4.4	10.2
pronghorn	1.5	2.3
mountain sheep	1.5	1.1
domestic sheep/goat	1.5	
turkey	7.3	11.4
wild bird	4.4	3.4
medium mammal		2.3
artiodactyl	11.8	19.3
medium to large mammal	4.4	3.4
unknown		1.1
total	100.0	100.0

there is little direct evidence (butchering marks or burning) that suggests these were eaten, most of the body parts were scattered throughout the sites. Carnivores were probably taken when encountered, skinned, and perhaps eaten. Elements from bear, wolf, and mountain lion occur infrequently and are represented by few body parts. They may have been imported or transported primarily for ceremonial use.

Sites 29SJ 423 and 29SJ 628 are unique. While the percentages of carnivore bones are similar, the burning is higher and the amount of dog bone and evidence of gnawing are lower than at other Basketmaker sites, which may suggest a different attitude towards eating carnivores and keeping dogs.

Artiodactyls

Recent studies (Speth and Scott 1984a, 1984b) are beginning to show that with increasing aggregation and dependence on horticulture there is a trend toward greater use of the artiodactyls in proportion to the lagomorphs and rodents. This is particularly interesting for Chaco where artiodactyl densities were always low. An increase in the human population should have led to more use and thus to decreases in the availability of the local artiodactyls. This, in turn, would result in more reliance on the smaller rapidly reproducing species (i.e., rabbits).

Deer would have been the most available of the artiodactyls. They inhabit both the grassland and desert scrub environs typical of the Chaco region. Deer populations are more sensitive to low temperatures and deep snow than to summer drought (Anthony 1976). Water can be obtained from grass and leaves. They tend to be non-migratory on ranges less than one mile (Dasmann 1971) and herd size is small. In the San Juan Basin densities of eight per km^2 in grasslands and 11 per km^2 in desert scrub and pinyon juniper may have been possible (United States Government 1976).

A successful deer hunter would need to be aware of the habits of the animal and the area hunted. Like the Hopis, the Chacoans probably hunted deer alone or in small parties and in the fall when their condition was best. Since few are taken at any one time, most of the meat was probably consumed fresh and the surplus jerked and stored (Bradfield 1973; Hill 1982).

Pronghorn are browsers that prefer open grasslands and basins or plateaus adjacent to rolling hills. Their numbers appear to be sensitive to winter snow and cold and to summer drought. Some migration from higher plains to sheltered valleys may occur (Bailey 1931; Buechner 1950). Densities are difficult to project since water and suitable habitat around Chaco are limited. Judd's Navajo informants claimed that pronghorn was hunted on the nearby mesas and a corral "near Escavada Wash" was probably for this species (1954). Range land in South Dakota can support 52 per km^2 (Hempworth 1965), but it is doubtful that the Chaco area could support that many.

The pronghorn are a herd animal that depends on alertness, speed, and numbers for escape. A few animals are always on guard and warn the rest of the herd of approaching danger (Bailey 1931). They were most likely hunted communally (Bradfied 1973), probably in August and October when they are fattest, December and January when the snow slows them down, and March and April when young are present. The Hopi communal hunts were led by a hunt leader and men from other villages were invited to participate. Although horses were used, the Hopi method of forming a circle miles in diameter then spooking the herd towards the hunters is probably similar to the prehistoric method. Most of the meat acquired in a communal hunt was dried and the skulls were place on shrines (Beaglehole 1936).

Mountain sheep are specialized grazers that can live on hard, abrasive, and dry foods and can get liquids from the food supply. They may wander over great distances between seasonal ranges, but are predictable and probably once inhabited environments very similar to deer--near buttes, rough badlands, or low rocky hills (Geist 1971; Hansen 1980; Manville 1980). The Hopis hunted mountain sheep in September either alone or in small parties, often with dogs. The meat was dried and stored and the bones placed in shrines. Judd's Navajo informants noted that mountain sheep, as well as deer and elk, were hunted in the mountainous country north of the Rio San Juan (1954).

Elk inhabit montane grasslands (Findley et al. 1975) and could not have been hunted near Chaco. Long distance hunting parties or trade with groups in the mountains north of the Rio San Juan, the Nacimento or Jemez mountains would have been necessary.

Relative Numbers

The NISP and percentages of both the identified and the total elements (Table 7.18; Figures 7.3 and 7.4) for even the most numerous artiodactyls (deer and pronghorn) are small; however, there are trends in use that show up in all of the graphs. The percent of the medium to large mammals and artiodactyls (Figure 7.5) is given to illustrate the relationship among the three taxa unencumbered by the amount of rabbit and collection bias. The figures show a series of very strong peaks which are in large part due to poor collection strategies. The smaller body sizes were not collected and therefore the percentages of artiodactyl bone are artificially high. There is also some distortion caused by small sample sizes and differences in the fragmentation; therefore, all three graphs should be considered.

The large number of pronghorn elements in the early samples suggests that the early residents of Chaco depended more on pronghorn than the other artiodactyls. Perhaps most of the deer in the immediate environment had already been harvested and the inter-community organization necessary for communal hunts was present from A.D. 600 on. Pronghorn elements begin to decrease between A.D. 920 to 950. Construction activities at the greathouse may have occupied much of communal labor pool so that solitary or small group hunting, which is more effective in hunting deer, became

Table 7.18 Artiodactyl NISP and Percentages of the Medium to Large Mammals, the Identified Elements, and the Total Elements

	Elk				Deer				Pronghorn				Mountain Sheep				Total Counts		
		%	%	%		%	%	%		%	%	%		%	%	%			
	NISP	m-l	ided	total	NISP	m-l	ided	total	NISP	m-l	ided	total	NISP	m-l	ided	total	med-lrg	ided	total
A.D.																			
Una Vida																			
950-1050					7	1.6	.4	.2					30	7.0	1.7	1.1	429	1746	2771
1050-1220					15	20.5	3.4	2.5					4	5.5	.9	.7	73	441	603
Pueblo Alto																			
920-1020	1	.1	-	-	30	3.4	1.2	.6	50	5.7	2.0	1.0	21	2.4	.9	.4	874*	2436	4864
1020-1120					361	9.8	4.5	2.4	45	1.2	.6	.3	40	1.1	.5	.3	3670*	8013	15037
1120-1220					142	10.3	2.4	1.5	63	4.5	1.1	.6	74	5.3	1.3	.8	1383*	5826	9666
Shabik'eshchee																			
600-750					5	3.9	2.3	1.5	29	22.5	13.2	8.5	4	3.1	1.8	1.2	129	220	339
29SJ 299																			
600-700									2	9.1	2.3	1.2	1	4.5	1.2	.6	22	86	166
780-820																	1	102	111
920-1020									2	25.0	5.9	5.0					8	34	40
29SJ 423																			
500-600	2	.6	.3	.1	3	1.0	.4	.1	11	3.5	1.4	.6	4	1.3	.5	.2	310	764	1964
29SJ 627 (samples)																			
1000-1050	1	.2	.1	-	22	4.1	2.0	1.1	22	4.1	2.0	1.1	7	1.3	.6	.3	535	1077	2018
1050-1080	1	.6	.3	.2	31	18.7	9.7	6.2	6	3.6	1.9	1.2	7	4.2	2.2	1.4	166	320	502
1130-1200					42	8.4	8.5	3.7	12	2.4	2.4	1.0	37	7.4	7.5	3.2	502	492	1148
29SJ 628																			
700-820	1	.2	-	-	16	2.6	.4	.3	63	10.1	1.4	1.3	30	4.8	.7	.6	625	4438	4997
29SJ 629																			
850-950					3	1.1	.4	.2	1	.4	.1	.1	1	.4	.1	.1	277	758	1494
975-1040	1	.7	.3	.2	10	7.0	3.3	1.8	6	4.2	2.0	1.1	3	2.1	1.0	.5	143	302	548
1100-1150					4	11.1	2.9	1.4	1	2.8	.7	.4	1	2.8	.7	.4	36	136	275
29SJ 633																			
1020-1120									1	2.0	.5	.3	1	2.0	.5	.3	49	214	346
1220-1250					1	9.1	-	-	3	27.3	.1	.1	1				11	2299	3407
29SJ 721																			
650-850																	1	13	26
29SJ 724																			
780-820									2	13.3	.5	.4					15	387	470
29SJ 1360																			
920-1020					14	3.5	3.5	2.0	52	13.2	13.0	7.3	6	1.5	1.5	.8	394	400	708

* estimated from samples (see note for Table 7.11 for the sample sizes and what taxa were included in medium to large)

Note: NISP = the number of identified specimens
ided = the total identified elements (the unknown categories are not included)
total elements = the entire sample including the unknown categories

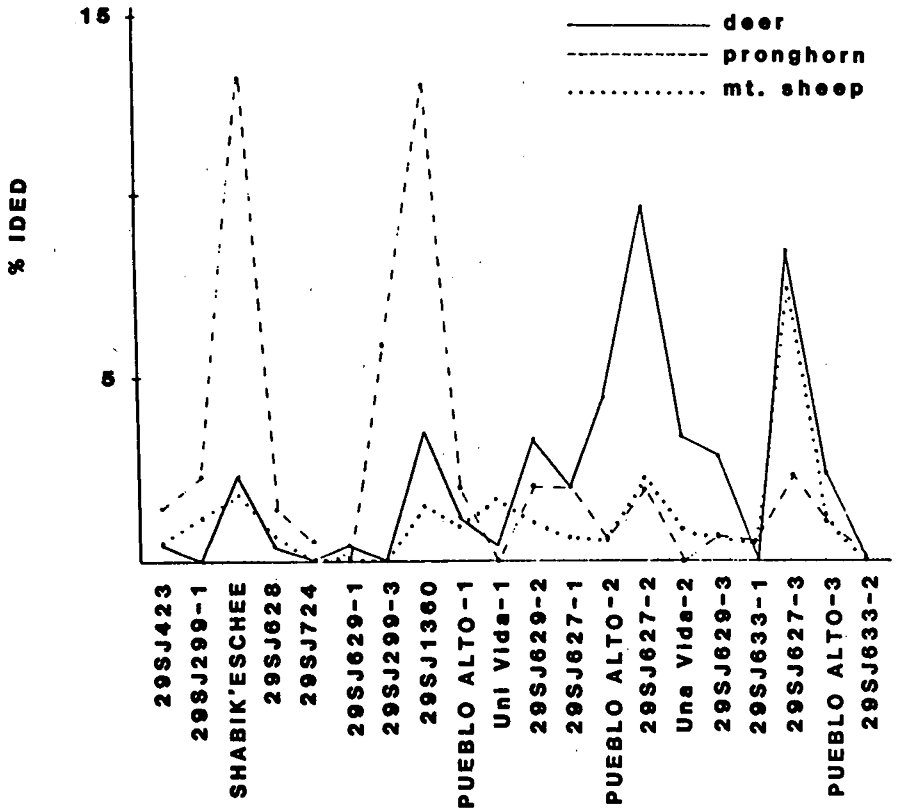


Figure 7.3 Deer, Pronghorn, and Mountain Sheep Percent of the Identified Elements

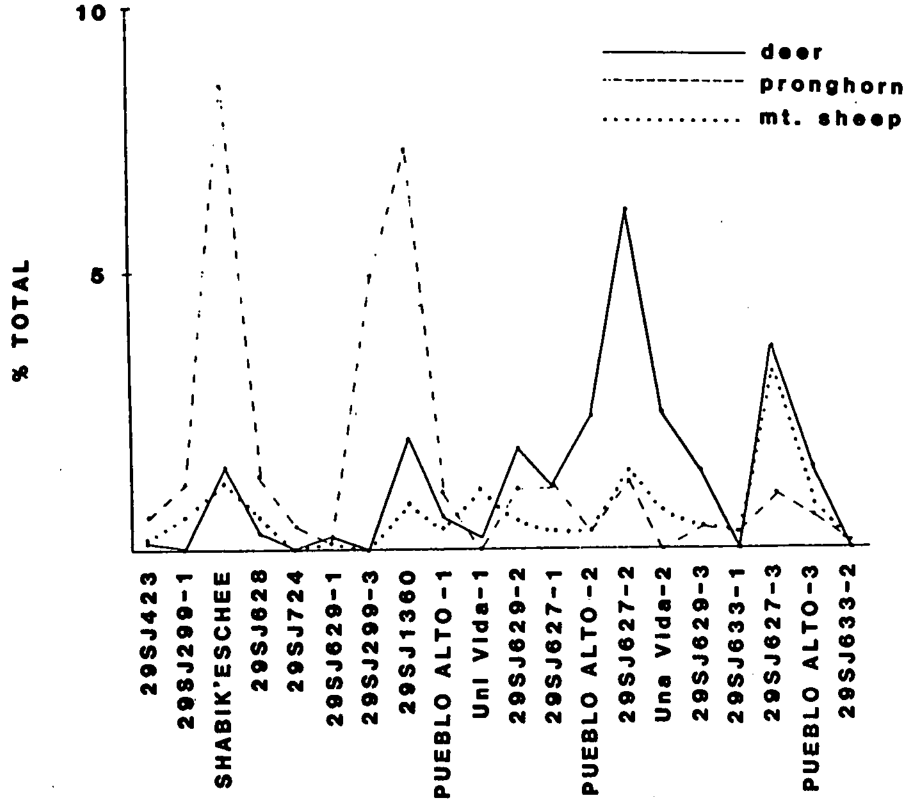


Figure 7.4 Deer, Pronghorn, and Mountain Sheep Percent of Total Sample

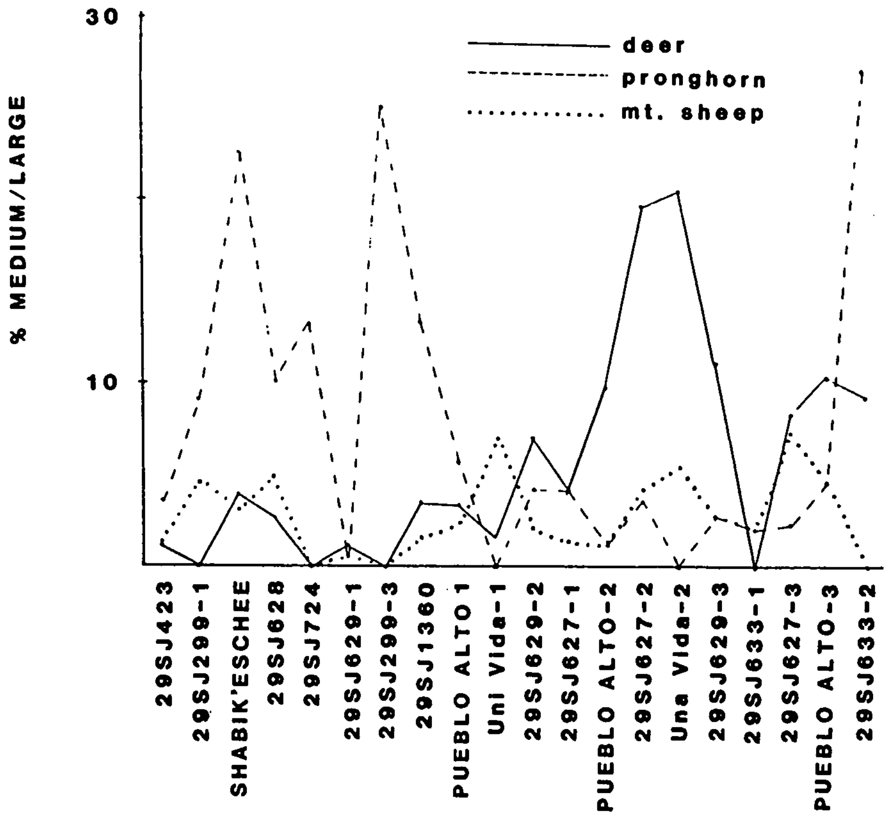
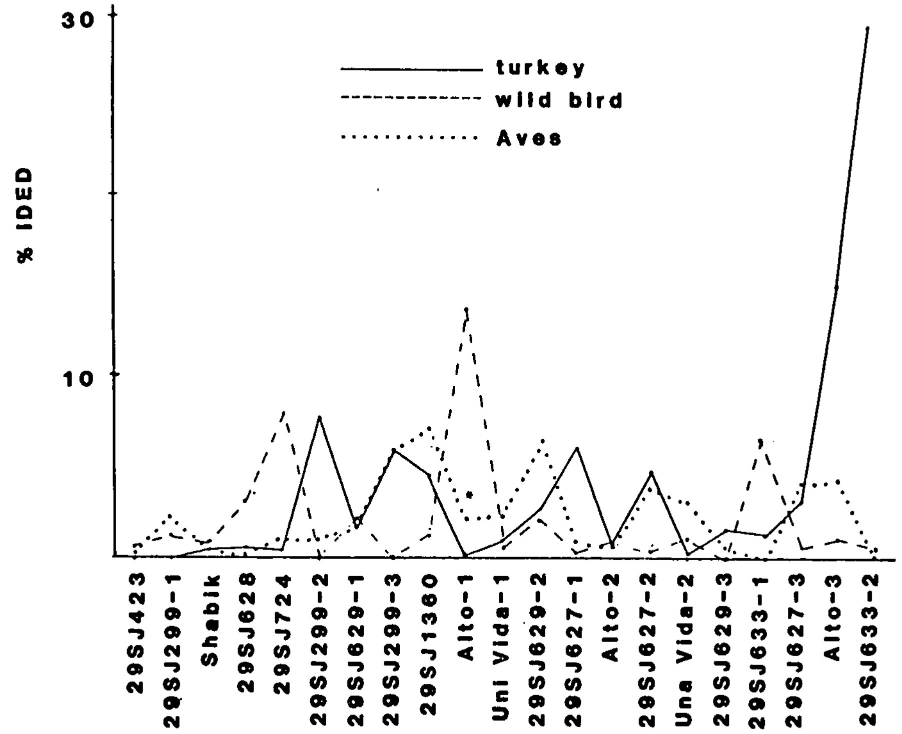


Figure 7.5 Deer, Pronghorn, and Mountain Sheep Percent of the Medium to Large Mammal Elements



* Without Plaza Grid 30 materials

Figure 7.6 Turkey, Wild Bird, and Aves Percent of the Identified Elements predominant. Decreases in the availability of pronghorn would likewise make its procurement more expensive in time and energy. Deer use remained fairly high until the A.D. 1200s.

Mountain sheep have a low fluctuating presence suggesting a relatively constant but low availability and use. Elk, interestingly, does not appear in deposits dating after A.D. 1080.

Processing

Much of the artiodactyl meat returned to the sites was probably stripped and dried and would not result in burned bone. When cooked fresh the body parts may have been placed in a stew or roasted. Either method would have resulted in partial burning or possibly "cooking brown." While some does occur (Table 7.19), the majority of the sample is unaltered.

Tables 7.20 and 7.21 summarize the butchering marks recorded. These marks can represent disarticulation, skinning, or tool manufacture. Chopping nearly always will be the result of disarticulation, while cuts are usually from skinning (Binford 1981; Guilday et al. 1962) but can also be from tool manufacture. The portions removed result from chops or cuts to disarticulate or from the manufacture of tools.

In the Chaco sites, the most common marks represent skinning. Hide removal most often began at the distal metapodial but occasionally higher up on the limb. Disarticulation is suggested at the pelvis and the feet above the metapodial. The vertebral column may have been divided or chopped up for stews. Portions removed from the humerus, radius, ulna, and phalanges most likely represent modification for tool manufacture.

The articulations recorded (Table 7.22) were all front lower limbs (radius and ulna) or feet. The elements used most often for tool manufacture are the metapodials, which may have been curated. Groups of two or three phalanges most likely represent discards. Limbs of two deer and one pronghorn were recovered from room floors at Bc 50 (Hibben 1937).

Body Part Distribution

For the artiodactyls more than any other group, the body part distribution can be informative. The "Schlepp Effect" states that "the farther a carcass had to be dragged, and the larger the carcass, the less of the relative heavy inedible bone portion that will arrive at the site" (Wing and Brown 1979:150). If the artiodactyl meat was traded in or taken at a distance, the meat would most likely be in the form of jerky, so those individuals would not be represented in the faunal assemblage. The elements that are returned in such a situation are the raw material for tools.

Tables 7.23 and 7.24 give the percentages of elements for the unknown medium to large mammal and artiodactyl fragments and the portion of the body for the known artidactyl elements. The minimum or whole site MNI is used for the calculations. Many of the sites are multicomponent. Raising

Table 7.19 Burned Artiodactyl Percentages for those Sites and Taxa in Which they Occur

Site	n=	Unburned	Cooking Brown	Slight Burn	Partial Burn	Complete Burn
Elk						
Pueblo Alto	1	100.0				
29SJ 423	2	50.0	50.0			
29SJ 627	5	100.0				
29SJ 628	1	100.0				
29SJ 629	1	100.0				
Deer						
Una Vida	22	100.0				
Pueblo Alto	572	90.2	1.7	.3	.5	7.2
Shabik'eshchee	5	100.0				
29SJ 423	3	100.0				
29SJ 627	224	89.7	2.2	.4	.9	6.7
29SJ 628	16	93.7				6.2
29SJ 629	22	95.4		4.5		
29SJ 633	1	100.0				
29SJ 1360	14	100.0				
Pronghorn						
Pueblo Alto	167	86.8	1.8	.6	1.2	9.6
Shabik'eshchee	29	93.1				6.9
29SJ 299	4	75.0				25.0
29SJ 423	11	81.8	9.1			9.1
29SJ 627	65	81.5	7.7		1.5	9.2
29SJ 628	63	95.2		1.6	1.6	1.6
29SJ 629	8	100.0				
29SJ 633	4	100.0				
29SJ 724	2	100.0				
29SJ 1360	52	100.0				
Mountain Sheep						
Una Vida	34	100.0				
Pueblo Alto	145	77.9	2.8		1.4	17.9
Shabik'eshchee	4	100.0				
29SJ 299	1					100.0
29SJ 423	4	50.0	50.0			
29SJ 627	73	97.2	1.4			1.4
29SJ 628	30	90.0			3.3	6.7
29SJ 629	7	85.7		14.3		
29SJ 633	1	100.0				
29SJ 1360	6	100.0				
medium to large mammal/artiodactyl						
Una Vida	448	96.9	2.2			.9
Pueblo Alto	4964	78.2	4.9	.2	.8	15.9
Shabik'eshchee	78	98.7			1.3	
29SJ 299	18	38.9				61.1
29SJ 423	241	75.5	18.2		1.2	5.0
29SJ 627	1561	85.8	5.2	.1	1.0	7.9
29SJ 628	307	90.9	1.6	.6	1.9	4.9
29SJ 629	317	90.5		9.5		
29SJ 633	36	91.7		8.3		
29SJ 724	9	100.0				
29SJ 1360	227	95.1	.9			4.0

Table 7.20 Evidence of Butchering for the Artiodactyls

		Deer			Pronghorn			Mountain Sheep			Lrg. mamm/artio.		
Site	Element	p.r.	chop	cut	p.r.	chop	cut	p.r.	chop	cut	p.r.	chop	cut
Una Vida	thoracic vertebra											1	
	lumbar vertebra											9	
	innominate											2	1
	metatarsal - distal									1			
Pueblo Alto	antler	1											
	mandible									1			
	thoracic vertebra	1									2	1	2
	lumbar vertebra	1	1								1		
	unknown vertebra										1		
	sacrum		2										
	innominate	1		1									1
	rib										1		4
	humerus - proximal	1											
	distal			1									
	radius - proximal			1	1								
	distal			1				1					
	carpal			1									
	metacarpal - distal			1			1			6			
	femur - proximal										1		
	tibia - distal			1									
	astragalus						1						
	calcaneum		2	1	1					1			
	metatarsal - distal									2			
	accessory metapodial			1									
	phalanx	1											
	longbone										1		3
Shabik'eshchee	metacarpal - distal						1						
	metarsal - distal						2						
	phalanx						1						
29SJ 299	metacarpal - shaft												1
29SJ 423	longbone												1
29SJ 627	cervical vertebra							1					
	thoracic vertebra										1		
	innominate										1		
	humerus - distal										1		
	ulna - distal		1										
	metacarpal - distal			1			1						
	femur - proximal												2
	tibia - proximal												1
	distal												1
	tarsal										1		
	calcaneum	1		1									
	metatarsal - distal			2			1						
	phalanx	1											
	longbone										1		4
29SJ 628	skull	1											
	mandible				1								
	atlas vertebra				1								
	carpal									2			
	metacarpal - distal						3			2			
	tibia - proximal				1								
	astragalus							1					
	metatarsal - distal									1			
	phalanx				2								
29SJ 1360	humerus - distal									1			
	radius - proximal						1						
	ulna - proximal						1						
	metacarpal - shaft						1						
	distal						2						
	astragalus			1									
	metatarsal - distal						5						
	longbone												1

p.r. = portion removed

Table 7.21 Summary of Artiodactyl Butchering Marks

Element	Portion removed	Chop	Cut
antler	1		
skull	1		
mandible	1		1
cervical vertebra	2		
thoracic vertebra	4	2	2
lumbar vertebra	2	10	
unknown vertebra	1		
sacrum		2	
innominate	2	2	3
rib	1		4
humerus - proximal	1		
- distal	1		2
radius - proximal	1		2
- distal	1		1
ulna - proximal			1
- distal		1	
carpal			3
metacarpal - shaft			2
- distal			18
femur - proximal	1		2
tibia - proximal	1		1
- distal			2
tarsal	1		
astragalus	1		2
calcaneum	2	2	3
metatarsal - distal			14
accessory metapodial			1
phalanx	4		1
longbone	2		9
totals	31	19	74

Table 7.22 Artiodactyl Articulations

Site	Taxon	n = articulation
Una vida	deer	1 phalanx
	mountain sheep	1 front foot
		1 rear foot
Pueblo Alto	deer	1 front foot
		3 rear feet
		7 phalanges
	pronghorn	1 phalanx
	immature artiodactyl	1 phalanx
Shabik'eshchee	pronghorn	1 partial rear foot
		1 phalanx
29SJ 627	deer	1 phalanx
	pronghorn	1 metapodial and phalanx
29SJ 628	mountain sheep	1 front foot
29SJ 1360	pronghorn	3 radius and ulna

Table 7.23 Body Part Percentages for the Unknown Medium to Large Mammals and Artiodactyls

	Una Vida	Pueblo Alto	Shabik'eschee	29SJ 299	29SJ 423	29SJ 627	29SJ 628	29SJ 724	29SJ 1360
skull	.2	3.8	5.1		5.8	1.7	2.9		.4
mandible		.8	1.3		.8	.4	1.9		
cerv. vertebra		.4	1.3		.4	.3	1.0		.4
thoracic vertebra	.4	1.2	1.3		.8	1.5	1.6		.9
i. vert/sacrum/caud.	3.6	1.6		5.5	.4	2.3	1.9		4.4
unknown vertebra	6.2	3.7	3.8		1.2	5.6	3.9		1.8
innominate	.9	.5	2.6		.4	1.1	2.3		2.2
rib	50.0	20.1	11.5	*	3.3	12.3	13.3		18.1
front leg	1.1	1.7	1.3	5.5	.8	4.5	1.9		7.0
front foot		.2		5.5		.3	*	*	.9
hind leg	.9	1.0	1.3		1.2	2.4	3.9	*	4.4
hind foot	*	.3	*	*	1.2	1.1	3.2		.9
unknown foot	.2	.7	1.3	11.1	.4	1.3	1.9		1.3
longbone	20.5	39.7	55.1	38.9	49.4	47.8	43.3	100.0	55.1
unknown	15.8	24.3	14.1	33.5	33.6	17.4	16.6		2.2
number of elements	448	4964	78	18	241	1561	307	6	227

* present in the tool assemblage

Table 7.24 Percentage of the Site MNI that Can Be Accounted for by Body Part (Elk, Deer, Pronghorn, and Mountain Sheep)

	Elk					Deer									
	Pueblo Alto	29SJ 423	29SJ 627	29SJ 628	29SJ 629	Una Vida	Pueblo Alto	Shab. Vil.	29SJ 299	29SJ 423	29SJ 627	29SJ 628	29SJ 633	29SJ 724	29SJ 1360
skull						50	67			100	33	100			
mandible	50					25	22				17	100			
cerv. vert.						50	44				17	100			
thor. vert.							33				33				
l. vert/sac/caud.							22				33				50
innominate							28				25				
rib cage			50	50		25	22				17				
front leg						25	72	50		50	33/50		50		50
front foot							28				17/25	50			
rear leg			50			100	33		/50		50				
rear foot						25	61	100		50	92			/83	25
unknown foot		25	50		25	25	19/22				21				
MNI	1	1	1	1	1	2	9	2	1	1	6	1	1	/3	2
# elements	1	2	5	1	1	22	572	5	1	3	224	16	1	/5	14

	Pronghorn									Mountain Sheep								
	Pueblo Alto	Shab. Vil.	29SJ 299	29SJ 423	29SJ 627	29SJ 628	29SJ 633	29SJ 724	29SJ 1360	Una Vida	Pueblo Alto	Shab. Vil.	29SJ 299	29SJ 423	29SJ 627	29SJ 628	29SJ 633	29SJ 1360
skull	70	25	50		33	40					40	50			25			
mandible	25/37	25		25	17	50	75				20					50		
cerv. vert.	25	25		50		20			25	100	40				50	50		
thor. vert.	50				33	20					40							
l. vert/sac/caud.	25														25			
innominate	12								12		10				12	25		50
rib cage	50				17					50	30					25		
front leg	62	75	25	50	33	70	25		75	50	60	100		50	62	50		100
front foot	50/62	25		25	33/50	30/50			37/50	50	70		50		25	75	50	/50
rear leg	37		50		17	20		50	25	50	20				25	/25		
rear foot	37	25/37	/25	25	67	50		50	87	50	40	/25	/50	50	12	75		50
unknown foot					8													
MNI	4*	4	2	2	3	5	2	1	4	1	5	2	1	1	4	2	1	1
# elements	167	29	4	11	65	63	4	2	52	34	145	4	1	4	73	30	1	6

*includes 1 very immature individual
/ with tools included

Note: The percentages are for a whole individual for axial parts, a half an individual for the paired elements, and one fourth an individual for the feet.

the MNI would further reduce the representation. The effect of adding the bone tools to the totals is also given. This does not change the MNI for any site, though it does add deer to assemblages at 29SJ 299 and 29SJ 724.

Body parts missing from some species may be in the unidentified assemblages. This is especially true for ribs and longbones, which are frequently broken into small pieces, and the vertebra, skull, and pelvis that have been crushed beyond recognition. The best representation is for limb and foot bones and may suggest curation of these parts for the manufacture of tools. The unusually large skull percentage for Pueblo Alto is from hyoids. These were probably returned to the site with the tongue (White 1953a) rather than the complete skulls.

Summary

Except for elk, most of the artiodactyls found could have occurred in small numbers in the Chaco Canyon area. The faunal assemblages suggest that deer were removed from the local environment before Basketmaker III. Pronghorn, a herd animal that is best hunted in communal drives, was the most utilized species between A.D. 500 and 950. After A.D. 950, possibly correlating with the greathouse use and construction, the use of deer increased. Solitary or small groups are most effective in hunting deer and may suggest that along with specialization in other areas of the economy, there were hunting specialists.

The number of bones and the body part representation do not indicate that a large number artiodactyls were procured, possibly because much of the utilization was as dried meat with the return of few bones to a site. Some animals may have been procured nearby and returned in their entirety; however, those taken at a distance would be represented by a few parts (such as the feet) that were returned and curated for later use.

Turkey

A study of the measurements of the turkey elements from 11 Chaco sites led McKusick (n.d.) to conclude that they were of the Large Indian Domestic Breed that was well established in the Mesa Verde area in the A.D. 600s.

The turkey is one of the more controversial species recovered from archeological sites; its occurrence is often taken as proof enough that it contributed to the Anasazi diet. As noted, there is little natural forage in the Chaco Canyon area and this species would have been expensive to maintain if food and water were provided. They are also destructive to crops, for most of their diet is plants. They eat greenery, e.g., corn plants, scratch at the bases of plants, and should be penned. Such formal structures are absent or unrecognized. Extensive dung deposits (200 to 300 m^3 at Stephouse) and pens were found at Mesa Verde (Schorger 1966:23). The lack of natural forage and evidence of pens suggest that throughout most of Chacoan history turkeys were rare and when subsidized it was mainly for a purpose other than eating, such as, feathers for prayer plumes or quilts. The birds may or may not have eventually been eaten, but the purpose and value were not as a food source, at least until late in the time sequence.

Relative Numbers

Turkey is the most numerous bird found in the archeological deposits and there are demonstrable trends in abundance over the occupation of the canyon (Table 7.25 and Figures 7.6, 7.7, and 7.8). The earliest turkey appears in Late Basketmaker III - Early Pueblo I deposits at Shabik'eshchee Village and 29SJ 628. A single turkey element was found in the fill of a structure at Shabik'eshchee. Three individuals, including a poult less than three days old, were recovered from the fill of three different pithouses at 29SJ 628. Turkey elements are rare in the Pueblo I deposits at 29SJ 724 but relatively abundant in the Pueblo I deposits at 29SJ 299. They appear to have been more numerous in the early portions of Pueblo II but decline toward the end of that period. Percentages at the greathouses (Una Vida and Pueblo Alto) in Pueblo II are lower than at villages of the same date (Figure 7.8). The percentages with deposits at the greathouse (Pueblo Alto) and the village site (29SJ 633) increase dramatically from A.D. 1200 on, beyond any previous indications.

Compared with that of wild birds, turkey use appears to have been rare until Late Pueblo I. Cumulative bird frequencies are highest during Pueblo II and at the very end of the time sequence. The very large wild bird percentage from Pueblo Alto (A.D. 920 to 1020) is the result of an unusual plaza pit that contained 270 bones from wild birds.

Processing

One method of preparation for consumption would have been roasting, possibly similar to a description related by Schorger (1966). Wild turkeys were bled, drawn, and slightly plucked, then placed on a bed of hot coals. Later a black mass was raked out of the coals and the skin peeled back to reveal the meat.

Table 7.26 shows that burning is low in the collections and often this is complete burning unrelated to cooking. The unidentified bird and cumulative wild bird percentages are given for comparison. Turkey shows more evidence of burning than does the cumulative wild bird at the sites. The unidentified bird burning is similar to the turkey burning at both sites with good samples (Pueblo Alto and 29SJ 627), suggesting that unidentified turkey comprises most of the bird remains at these two sites. The slight and partial burning that might result from roasting is found most often in the assemblages from Pueblo Alto and 29SJ 627. At Pueblo Alto (n=54) the most frequently burned element was the coracoid (n=10) with the other thorax elements also fairly high (4 vertebrae, 1 sternum, 3 furculae, 5 ribs, and 1 innominate). More wing elements were partially burned (4 humeri, 6 radii, 5 ulnae, 1 carpal, 4 digits) than leg elements (3 femurs, 3 tibias, 3 ungals). The evidence for 29SJ 627 is not as good (n=6). Half are mandibles and foot elements and the remainder includes a coracoid, a radius, and an ulna. Hargrave (1965) did not let a lack of

Table 7.25 Turkey, Wild Bird, and Aves NISP, Percent of the Identified Elements, and Percent of the Total Elements

site/date	Turkey			Wild bird			Aves			Totals		
A.D.	NISP	% ided	% total	NISP	% ided	% total	NISP	% ided	% total	bird	ided	elements
Una Vida												
950-1050	16	.9	.6	10	.6	.4	40	2.3	1.4	66	1746	2771
1050-1220	1	.2	.2	5	1.1	.8	14	3.2	2.3	20	441	603
Pueblo Alto												
920-1020	3	.1	.1	337	13.8[3.7]	6.9	53*	2.2	1.1	393	2436	4864
1020-1120	68	.8	.4	75	.9	.5	45*	.6	.3	188	8013	15037
1120-1220	878	15.1	9.1	56	1.0	.6	251*	4.3	2.6	1185	5826	9666
Shabik'eshchee												
600-750	1	.4	.3	2	.9	.6	1	.4	.3	4	220	339
29SJ 299												
600-700				1	1.2	.6	2	2.3	1.2	3	86	166
780-820	8	7.8	7.2				1	1.0	.9	9	102	111
920-1020	2	5.9	5.0				2	5.9	5.0	4	34	40
29SJ 423												
500-600				5	.6	.2	2	.3	.1	7	764	1964
29SJ 627												
1000-1050	65	6.0	3.2	2	.2	.1	10	.9	.5	77	1077	2018
1050-1080	15	4.7	3.0	1	.3	.2	12	3.7	2.4	28	320	502
1130-1200	15	3.0	1.3	3	.6	.3	20	4.1	1.7	38	492	1148
29SJ 628												
700-820	24	.5	.5	143@	3.2	2.9	7	.2	.1	174	4438	4997
29SJ 629												
850-950	13	1.7	.9	16	2.1	1.1	13	1.7	.9	42	758	1494
975-1040	8	2.6	1.5	6	2.0	1.1	20	6.6	3.6	34	302	548
1100-1150	2	1.5	.7				1	.7	.4	3	136	275
29SJ 633												
1020-1120	3	1.4	.9	14	6.5	4.0				17	214	346
1220-1250	681	29.6	20.0	11	.5	.3	3	.1	.1	695	2299	3407
29SJ 721												
650-850											13	26
29SJ 724												
780-820	1	.3	.2	31	8.0	6.6	4	1.0	.8	36	387	470
29SJ 1360												
920-1020	18	4.5	2.5	5	1.2	.7	29	7.2	4.1	57	400	708

[ ] percentage without Plaza Grid 30 materials
* estimated from samples (see Table 7.11 for the size of samples used)
@ 41 lost bird bones are counted as potentially identifiable wild bird

Note: NISP = the number of identified specimens
ided = the total identified elements (the unknown categories are not included)
total elements = the entire sample including the unknown catergories

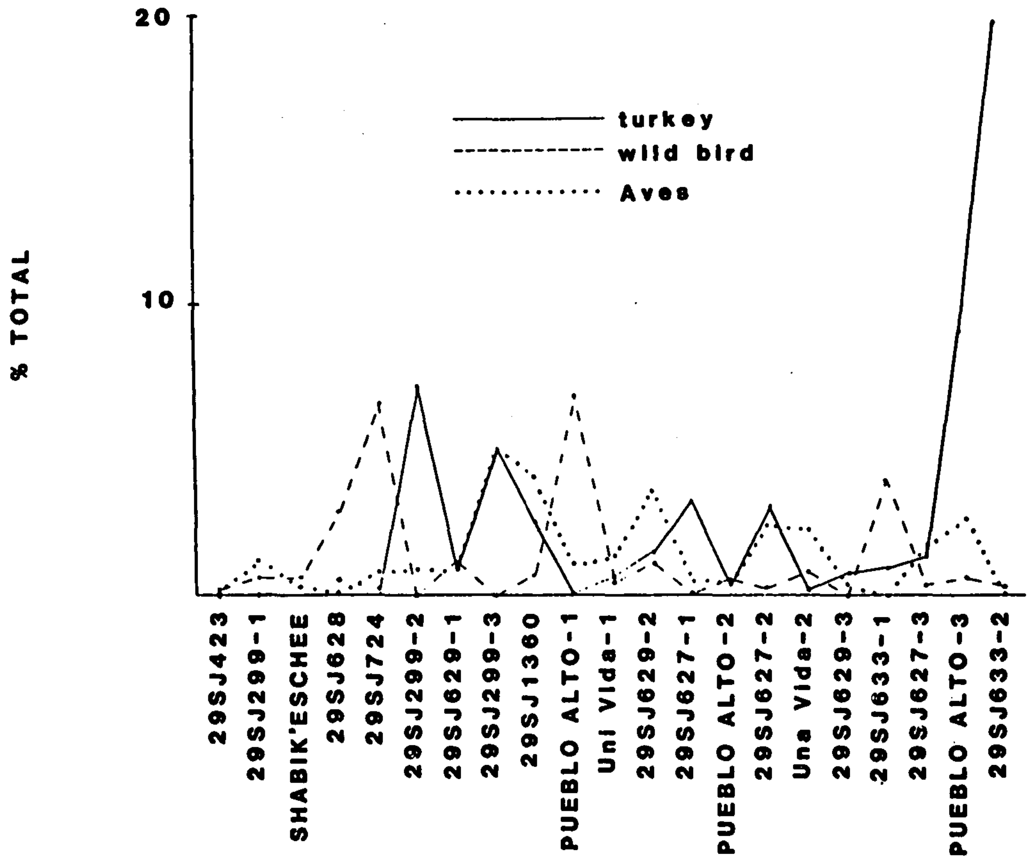
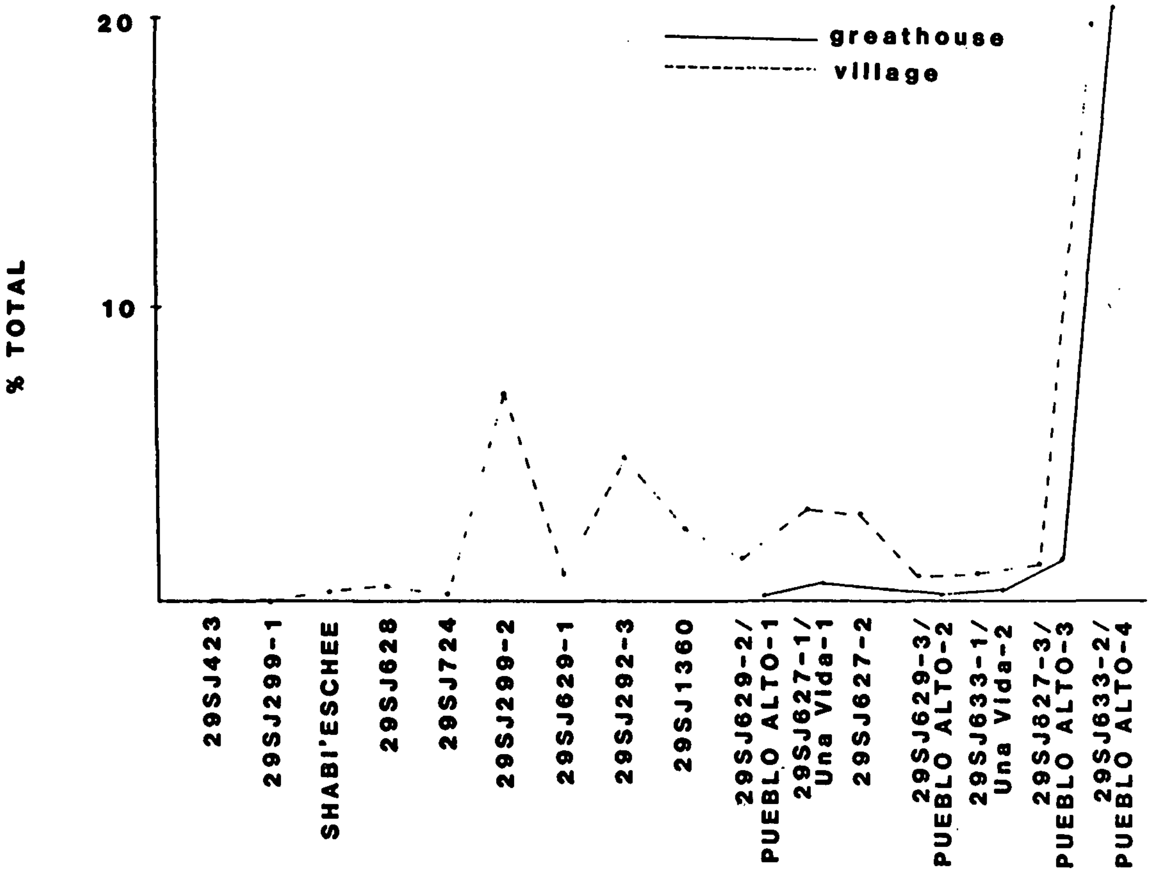


Figure 7.7 Turkey, Wild Bird, and Aves Percent of the Total Sample



note: Pueblo Alto A.D. 1120 to 1220 is represented by two samples. The A.D. 1120 to 1200 sample consists of Other Structure 6; Kiva 10 levels 15-27; Kiva 15 floor fill; Kiva 16; Room 112 subfloor fill; and Room 143 Floor 1 fill. The post-A.D. 1200 sample is from the East Plaza Units 1 and 2, Surface 1; Room 142 roof fall; Room 146 roof fall; Room 147 Floor 1 associations.

Figure 7.8 Turkey Percent of the Total Sample in Greathouse Versus Village Sites

Table 7.26 Burning Percentages for Turkey, the Wild Birds, and Aves

Site	n=	Unburned	Cooking Brown	Slight Burn	Partial Burn	Complete Burn
Turkey						
Una Vida	17	100.0				
Pueblo Alto	987	86.8	.2	4.5	1.3	7.2
Shabik'eshchee	1	100.0				
29SJ 299	10	100.0				
29SJ 627	190	93.7*	2.1	2.6	.5	1.0
29SJ 628	24	100.0				
29SJ 629	54	-------100.00------				
29SJ 633	766	--------96.7-------		------------3.3------------		
29SJ 724	1	100.0				
29SJ 1360	18	88.9	5.5			5.5
* 88.4% of the mature turkey elements						
Wild Bird						
Una Vida	15	93.3	6.7			
Pueblo Alto	473	93.9	2.3	.6	1.5	1.7
Shabik'eshchee	2	100.0				
29SJ 299	1				100.0	
29SJ 423	5	100.0				
29SJ 627	18	100.0				
29SJ 628	143	99.3	.7			
29SJ 629	27	--------96.3-------		------------3.7------------		
29SJ 633	25	-------100.0-------				
29SJ 724	31	100.0				
29SJ 1360	10	100.0				
Unidentified Birds						
Una Vida	54	94.4	5.6			
Pueblo Alto	427	83.3	3.8	2.4	.9	9.8
Shabik'eshchee	1	100.0				
29SJ 299	5	100.0				
29SJ 423	2	100.0				
29SJ 627	125	84.8	3.2	.9		12.0
29SJ 628	7	100.0				
29SJ 629	39	------97.4--------		------------2.6------------		
29SJ 633	3	-----100.0--------				
29SJ 724	4	100.0				
29SJ 1360	29	96.5				3.4

Note: The brown discoloration referred to as "cooking brown' may mean something different for birds than mammals. Bird bone appears to take on the coloration for different reasons and is more likely a condition of deposition.

definite burning deter him from concluding turkey was eaten on the Wetherill Mesa.

Evidence of butchering (Table 7.27) that might have resulted from removing the heads and feet before roasting or to fit a large bird into a cooking pot is extremely rare. Cut marks and portions removed from the longbones are generally the result of bead or tube manufacture rather than disarticulation. The recorded articulations (Table 7.28) are mainly wings and feet. Both hold little meat and the lower wing bones may represent feather fans or could have been set aside for ornament manufacture.

Large portions of thorax suggest the bird was discarded in the flesh. Another indication of discard without consumption is the presence of muscle splints. A fair number were recovered from Pueblo Alto (117 or 11.8% of the elements) and some from 29SJ 627 (9 or 4.7%).

Body Part Representation

The majority of the aves (unidentified bird) elements (Table 7.29) are longbone or unknown fragments indicating a fair amount of breakage. The parts that are rare and not accountable in the identified taxa are the skull, vertebral, and thorax elements that were possibly crushed and became the unknown fragments. Dogs could have caused a considerable amount of crushing at some sites.

In general the minimum or site MNIs are small. These include only mature and non-articulated birds. No patterns are apparent across the sites.

Raising Turkeys

Domestic turkeys can breed at one year of age. In the wild, egg laying begins in April and all eggs are usually hatched by mid-May (Schorger 1966). While domestic breeds have longer periods of laying, those in Chaco Canyon were probably limited by the weather and similar in breeding habits to the wild birds. A wild hen can lay up to 30 eggs, usually in two groups. Clutches of up to 15 are possible. Incubation lasts 28 days and the eggs are usually all hatched with 24 hours. The first 10 to 14 days are the most critical, when wet conditions and chilling may kill them (Schorger 1966).

Hens at the sites were undoubtedly provisioned with food and water throughout the incubation period; therefore, immatures at a site suggest deliberate raising of the birds. May temperatures at Chaco are cool and losses were probably heavy. One instance at 29SJ 627 where eight two-week old poults were found just above the floor of a pit structure suggests they were penned and died of exposure or were tossed into the vacant structure after dying elsewhere.

Egg shell is not as good an indicator of raising turkeys as immature turkey bones. The eggs could have been collected from wild birds or

Table 7.27 Butchering Marks Found on Turkey and Aves Elements

Site	Taxon	n=	Element	Mark
Pueblo Alto	turkey	1	cervical vertebra	portion removed
		2	tibia - shaft	portion removed
		1	tarsal	portion removed
	Aves	1	tibia - shaft	light cuts
		1	longbone - shaft	portion removed
29SJ 627	turkey	1	tarsometatarsus - prox.	portion removed
	Aves	1	unknown fragment	portion removed
29SJ 629	turkey	1	tarsometatarsus - shaft	portion removed
29SJ 633	turkey	1	tibiotarsus - shaft	light cuts

Table 7.28 Turkey Articulations

Site	Articulation
Pueblo Alto	right wing: radius, ulna, carpometacarpus
	right wing: radius, ulna
	vertebral column
	ribs, sternum, furculum
	right foot: tarsometatarsus, digits
	right foot: tarsometatarsus, digits, muscle splints
29SJ 629	wing (3)
	foot (4)
29SJ 633	right wing: humerus, radius

Table 7.29 Aves Element Distribution and Turkey Body Part Representation

Unidentified Bird (% of elements)

	Una Vida	Pueblo Alto	Shab. Vil.	29SJ 299	29SJ 423	29SJ 627	29SJ 628	29SJ 724	29SJ 1360
skull	1.8	1.4							
mandible		1.2							
cervical vert.		2.8				.8			3.4
vert. column	3.7	2.3				.8	14.3		
thorax	7.4	2.3	100.0	20.0		4.0			
rib	3.7	19.9		20.0		12.0	14.3		
innominate		1.2				1.6			
wing	1.8	4.4		20.0	50.0	4.8			3.4
leg	1.8	1.2				.8	42.8		6.9
foot	1.8	2.1			50.0	3.2			
muscle splint	22.2	.7				2.4			
longbone	35.2	34.0		40.0		56.0			86.2
unknown	20.4	26.2				13.6	28.6	100.0	
n=	54	427	1	5	2	125	7	4	29

Turkey (% of body part represented)

	Una Vida	Pueblo Alto	Shab. Vil.	29SJ 299	29SJ 627	29SJ 628	29SJ 633	29SJ 724	29SJ 1360
skull	100	56			60		11		
mandible	50	12			40		22		
cervical vert.	50	25			20		?		50
vert. column	50	81			20	50	?		
thorax	25	100		50	30	50	94		50
innominate	25	41			20	50	28		25
wing	50	69		100	80	25	72		75
leg		62		100	20	75	94	50	50
foot		34	50	50	30	50	100		50
MNI	2	16	1	1	5	2	9	1	2
# elements	17	934	1	6	103	16	766	1	18

Note: The MNIs and body parts represented do not include immature elements or articulated skeletons; paired elements are in one half of an individual.

traded. They are also extremely vulnerable to collection biases making quantitative comparisons tenuous.

Tables 7.30 and 7.31 give available information on ages. Bones of immature individuals were found in a large number of sites and definitely suggest that turkeys were raised throughout the canyon with varying degrees of success. Sites that have fair sample sizes and few immature elements could suggest that the birds were imported as adults, possibly for consumption. This may be true for Pueblo Alto A.D. 1120 to 1220, Pueblo Bonito, Una Vida, and Kin Kletso. Unfortunately element percentages are not available for 29SJ 633, but Table 7.31 does suggest that the majority of the birds were mature.

Some sites have a fair number of immature birds represented and a variety of age groups that include birds past the more critical period for survival. Poults in the 6 to 11-month age group may have succumbed to winter weather. The Pueblo Alto (A.D. 1020 to 1120) assemblage includes 42 elements from the trash mound. Immatures made up 88.1% of these and were apparently tossed out with the domestic trash.

A range of ages was found at Mound 7 of Gran Quivira (McKusick 1981) along with no evidence of butchering. Turkey made up 26% of that collection, and it was concluded that the birds had been kept for their feathers.

Articulated Skeletons

Skeletons of turkeys have been found in several Chaco sites (Table 7.32), as a result of both the disposal of dead birds in abandoned structures and the ceremonial disposal of them. Only Bc 50 (Hibben 1937) had consistent evidence of the latter. Headless female birds were found on the floor between the deflector and ventilator shafts of five kivas. Only one appears to have been afforded a burial. Most were tossed into a convenient location and some survived canine ravages.

Summary

The presence of immature turkey elements suggests that they were at a few sites beginning in the late eighth century. The numbers remained low with a slight increase then decrease in Pueblo II. Percentages were lower at the greathouses than villages at that time and continuing into Pueblo III. In the early thirteenth century the percentages balloon in both the greathouse and village sites with deposits from this time period. It is only during this latter that we have the numbers, the age distribution, and the burning pattern to suggest that turkey was used as a food source.

Turkey elements scattered throughout an archeological site have often been interpreted as proof they were eaten (Hargrave 1965). For turkeys to have made much of a contribution to the diet a number of conditions should be met. Economic species should occur in fair numbers. This is simply not true in most of the recent excavated sites--in only two cases do they exceed 10% of the identified elements. Disarticulation in sites with dogs

Table 7.30 Turkey Age Distribution

% of Elements

Site	n=	% Mature	% Immature
Una Vida	17	100.0	
Pueblo Alto	987	94.6	5.4
[920-1020]	3	100.0	
[1020-1120]	68	41.2	58.8
[1120-1220]	878	98.5	1.5
Shabik'eshchee	1	100.0	
29SJ 299	10	90.0 [2]	10.0 [1]
29SJ 627	190	54.2	45.8 [6]
samples:			
[1000-1050]	65	9.2	90.8 [6]
[1050-1080]	15	13.3	86.7
[1130-1220]	15	100.0	
29SJ 628	24	66.7	33.3
29SJ 724	1	100.0	
29SJ 1360	18	100.0	
[McKusick n.d.]			
Bc 50	14	100.0	
Bc 53	7	100.0	
Bc 236	19	100.0	
Bc 288	7	100.0	
Bc 362	40	82.5	17.5
Una Vida	56	92.9	7.1
[Hargrave n.d.]			
Bc 236	45	100.0	
Leyit Kin	69	62.3	37.7
Kin Kletso	191	100.0	
Pueblo Bonito	109	93.6	6.4
[Hargrave archeo-ornothology files]			
Bc 50	29	100.0	
Bc 51	19	89.5	10.5
Bc 362	58	79.3	20.7
Chetro Ketl	29	89.6	10.3
Kin Kletso	212	100.0	
Leyit Kin	12	83.3	16.7
Talus Unit	83	94.0	6.0
Una Vida	946	97.1	2.8

[an articulated skeleton counted as one element]

Table 7.31 Ages of Turkeys Represented in Chaco Canyon Sites

Age Distribution

Site	MNI n=	Ages
Pueblo Alto		
1020-1120	5	less than 1 week
	1	3 to 5 weeks
1120-1220	2	2 to 3 days
	1	3 weeks
	1	less than 4 weeks
	2	immature
	11-61	mature, 5+ males
29SJ 299	1	immature
	3+	mature
29SJ 627	2	less than 3 days
	8	2 weeks
	1	4 weeks
	1	less than 2 months
	1	6 months
	5+	mature, 3+ males
29SJ 628	1	3 days
	1-2	mature
29SJ 629	3	4 to 5 weeks
	1	4 months
	3+	mature
29SJ 633	2	1 week
	10+	mature
Bc 50 (Hargrave archeo-ornothology file)		
	1	about 20 days
	1	less than 5 months
Bc 362 (McKusick n.d.)		
	1	less than 5 months
	1	3 to 5 months
	1	6 to 11 months
Chetro Ketl (Hargrave archeo-ornothology file)		
	1	less than 1 month
	1	9 to 11 months
Leyit Kin (Hargrave and Dodgen 1962)		
	1	less than 1 month
	1	less than 5 months
	2	6 to 11 months
Una Vida (McKusick n.d.)		
	1	less than 1 month
	1	3 to 5 months
	1	6 to 11 months

Table 7.32 Turkey Skeleton Found in Chaco Canyon Sites

Site	n=	Location/comments
Pueblo Alto	1	an irregular pit in the trash mound; it was not in the analyzed sample - age, sex, and completeness are not known
29SJ 299	2	floor of pitstructur; mature
	1	fill of a surface room; partial; mature
29SJ 627	8	pitstructure just above floor; 2 weeks old
29SJ 628	1	fill of pithouse: fragmentary; 3 days old
	1	fill of pithouse: fragmentary; mature
29SJ 629	3	plaza pit; 4 to 5 weeks old
	1	same plaza pit; partial; mature male
	1	plaza grid; partial; mature
	1	trash midden; partial; about 4 months
Bc 50 (Hibben 1937)	5	1 each in 4. 2 in 1 kiva - between the deflector and ventilator; females with skulls missing
Bc 235 (Hargrave archeo-ornithology files)	1	in a pit on the west side of the ruin; partial
Pueblo del Arroyo (Hargrave archeo-ornithology files)	2	Room 50; complete; 1 with skull cap removed
(Judd 1954)	1	Room 64; partial
Talus Unit (Hargrave archeo-ornithology files)	1	Kiva J; feet missing
Una Vida (Vivian and Mathews 1965)	7-8	Room 45; not burials, tossed into a room

(and humans) is not adequate proof, nor is the raising of turkeys. The expense generated in raising a bird to adulthood or keeping it for any length of time is not justified if it is only to be eaten. It takes only 20 days of feeding an adult bird to use up its equivalent in protein from corn. If the birds were mainly for eating, it would have been more economical to import large birds that would be kept for only a few days.

Wild Birds

At least 30 species of wild bird (birds other than turkeys and macaws) have been recovered from the recently excavated sites. Twenty-six of these occurred at Pueblo Alto. Nine are small birds that have seldom been found with previous excavation techniques.

Uses for wild birds fall primarily into two categories: food and ceremonial. There are few specific ethnographic references that identify the birds that were eaten. Vivian and Mathews went so far as to say "no ethnographic references were found to the eating of any of these [the most commonly utilized birds from Chaco sites]" (1965:22). Judd states that "...the Pueblos have always shunned winged creatures as a source of food" (1954:266). However, Henderson and Harrington (1914) note that mourning doves and blackbirds were eaten by the Tewas; and Beaglehole (1936) reports that all species of birds were snared, suitable feathers were used for dance costumes, and the flesh of the larger birds was roasted and eaten by the Hopis. Most sources agree that hawks and eagles were not eaten (Beaglehole 1936; Henderson and Harrington 1914; Judd 1954; Vivian and Mathews 1965).

Probably the most important use of wild birds was to provide feathers for ceremonies. Judd noted the importance of prayer sticks and that each ritual had its own kind of prayer stick:

> No two are precisely alike, but all or nearly all require feathers--feathers from designated parts of certain birds. Turkey feathers, and preferably wild turkey, are utilized most frequently, yet I would venture to guess that every other bird native to the Southwest except, possibly three carrion-feeders--the crow, raven, and turkey buzzard--is likewise called upon (1954:262-263).

Vivian and Mathews (1965) list 25 species of birds (other than turkeys, eagles, and hawks) that were used ethnographically as skins, feathers, or in carved representations. Many of the species on this list were found in the sites. They also note that carved or stuffed birds of the smaller species are common on Zuni Shalako altars, and at Acoma the K'ashale altar was decorated wih stuffed wrens and mockingbirds during scalp ceremonies. At Hopi the manufacture of prayer sticks was an "overriding occupation," with these offerings made for every conceivable purpose and on every occasion (Vivian and Mathews 1965:21). Prayer feathers were important parts of masks and ceremonial costumes, used in altar arrangements, and placed in fields at planting time. Prayer sticks were specially made and expended within a few days of manufacture (Judd 1954), producing a perpetual need.

A crude, irregularly shaped pit in the northeast corner (Plaza Grid 30) of the plaza at Pueblo Alto suggests that the ceremonial use of feathers was equally important prehistorically. This partially excavated pit contained a total of 891 bones in less than one cubic meter of dense Red Mesa (Early Pueblo II) fill. Of these, 270 were from wild birds and most were hawk or eagle. While the materials from this pit comprise only 2.9% of the total elements analyzed from Pueblo Alto, they constitute the following percentages of that taxon from the site: *Buteo* sp. 91.6%, rough-legged hawk, 100.0%, ferruginous hawk 66.7%, red-tailed hawk 79.4%, Swainson's hawk 85.7%, golden eagle 55.4%, raven 27.3%, and the blue birds 33.3%.

The species distribution, the large number of wing and foot articulations, and the butchering marks on the wing elements are unusual. Wing elements account for 59.8% of the elements (or 17 left and 12 right wings), leg for 29.7% (or 5 left and 7 right legs), and axial parts for 8.9%. Only the eagle and unidentified taxa are represented by skull and other axial portions. The wings and feet may have been parts of costumes that were disposed of at the end of a ceremony. Several ornaments including a pendant and beads of calcite, argillite, and *Spondylus* were also found (Mathien 1981). The ratio of cottontail rabbit to jack rabbit bones in the pit is very similar to that in the construction debris found in the trash mound and the deposit could have marked the construction or completion of Pueblo Alto.

Relative Numbers

Table 7.33 gives the element distribution for the sites. Pueblo Alto had the largest number by far, but 270 came from a single feature. The majority of the wild birds from all sites were hawks, eagles, or falcons (73.1%), species that were most likely to be utilized for feathers. Not surprising, the red-tailed hawk (a regular year-round resident of the canyon) is the most common. Golden eagles (uncommon migrants) are also relatively numerous suggesting that they were sought out and some were probably obtained by capture or traded. The rough-legged hawk and sandhill crane have not been reported in the park and are also good prospects for import.

The two other commonly found taxa are the horned lark (*Eremophilia alpestria*) and the common raven (*Corvus corvus*). While the shiny black feathers of the raven may have been used, there is little about the lark that suggests its feathers would be used. An articulated lark skeleton was found in a posthole of Plaza Feature 1, a communal structure at Pueblo Alto and may suggest some ceremonial significance. On the other hand, both are common year-round residents and may have been trapped as field pests.

Figures 7.6 and 7.7 suggest more wild bird utilization earlier in the time sequence. Sample size and collections practices can account for much of the greater diversity at Pueblo Alto. There is no overwhelming evidence, on the basis of these samples, of differences between the greathouse and village sites.

Table 7.33 Number of Wild Bird Elements and Percent of the Bird by Site

	Una Vida		Pueblo Alto		Shabik. Village		29SJ 299		29SJ 423		29SJ 627		29SJ 628		29SJ 629		29SJ 633		29SJ 724		29SJ 1360		total bird
	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#
duck or goose									1	20.0							1	4.0					2
mallard duck			3	.6																			3
hawk or eagle	1	6.2	10	2.1											1	3.6			1	3.2			13
Buteo sp.			120	25.4					2	40.0	6	33.3	3	2.1	12	42.8	5	20.0	5	16.1	3	60.0	156
rough-leg. hawk			1	.2																			1
ferruginous hawk			3	.6							2	11.1	51	35.7					18	58.1			74
red-tailed hawk			126	26.7									39	27.3	2	7.1			3	9.7			170
Swainson's hawk			6	1.3																			6
eagle	1	6.2																					1
golden eagle	1	6.2	82	17.4							6	33.3			11	39.3	1	4.0	2	6.4			103
bald eagle																			1	3.2			1
marsh hawk													4	2.8									4
falcon									1	20.0													1
prairie falcon																					1	20.0	1
American kestrel			14	3.0																			14
quail			7	1.5					1	20.0							12	48.0					20
sandhill crane			1	.2									2	1.4	1	3.6							4
mourning dove			4	.8																			4
screech owl			3	.6																			3
great horned owl											2	11.1					2	8.0					4
hummingbird			1	.2																			1
common flicker			3	.6																			3
PASSERIFORMES	6	37.5	16	3.4																			22
horned lark	2	12.5	17	3.6	1	50.0					1	5.5					1	4.0					22
swallow			1	.2																			1
Corvidae			1	.2																			1
pinyon jay			7	1.5																			7
black-billed magpie	12	2.5																					12
common raven			11	2.3	1	50.0	1	100.0			1	5.5	3	2.1	1	3.6	1	4.0			1	20.0	20
black bird/oriole	2	12.5	7	1.5																			9
blue birds			3	.6															1	3.2			4
Fringillidae	3	18.7	7	1.5																			10
shrikes			3	3.6																			3
junco			1	.2																			1
towee			2	.4													2	8.0					4
lost bird *													41	28.7									41
total	16		472		2		1		5		18		143		28		25		31		5		746
% ided		.7		2.8		.9		.4		.6		.5		3.2		1.9		1.0		8.0		1.2	
% total		.5		1.5		.6		.3		.2		.3		2.9		1.0		.6		6.6		.7	
# species	6		26		2		1		4		5		5+		4		5		5		3		

* lost bird: these elements were sent to McKusick and were lost before the identifications could be made

Processing

Burning was infrequent but occurred at some sites for some taxa (Table 7.34). Partial burning of red-tailed hawk, eagle, Passeriformes, magpie, pinyon jay, and raven suggest that some may have been roasted and eaten; however, the mid-sized birds most readily available (e.g., quail, mourning dove, pinyon jay, and raven) are not common in archeological sites, supporting the conclusion that they were not actively sought for food.

The butchering marks and articulations (Table 7.35) suggest ceremonial use. All of the butchering marks and the articulated elements from Pueblo Alto are from Plaza Grid 30. The marks are so small that a microscope was needed to detect them. Obvious care was taken to disarticualte the radius and ulna from the humerus. The cut on the radius of the Swainson's hawk ran the length of the element indicating that the skin and associated feathers were removed.

Body Part Distribution

Hargrave (1970) points out that groups of related material are important in determing how a bird was used. The closely associated head and wings of a bird may represent a stuffed bird skin; the closely associated body bones of a bird may indicate that a bird skin had been prepared and the flesh-covered body discarded. The presence of several wing bones (but not the humerus) suggests a fan was used.

Even if birds were used ceremonially after being processed at the site, all of the body parts should be represented. Birds that were kept and routinely plucked but not eaten may also be found. The body part distribution from ceremonially utilized birds may not differ significantly from that which might result from consumption.

Table 7.36 gives the body part distributions for the wild bird taxa with sample sizes over 20. Although wings, legs, and feet are the best represented, they are also the least susceptible to destruction and the most easily identified. When a fair sample of bones is recovered most or all parts are represented. The sample size and different potential for breakage are largely responsible for the distribution observed in sites with small samples. Attention to the association of articulated elements may be our best clue to utilization of the wild bird taxa.

Summary

A variety of wild bird species has been recovered from Chaco Canyon sites. The majority of the elements are hawk, eagle, or falcon and were most likely utilized primarily for their feathers. More use of these species is indicated for the earlier time periods, perhaps being replaced by turkey as that taxon became increasingly available.

Table 7.34 Wild Bird Burning for the Sites and Taxa in Which it Occurs

Site/Taxon	n=	No Burn	Cooking Brown	Slight Burn	Partial	Complete
Una Vida						
PASSERIFORMES	6	83.3	16.7			
Pueblo Alto						
red-tailed hawk	126	93.6	.8		1.6	4.0
golden eagle	82	91.6	3.6		2.4	2.4
PASSERIFORMES	16	87.5	6.2	6.2		
magpie	13	92.3			7.9	
pinyon jay	7	85.7		14.3		
raven	11	45.4	27.3		18.2	9.1
Fringillidae	7	85.7	14.3			
29SJ 423						
duck sp.	1		100.0			
Buteo sp.	2	50.0	50.0			
quail	1		100.0			
29SJ 628						
red-tailed hawk	39	97.4	2.6			
20SJ 629						
Buteo sp.	12	------91.7------		----------8.3-----------		

Table 7.35 Butchering Marks and Articulations for the Wild Birds

Processing	n=	Element	
Butchering Marks:			
Pueblo Alto			
red-tailed hawk	3	radius	light cuts - proximal
	9	ulna	light cuts - proximal
Swainson's hawk	1	radius	light cuts - length of shaft
golden eagle	1	ulna	light cuts - proximal
common raven	1	ulna	light cuts - proximal
Articulations:			
Pueblo Alto			
red-tailed hawk	3	right wing:	radius/ulna to tip
	4	left wing:	radius/ulna to tip
	1	right wing:	radius/ulna
	2	left wing:	radius/ulna
	4	right leg:	tarsometatarsus to talons
Swainson's hawk	1	left wing:	radius/ulna and carpometacarpus
ferruginous hawk	1	left wing:	radius/ulna
eagle	2	left wing	radius/ulna and carpometacarpus
	1	right wing:	radius/ulna and carpometacarpus
	1	right wing:	radius/ulna
horned lark	1	skeleton	in a posthole
shrike	2	skeletons	in an abandoned room
29SJ 724			
ferruginous hawk	1	left foot:	tarsometatarsus and digits

Table 7.36 Body Part Distribution for Wild Bird Taxa with Sample Sizes over Twenty

	Buteo sp. (% of elements)								Lost Bird	Ferruginous (% of MNI)				Red-tailed Hawk (% of MNI)			
	Pueb. Alto	29SJ 423	29SJ 627	29SJ 628	29SJ 629	29SJ 633	29SJ 724	29SJ 1360	29SJ 628	Pueb. Alto	29SJ 627	29SJ 628	29SJ 724	Pueb. Alto	29SJ 628	29SJ 629	29SJ 724
skull															50		
mandible									2.4								
cerv. vert.									2.4						100		
vert. col.	2.5								12.2			50					
thorax	4.2	50.0			8.3				14.6			25	100	9	50	50	
innominate	1.7				8.3				2.4			50			50		
scap/hum.	.8				8.3				7.3		50	50		4	75	50	
wing	1.7			66.7					17.1	50		25	50	86	50		50
wing digits	48.7	50.0	50.0			80.0		66.7	4.9			25		32			
leg	1.7			33.3	25.0				7.3	50	50	50	25	9	75		
foot	38.6		50.0		50.0	20.0	100.0	33.3				50		41	100		
unknown									29.3								
MNI										1	1	2	2	11	2	1	1
n=	120	2	6	3	12	2	5	3	41	3	2	51	18	126	39	2	3

	Golden Eagle (% of MNI)						Quail (% of MNI)			Horned Lark (% of MNI)					Raven (% of MNI)							
	Una Vida	Pueb. Alto	29SJ 627	29SJ 629	29SJ 633	29SJ 724	Pueb. Alto	29SJ 423	29SJ 633	Una Vida	Pueb. Alto	Shab. Vil.	29SJ 627	29SJ 633	Pueb. Alto	Shab. Vil.	29SJ 299	29SJ 627	29SJ 628	29SJ 629	29SJ 633	29SJ 1360
skull		25																				
mandible		37								100												
cerv.vert.		25																				
vert. col.		25																				
thorax		25	50	50			100		50		100		50									50
innominate		12	50				100	50														
scap./humer.		25							100		75	50		50				50	100	50		
wing		100	50	75		50	100		25	50	75				75	50						
wing digits		37	50	25	50																	
leg		37		25					50		25						50		50			
foot	50	12		25		50	50		25		25				25						50	
MNI	1	4	1	2	1	1	1	1	2	1	2	1	1	1	2	1	1	1	1	1	1	1
# elements	1	82	6	11	1	2	7	2	12	2	16	1	1	1	11	1	1	1	3	1	1	1

Distributional Changes

The sites used in this analysis are complex architecturally and stratigraphically; they have a wide range of sample sizes (from 26 to 30,509 elements) and were subject to varying collection strategies. The provenience divisions within the sites were site specific.

When considering an archeological assemblage of any kind it is important to remember that the sample considered is just that--a sample--particularly with regard to faunal remains which undergo a number of different filtering processes. There are no guarantees that the sample is an accurate reflection of the population or that all individuals (or all of the taxa) used as food are represented in the faunal assemblage. For example, parts of larger animals are more likely to be selectively returned (i.e., the Schlep Effect [Wing and Brown 1979:150]); elements of some species or of those taken on certain occasions may have been deposited outside of the site area; larger elements are not only more visible during excavation but take longer to be buried and therefore may be moved around more in a site than those of smaller animals; the local dog population probably affects the distribution of some body sizes more than others; and the size of the dog population at any one site is likely to have been different from the others. Bone is also a raw material for tools and could have been traded just as lithic raw materials were. It is not possible to compensate for the myriad of factors that condition our final sample. We can assume these provided a relatively constant effect throughout the samples involved, remembering that our conclusions are no more than suggestions based on those samples and some personal biases.

The most "damaging criticism" for the use of the NISP as the measure of taxonomic abundance is that the counts assume each item is independent of every other one (Grayson 1981). Bones do break and more than one fragment of a bone is usually identifable. The use of MNIs as a measure of taxonomic abundance includes not only that assumption but one that every individual (one MNI) is independent of all others (i.e., an element from the front limb of one taxon is not from the same individual as another element from a front limb of the same taxon in the room next door). The total MNI is largely a function of the sample size as well as of the number and size of the provenience divisions (or aggregates) used to calculate the MNI. Changes in abundance produced by the use of different aggregates of the same sample may occur differentially across taxa (Grayson 1981).

The estimated MNI and the estimated economic species MNI are closely related to the sample size (r^2=0.84 and 0.97 respectively) for these sites; however, the estimated MNIs are also related to the number of provenience units used to divide the sites and calculate the MNI (r^2=0.87). Any analysis based on the estimated MNIs for these sites monitors the effect of sample size and the number of provenience units. It is more appropriate to use the NISP without the effect of the number of provenience divisions for the analysis. Appendix 2 gives the complete faunal tabulations including the NISP, the site or minimum MNI, the estimated or additive MNI, and the number of provenience divisions for each site.

Economic Contribution

An economic breakdown based on the MNIs for small mammals and butchering units for carnivores and large mammals can be found in Appendix 4 with an explanation of the derivation in Appendix 3. These were routinely calculated for all Chaco sites on a site-by-site basis. Because these were calculated for the site rather than by chronologic units much information on changes through time has been lost. The MNIs and butchering units are based on provenience units and susceptible to the problems stated above.

The NISP will be used as the basic numerical unit to evaluate the contribution of the economic taxa. Since a variety of body sizes is represented, a means by which to compare the different taxa is necessary. Table 7.37 illustrates a way of scaling the body sizes. The NISP is multiplied by a constant that is 0.01 of the estimated meat weight for that taxon. The arbitrary figure 0.01 merely reduces the numbers to a manageable size. When the percentages are compared, any constant can be used. The estimated meat weights were derived by Gillespie (1981a) from the live weight and percent of usable meat for each species.

The object is not to determine actual amounts of meat represented but to arrive at relative figures for comparative purposes. The rodents are not included because of sampling problems at many of the sites; their potential contribution has been shown to be quite low in even the better sampled sites (Appendix 4). Not all of the carnivores were used. The canids, including *Canis* sp., coyote, and dog, are lumped and an average of the two weights used as the constant. Bobcat and badger occur often enough, and with some evidence of processing, and are included. Elk was left out because, even scaled, the effect of such a large animal on those assemblages with smaller sample sizes was inordinate and not likely to be representative. Turkey is presented for all sites even though the likelihood of its use as a food source is low until late in time. The very immature elements (foetal to a third of adult size) of pronghorn, deer, turkey, the canids, and the articulated skeletons are not included in the calculations. It is assumed that most of these were not eaten and even if they were would not represent the same amount of meat. The number of immature elements was not available for 29SJ 633 and has an undeterminable effect from those sites.

Graphs of the weighted percentages differ considerably from those using frequencies (compare Figures 7.1 and 7.2 with Figure 7.9, and Figures 7.3 and 7.4 with 7.10). There are anomalies including peaks, narrow peaks, and plunges that may have implications for changes is subsistence, may correlate with other happenings in the canyon, or may result from collection or sampling practices. Two ways in which the latter may occur include (1) poor collections that result in over-representation of the artiodactyls and the carnivores; or (2) violations of the assumption of independence in small samples that result in the contribution of some taxa appearing inordinately large. These would affect individual samples and appear as anomalies.

Table 7.37 Comparative Frequencies Weighted by .01 of the Estimated Meat Weight

	Cottontail		Jack		Pr. Dog		Small	Canid		Bad/Bob.		Carn.	Deer	
Constant	3.8		11		3.7			45		50			332	
	g	%	g	%	g	%	%	g	%	g	%	%	g	%
Una Vida														
950-1050	1987	9.5	4455	21.3	778	3.7	34.5	630	3.0	450	2.1	5.1	2324	11.1
1050-1220	403	4.7	1518	17.7	196	2.3	24.7	135	1.6			1.6	4980	58.0
Pueblo Alto														
920-1020	3823	11.5	7667	23.0	659	2.0	36.5	1035	3.1	450	1.3	4.4	9628	29.0
1020-1120	12293	6.6	26598	14.3	3670	2.0	22.9	315	.2	150	.1	.3	119520	64.5
1120-1220	5453	4.1	16181	12.3	5102	3.9	20.3	180	.1	400	.3	.4	47144	35.9
Shabik'eshchee														
600-750	391	3.9	396	3.9	15	.1	7.9	270	2.7	200	2.0	4.7	1660	16.5
29SJ 299														
600-700	141	11.0	297	23.1	22	1.7	35.8	45	3.5	50	3.9	7.4		
780-820	137	18.2	440	58.6	37	4.9	81.7	45	6.0			60.0		
920-1020	11	1.6	77	11.4	4	.6	13.6	90	13.3	50	7.4	20.7		
29SJ 423														
500-600	2238	25.0	1067	11.9	22	.2	37.1	945	10.6	150	1.7	12.3	996	11.1
29SJ 627														
1000-1050	1642	7.4	4565	20.6	178	.8	28.8	1395	6.3	200	.9	7.2	7304	33.0
1050-1080	205	1.3	2013	12.7	7	-	14.0	45	.3	100	.6	.9	9960	62.7
1130-1200	205	.6	1683	5.3	562	1.8	7.7	315	1.0			1.0	13944	43.9
29SJ 628														
700-820	7760	13.1	18887	31.8	647	1.1	46.0	3195	5.4	1950	3.3	8.7	5312	8.9
29SJ 629														
850-950	1034	10.5	2189	22.3	266	2.7	35.5	4455	45.4	50	.5	45.9	996	10.1
975-1040	148	1.9	1287	16.4	222	2.8	21.1	585	7.5			7.5	3220	41.1
1100-1150	68	2.8	286	11.6	107	4.3	18.7	90	3.7			3.7	1328	54.1
29SJ 633														
1020-1120	338	23.7	253	17.7	52	3.6	45.0	135	9.4	50	3.5	12.9		
1220-1250	3659	15.3	3509	14.6	488	2.0	31.9			150	.6	.6	332	1.4
29SJ 724														
780-820	505	16.6	1958	64.3	67	2.2	83.1	45	1.5	50	1.6	3.1		
29SJ 1360														
920-1020	148	.7	1595	7.2	92	.4	8.3	2925	13.2	50	.2	13.4	4648	20.9

Note: Articulated skeletons and immature deer, pronghorn, dog and turkey are not included (except for 29SJ 629 and the dog and turkey from 29SJ 633 - those may be overestimations).

Table 7.37 continued

Constant	Pronghorn 199 g	%	Mt. Sheep 332 g	%	Artio. %	Turkey 23 g	%	total g
Una Vida								
950-1050			9960	47.5	58.6	368	1.8	20952
1050-1220			1328	15.5	73.5	23	.3	8583
Pueblo Alto								
920-1020	2985	9.0	6972	21.0	59.0	69	.2	33288
1020-1120	8955	4.8	13280	7.1	76.4	552	.3	185333
1120-1220	12537	9.5	24568	18.7	64.1	19895	15.1	131460
Shabik'eshchee								
600-750	5771	57.4	1328	13.2	87.1	23	.2	10054
29SJ 299								
600-700	398	31.0	332	25.8	56.8			1285
780-820						92	12.2	751
920-1020	398	58.9			58.9	46	6.8	676
29SJ 423								
500-600	2189	24.5	1328	14.9	50.5			8935
29SJ 627								
1000-1050	4378	19.8	2324	10.5	63.3	138	.6	22124
1050-1080	1194	7.5	2324	14.6	84.8	46	.3	15894
1130-1200	2388	7.5	12284	38.7	90.1	345	1.1	31726
29SJ 628								
700-820	11343	19.1	9960	16.8	44.8	368	.6	59422
29SJ 629								
850-950	199	2.0	332	3.4	15.5	299	3.0	9820
975-1040	1194	15.2	996	12.7	69.0	184	2.3	7836
1100-1150	199	8.1	332	13.5	75.7	46	1.9	2456
29SJ 633								
1020-1120	199	13.9	332	23.2	37.1	69	4.8	1428
1220-1250	199	.8			2.2	15617	65.2	23954
29SJ 724								
780-820	398	13.1			13.1	23	.7	3046
29SJ 1360								
920-1020	10348	46.6	1992	9.0	76.5	414	1.9	22212

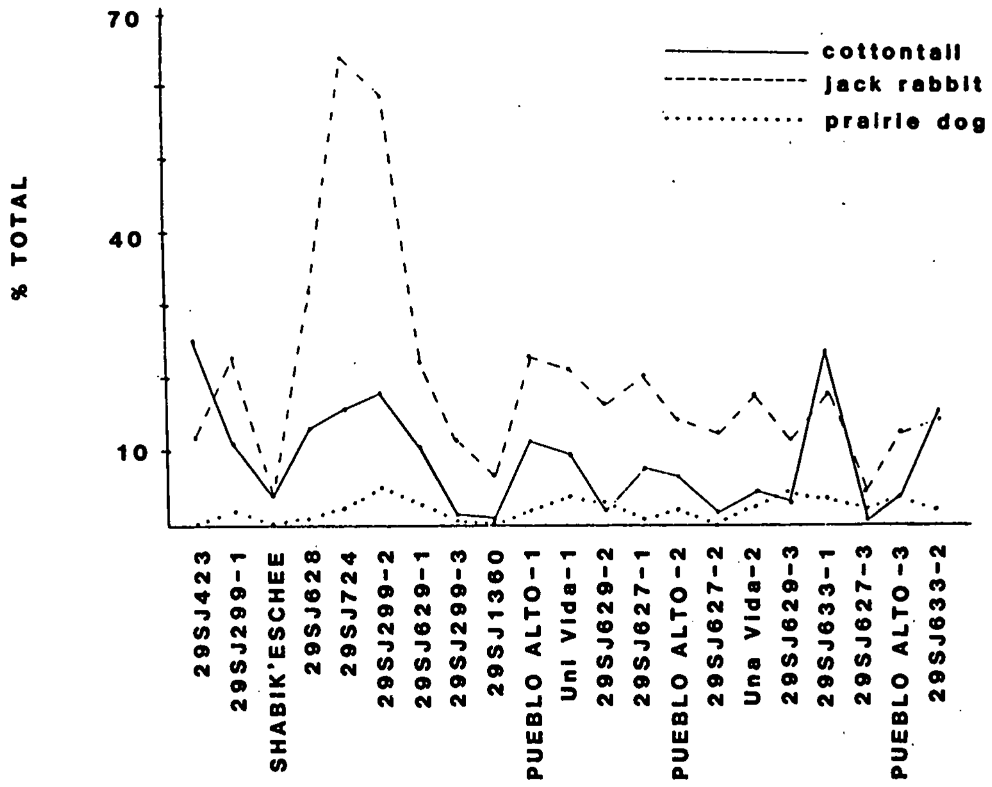


Figure 7.9 Percent of the Weighted Frequencies for Cottontail, Jack Rabbit, and Prairie Dog

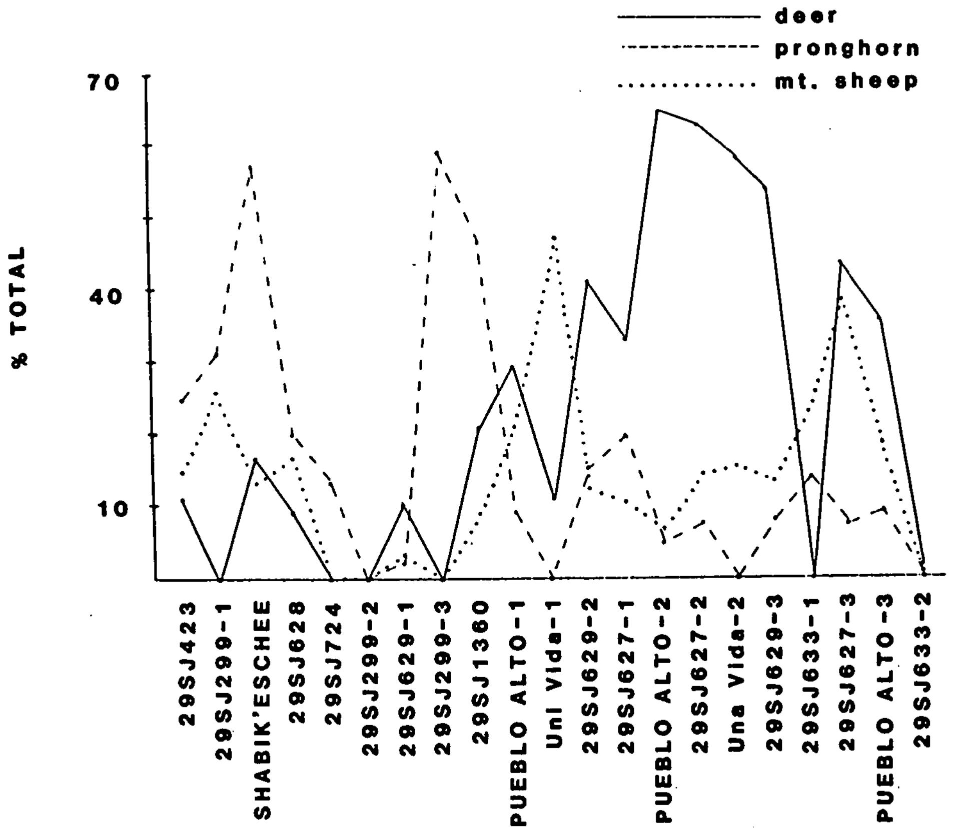


Figure 7.10 Percent of the Weighted Frequencies for Deer, Pronghorn, and Mountain Sheep

The weighted cottontail rabbit percentages exceed those of the jack rabbit only three times in this sequence, at 29SJ 423 and both deposits at 29SJ 633. It is tempting to suggest that this pattern at the beginning and end of the time sequence represents a more or less natural situation where the cottontail populations have not been as affected by human predation as points in between. The earlier 29SJ 633 sample is fairly small and consists entirely of subfloor fill and features of one and a half rooms. It may not be representative of this time period even at that site. Prairie dog has a fairly low presence throughout. It does appear to overtake cottontail rabbit in importance in a few instances but not by very much.

The weighted artiodactyl graph (Figure 7.11) shows a number of trends. The pronghorn distribution has a noticeable plunge around the time of the first 29SJ 629 sample. These deposits are all from the lower and middle trash mound; although the sample size is relatively large, it is unusual. The canids make up 45.4% of the weighted frequencies and artiodactyl elements were sparse. The immature elements could not be removed from the calculations for this site, so this may be an overestimation. The large percentage may suggest differential deposition of carnivore remains at the site or that a lot of carnivores were eaten or processed at that time.

The peaks at Shabik'eshchee Village, the 29SJ 299 Pueblo II sample, and at 29SJ 1360 are probably related to sampling. The 29SJ 299 sample is small and the other two are suspected to be poorly collected. The absence of deer in the earlier sample from 29SJ 633 is most likely a sampling error.

The mountain sheep percentages are variable. The peak at Una Vida is largely the result of two articulated feet which make up just over a third of the elements. If this were adjusted for, the peak would not be as pronounced. The other peak, from the late deposits at 29SJ 627, is paired with large amounts of deer indicating heavy artiodactyl use.

From the perspective of large versus small (Figures 7.11 and 7.12), there are more general trends. Figure 7.12 eliminates those examples with an identified total of fewer than 200 elements as well as the two sites most suspect for collection bias (Shabik'eshchee Village and 29SJ 1360). The early 29SJ 629 deposits continue to stand out as very unusual.

Elimination of the smaller sample sizes leaves the possibility of summer versus winter sites as a partial explanation for changes in body size utilization. The argument states that during the spring and summer months, horticulturalists concentrate on planting activities and animal procurement is directed toward trapping and snaring of small mammals, a strategy that not only provides meat but protects the fields from these same animals. Artiodactyls are hunted after the harvest when time allows and when the animals are in good condition. Communal hunts are most often held after the pinyon harvest (Beaglehole 1936), thus if our sites represent seasonal use, different faunas would result.

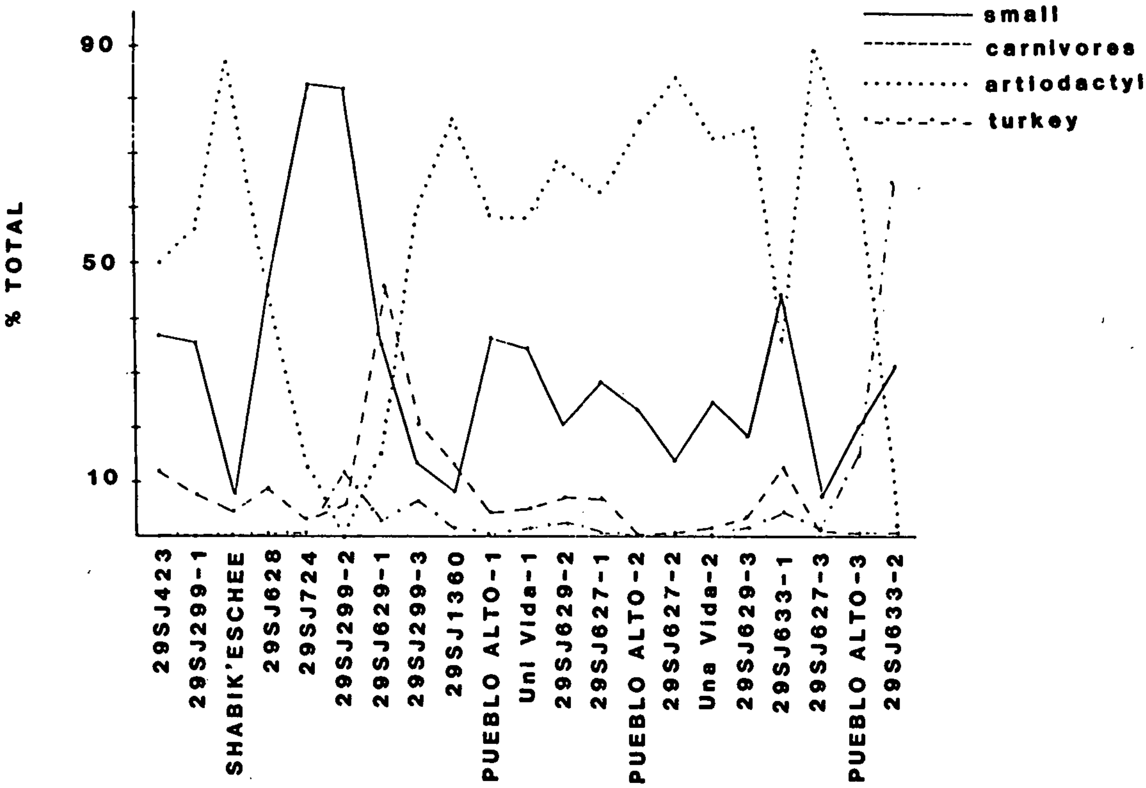


Figure 7.11 Percent of the Weighted Frequencies for the Small Economic Mammals, Carnivores, Artiodactyls, and Turkey

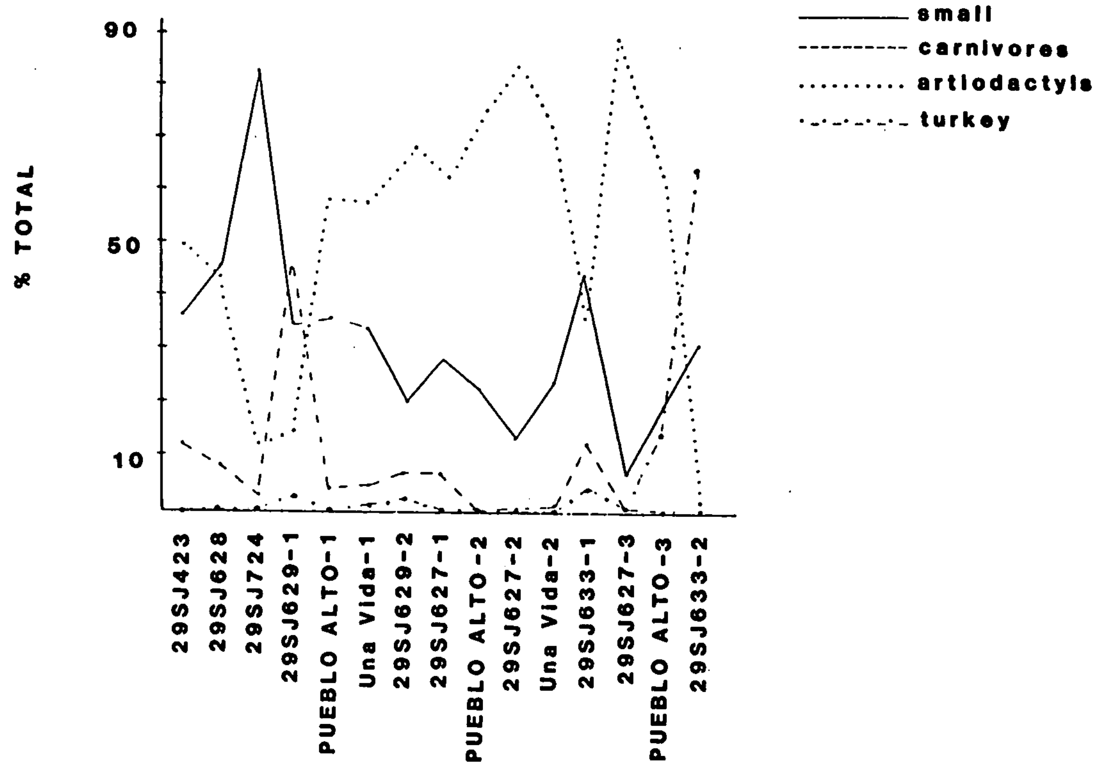


Figure 7.12 Percent of the Weighted Frequencies for the Small Economic Mammals, Carnivores, Artiodactyls, and Turkey (Cases with Less than 200 Identified Elements and the Poorly Collected Sites Omitted)

One problem with the application of the summer-winter dichotomy at Chaco is that the trends are temporal. The early sites exhibit a summer-like pattern with predominately small mammals and the later ones a winter strategy with utilization of the larger taxa (Figure 7.12). This would have to be interpreted as a change from spring-summer to fall-winter occupation of the canyon. While there is always the possibility that some of the site may have been seasonally occupied or the sampled deposits were highly seasonal, it is unlikely that it would be so clear-cut and appear as a temporal change.

The samples with large percentages of small mammals include the Pueblo I deposits at 29SJ 299, 29SJ 628, 29SJ 633, and 29SJ 724. Three of these were not screened and the small mammal contributions may be even greater than indicated. Table 7.38 gives the age distributions for the small economic taxa in order to evaluate the possiblility that summer use is responsible for the patterning. Site 29SJ 299 has one of the highest percentages of mature elements that are more suggestive of the opposite or late winter-early spring deposits. It is a relatively small sample and most likely a sampling error. Numerous pithouses were excavated at 29SJ 628, and immature elements from two or three of the taxa were found in each. While this tends to support summer occupation of the site, it does not necessarily mean there was no winter use, especially given the number of structures and amount of trash at the site. A better example of primarily summer use can be made for 29SJ 724 where little trash was found and the proportion of artidactyls is very small. Immature percentages are not available for 29SJ 633; however, Gillespie (1981b) believes that the presence of immature and juveniles suggest a summer use of the site and that there was little to suggest definite winter use.

If the presence of large amounts of artiodactyl remains at a site is taken to suggest a winter occupation, then winter use could be suspected at Shabik'eshchee Village, the latest sample from 29SJ 299, and 29SJ 1360. The 29SJ 299 assemblage is most likely the result of a small sample size, while Shabik'eshchee Village and 29SJ 1360 have enough immature elements present to conclude that poor collection indeed caused the distribution.

Although fairly balanced in body size use, 29SJ 423 has one of the lowest totals of immature elements observed. The poor preservation at this site may have differentially destroyed many of the immature bones, so it may not be representative.

The smoothed curve (Figure 7.12) does suggest that there was a change in the size of animal utilized, especially if 29SJ 633 and 29SJ 724 are considered as highly seasonal. A predominately small mammal oriented subsistence strategy appears to have changed to one utilizing large mammals, and finally to the use of turkey combined with small mammals.

Village-Greathouse Comparisons

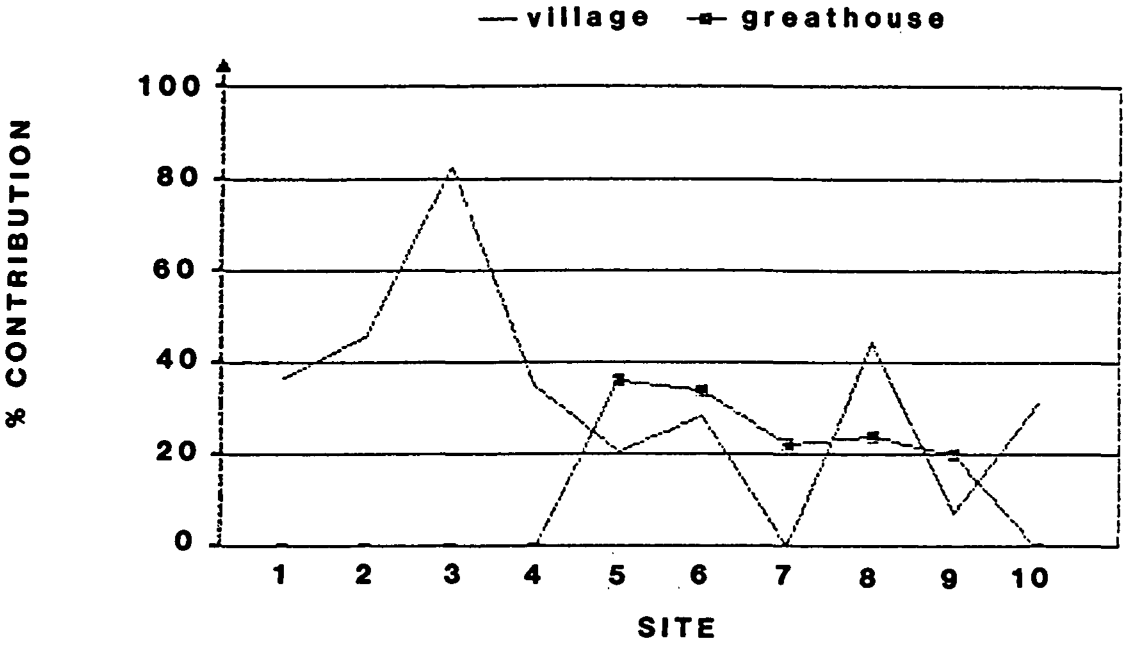
Figures 7.13 - 7.15 present the village and greathouse samples in a roughly chronological sequence, illustrating that the utilization of body sizes was similar at the two kinds of sites, at least as represented in the sites included. Similar proportions of large and small mammals were

Table 7.38 Percentage of Immature and Young Adult Elements for the Three Small Economic Taxa

		Cottontail Rabbit			Jack Rabbit			Prairie Dog		
		imm	y.a.	mature	imm	y.a.	mature	imm	y.a	mature
Shabik'eshchee		4.8	14.5	80.6	11.1	2.8	86.1		50.0	50.0
29SJ 299	A.D. 600-700	10.8	8.1	81.1	7.4	7.4	85.2		16.6	83.3
	A.D. 780-820		8.3	91.7		10.0	90.0		10.0	90.0
	A.D. 920-1020			100.0			100.0			
29SJ 423		.5	12.0	87.5	1.8	5.4	92.7		16.6	83.3
29SJ 627 (samples - Appendix 1)										
	A.D. 1000-1050	3.0	14.6	82.4	.5	14.2	85.3	14.6	2.0	83.3
	A.D. 1050-1080	9.2	16.7	74.1	.5	9.8	89.6			100.0
	A.D. 1130-1220	11.1	20.4	68.5	.6	3.3	96.1	7.2	13.2	79.6
29SJ 628 (see note)										
	Pithouse A	7.0	13.9	79.0	3.9	17.6	78.4	4.3	10.9	84.9
	Pithouse C	3.4	17.3	79.3	1.1	6.1	92.8	11.3	9.4	79.2
	P. C antechamber	1.6	11.0	87.4	.7	27.3	71.9			100.0
	Pithouse D	4.5	13.6	81.8	1.6	11.3	87.1		42.9	57.1
	P. D antechamber	5.4	16.2	78.3		7.7	92.3	41.7	8.3	50.0
	Pithouse E	7.3	14.6	78.1	.8	5.3	93.9	9.1	9.1	81.9
29SJ 724		6.1	13.6	80.3	.6	8.4	91.0			100.0
29SJ 1360		5.0	15.0	80.0	2.1	4.9	93.0		16.0	84.0

Note: 29SJ 628 samples include the following proveniences
Pithouse A - level 3 (n=141) and level (n=87)
Pithouse C - layer 1 (n=113), layer 2 (n=731), layer 3 (n-1607), and floor associations (n=151)
Pithouse C antechamber - levels 2 and 3 (n=509)
Pithouse D - layer 1 (n=72) and layer 2 (n=140)
Pithouse D antechamber - fill (n=75) and floor associations (n=79)
Pithouse E - levels 1 and 2 (n=136), level 3 (n=135), and levels 4 and 5 (n=157)

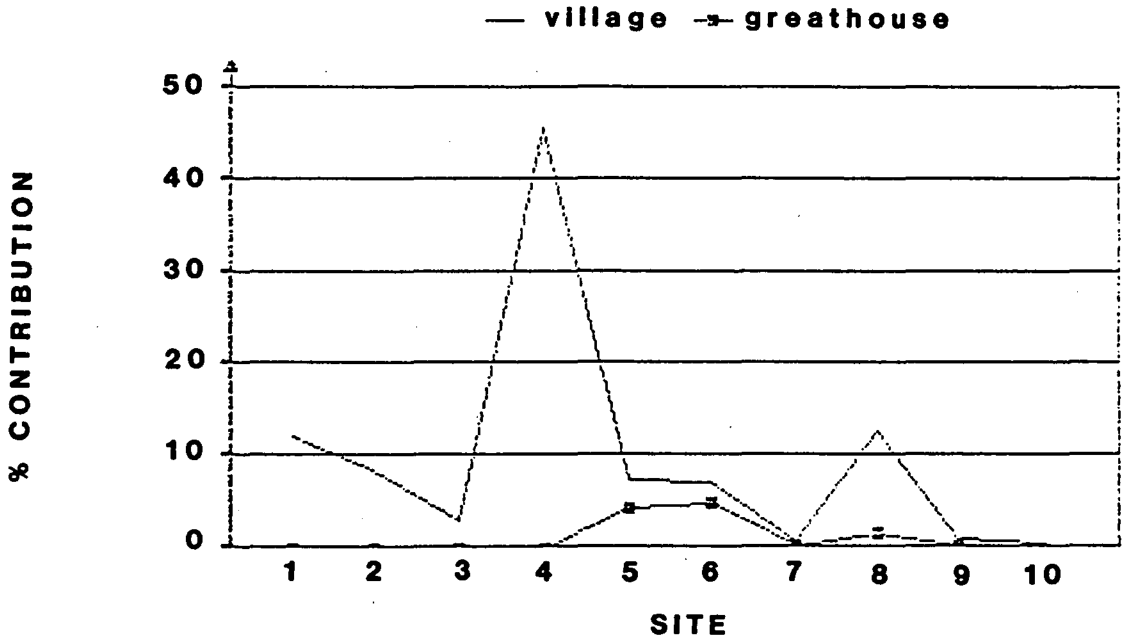
see Table 7.6 for the other sample sizes



1 = 29SJ423 A.D. 500-600
2 = 29SJ628 A.D. 700-820
3 = 29SJ724 A.D. 780-820
4 = 29SJ629 A.D. 650-950
5 = 29SJ629 A.D. 975-1040/
Pueblo Alto A.D. 950-1050
6 = 29SJ627 A.D. 1000-1050/
Una Vida A.D. 950-1050

7 = 29SJ627 A.D. 1050-1080/
Pueblo Alto A.D. 1050-1150
8 = 29SJ633 A.D. 1020-1120/
Una Vida A.D. 1050-1250
9 = 29SJ627 A.D. 1130-1200/
Pueblo Alto A.D. 1150-1220
10 = 29SJ633 A.D. 1220-1250

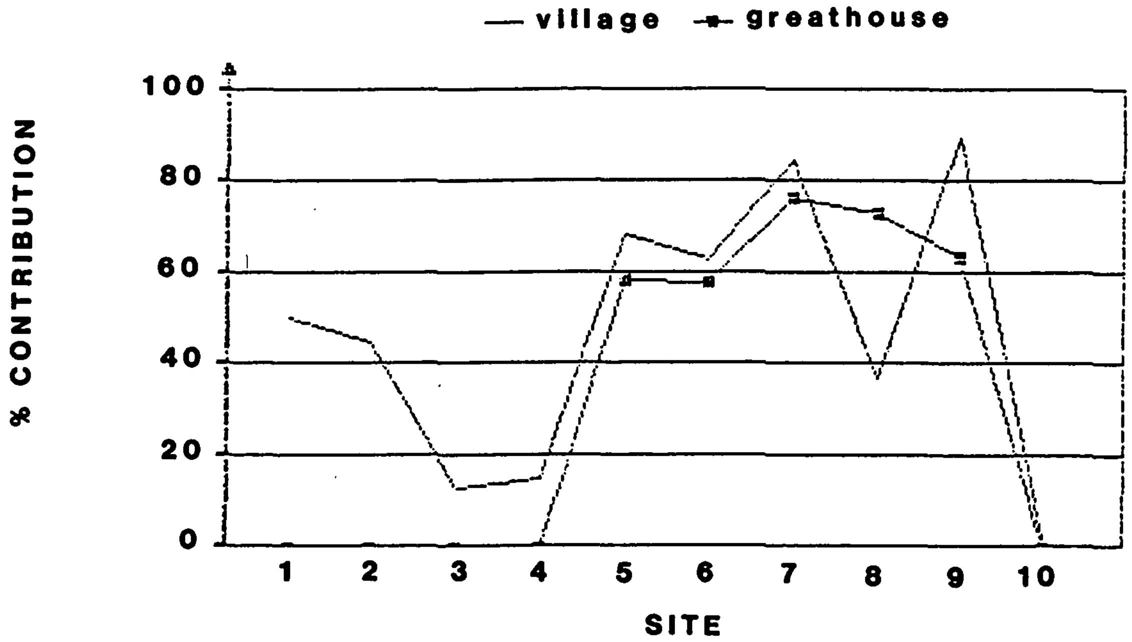
Figure 7.13 Percent of the Weighted Frequencies for the Small Economic Mammals. Good Samples Only and Greathouse Versus Village Sites



1 = 29SJ423 A.D. 500-600
2 = 29SJ628 A.D. 700-820
3 = 29SJ724 A.D. 780-820
4 = 29SJ629 A.D. 650-950
5 = 29SJ629 A.D. 975-1040/
Pueblo Alto A.D. 950-1050
6 = 29SJ627 A.D. 1000-1050/
Una Vida A.D. 950-1050

7 = 29SJ627 A.D. 1050-1080/
Pueblo Alto A.D. 1050-1150
8 = 29SJ633 A.D. 1020-1120/
Una Vida A.D. 1050-1250
9 = 29SJ627 A.D. 1130-1200/
Pueblo Alto A.D. 1150-1220
10 = 29SJ633 A.D. 1220-1250

Figure 7.14 Percent of the Weighted Frequencies for the Carnivores, Good Samples Only and Greathouse Versus Village Sites



1 = 29SJ423 A.D. 500-600
2 = 29SJ628 A.D. 700-820
3 = 29SJ724 A.D. 780-820
4 = 29SJ629 A.D. 650-950
5 = 29SJ629 A.D. 975-1040/
Pueblo Alto A.D. 950-1050
6 = 29SJ627 A.D. 1000-1050/
Una Vida A.D. 950-1050
7 = 29SJ627 A.D. 1050-1080/
Pueblo Alto A.D. 1050-1150
8 = 29SJ633 A.D. 1020-1120/
Una Vida A.D. 1050-1250
9 = 29SJ627 A.D. 1130-1200/
Pueblo Alto A.D. 1150-1220
10 = 29SJ633 A.D. 1220-1250

Figure 7.15 Percent of the Weighted Frequencies for the Artiodactyls. Good Samples Only and Greathouse Versus Village Sites used. More carnivores are suggested for the smaller sites, but in general the villages also have smaller sample sizes which can make the contribution of less frequently found taxa appear larger (Grayson 1981). Deer use (Figure 7.10) appears to increase earlier in the greathouse sites of Pueblo Alto and Una Vida than at village sites during the same time (29SJ 299 and 29SJ 1360).

This increase seems to support the opinion that the trends in selection of species used were similar. It can be argued that there are differences in the quantity of faunal remains found at the two kinds of sites. To complement lithic use rates at the sites (Cameron 1982), faunal use rates were computed (Akins 1982c). The maximum meat available, which takes the estimated MNI (the estimate available from Appendix 4) and assumes a complete animal for each MNI, was translated into man-days of calories (at 200 calories per person per day), The man-days are then compared with estimates of the population and length of occupation at a site. By virtue of the additive nature of an estimated MNI and the assumption of a complete animal for each MNI, these may be huge over-estimations. Since the sites were not divided in the same manner and there are differences in complexity, they may not be comparable.

Site 29SJ 299 with three pithouses, a kiva, and late trash was approximately 80% excavated, although no midden was found or tested. The fauna recovered would at best represent two man-years of meat or 81 days for the estimated nine persons living there. The estimated length of occupation for that site is over 150 years.

At 29SJ 628, six pithouses and six cists, totaling approximately 70% of the site, were excavated. Some of these were trash filled. Other trash may have been present and unsampled. The large sample from the site may represent as much as 14.1 man-years of meat or assuming that only one structure was occupied at a time, five persons could have been fed for 2.8 years. The estimated length of occupation is 75 years.

Ten rooms, a pithouse, and some trash were excavated at 29SJ 724. Most of the structural features and the trash were sampled. The maximum meat available here would provide one man-year of food or 40.5 days for the nine persons thought to live here. The estimated length of occupation was 30 years.

Thirteen rooms, a kiva, a pithouse, a ramada, and some trash were excavated at 29SJ 1360. The majority of the structures were tested, but only an estimated 10% of the midden was examined. In sites of this time period much of the trash deposition was in abandoned structures. The midden tests resulted in the recovery of 23 elements (3.2% of the site sample). Complete excavation of the midden may have added as many as 207 additional bones. If all of these were identifiable, it would have added as much as 22% to the amount available. This is unlikely since 61% of those recovered were not identifiable and did not contribute to the economic totals. The analyzed sample would, at best, represent 7.9 man-years or enough to have fed 20 persons for 145 days. The site occupation was estimated to be over 50 years.

The largest of the village sites, 29SJ 627, was tested, yielding data from 18 rooms, three pithouses, a pit structure, three kivas, a ramada, and a trash area. Percentages similar to those from 29SJ 1360 resulted. A total of 510 bones (7.5% of the sample) were recovered from the midden tests. A projection for the entire midden might add an additional 4,590 elements. If 46% of these were identifiable, an additional 1,652 elements could have added 35% to the estimated meat available. The analyzed sample resulted in a maximum of 50 man-years of potential meat or enough to feed 10 persons for five years. This site was estimated to have been occupied for 250 years.

Although Judd (1954) stated that animal bones were rather sparse in the trash mound at Pueblo Bonito, appearances can be deceptive. The analyzed portion of the Pueblo Alto trash mound was approximately 0.5% of the volume and produced 8,771 bones. Assuming similar densities for the entire mound, it has the potential of containing 1,754,200 bones. The maximum contribution for the sample--assuming independence of the layers, excluding carnivores, and projecting for the entire mound from the analyzed sample--would equal 6,360 man-years or enough meat to have fed 100 persons for 63 years. Considering that there are contemporary trash deposits within the house mound, this total closely approximates the estimate that Pueblo Alto was occupied by 50 to 100 persons for 70 years.

It would appear that there are quantitative differences in the amount of meat represented at Pueblo Alto and the village sites; however, our perception of how long sites were occupied is based mainly on ceramic and architectural information and may be greatly exaggerated especially for the small sites. Actual use of some sites may have been intermittent and the actual length of habitation relatively short. In addition, the faunal calculations are based on MNIs with site specific provenience divisions that are not necessarily equivalent. While treating layers as distinct units in the Pueblo Alto trash mound might be justifiable on the grounds that they are distinct and represent small samples of the mound, the fact that the 8,771 bones were divided into 41 units does affect the outcome. Units larger than layers were used for the village sites.

On the basis of sheer numbers there are more faunal remains at Pueblo Alto, so it is probably safe to conclude that there are differences between the site types. Sherds and lithics (Table 7.39) are also more abundant. The arguments for these classes of materials do not need to account for preservation and aggregation method. Projected ceramic consumption rates (Toll and McKenna 1983) are quite high--from 8 to 100+ times--as much for the Gallup portion of the Pueblo Alto trash mound as for the village sites. Other trash at the site does not show a similar pattern; however, the years of deposition and number of families are often high and may be unrealistic.

Cameron (1982) estimated the volume of chipped stone use per household per year using the same figures as for the ceramic and bone. She found quantities of 0.9 kg for Pueblo Alto verses 0.2 kg at the village and concluded that either the greathouse occupants were using lithic

Table 7.39 Comparison of Ceramic, Lithic, and Bone Frequencies from the Chaco Sites

Site	Ceramics	Lithics	Bones
Pueblo Alto	90,739	12,339	55,000+
Una Vida	1,248	103	3,374
Shabik'eshchee Village	777	172	339
29SJ 299	4,093	265	318
29SJ 423	1,700	2,827	1,964
29SJ 627	84,473	7,145	6,752
29SJ 628	6,889	1,055	4,997
29SJ 629	32,724	7,025	2,818
29SJ 633	7,312	632	3,904
29SJ 721	607	126	26
29SJ 724	2,870	1,095	470
29SJ 1360	12,792	1,047	708

Sources: Ceramics - 29SJ 299, 29SJ 721, and 29SJ 724 (Windes, personal communication 1981). All Others, Toll personal communication 1983).
Lithics - Cameron, personal communication 1984.

materials at a greater rate or more people lived at Pueblo Alto than previously presumed.

Summary

When the number of elements recovered is adjusted to reflect the weight of the animal, a number of trends emerge. Jack rabbits, because of their larger size, appear to have contributed more to the diet than cottontails for all but the very beginning and end of the time sequence. Prairie dog use was always fairly low and appears to fluctuate very little. The artiodactyls show a change from the primary utilization of pronghorn to deer at around A.D. 920 to 950. Mountain sheep fluctuate with no clear patterning. Carnivore utilization is low with a possible increase in use between A.D. 850 and 1000. Turkey maintains a low presence until very late. Overlying this is a trend towards the use of larger body size animals that begins around A.D. 950 and continues until A.D. 1220. The patterns appear in both greathouse and village sites and suggest that there were no substantial differences in the relative use of the taxa.

Although quantitative differences between the greathouses and villages may be present, attempts to demonstrate them entail too many assumptions to be taken as conclusive evidence. Ceramic and lithic studies also suggest some quantitative differences, but these are based on many of the same assumptions regarding length of occupation and site populations.

Discussion

> The inhabitants of Pueblo Bonito could probably have slaughtered in a single season every animal within a days journey...(Judd 1954:67).

It is not difficult to make a case for the necessity of prehistoric populations to procure animal resources outside of Chaco Canyon. Bailey (1931) estimated that, for New Mexico in general, jack rabbit and cottontail densities were about one per two acres (0.5 per acre). Studies in better environments, such as pasture in northeastern Colorado, indicate cottontail densities of only 0.022 per acre (Flinders and Hansen 1975) suggesting Bailey may have been generous in his estimates. Assuming that the density of cottontails may have been twice Bailey's estimate and that 40% of the animals available were utilized, the rabbits would have provided meat for a relatively small human population. The approximate area of the park (116.5 km^2), could sustain 11,520 cottontails and 5,760 jack rabbits a year for cropping. If the population ranged 10 km beyond the canyon (450 km^2), the numbers would increase to 44,465 cottontails and 22,234 jack rabbits. Translated into food values (at 200 calories per day) the rabbits in the park area would support approximately 183 persons and the larger area 710 persons (or double these if 100 calories is used).

Deer are the most straightforward of the artiodactyls for which to predict densities. The desert scrub environments of the San Juan Basin are estimated to support 0.11 per hectare (or 11 per km^2) (based on Bureau of Reclamation 1976 estimates). If deer were taken at a rate of 30%, there would be approximately 350 available within the park and 1,350 in the larger area. Deer alone would annually provide meat for 238 and 926 persons respectively (at 200 calories per person per day).

The rabbits and a primary artiodactyl probably accounted for at least 60% of the Anasazi meat diet, thus local animal resources could have provided the meat diet of 702 persons in the park and 2,727 in the larger area. Even the most pessimistic of population estimates would agree that these numbers are low. Hayes (1981), believed that during Basketmaker III a population of 1,053 inhabited the park area. This figure was based on the number of sites and rooms, but also assumed only 12.5% of the sites were occupied contemporaneously and that the use life of a structure was 25 years. His estimates suggest that even at this early date the Chacoan population may have been one third over the land's capacity to provide them with animal resources. With local resources already taxed beyond their ability to sustain the population, measures to compensate should have already begun.

One such compensatory measure may have been the importation of dried meat. As Davis (1960:18) has noted, dried meat probably played an underestimated role in the prehistoric economy. Southwestern ethnographies are filled with accounts of hunting trips where most of the take was dried (Beaglehole 1936; Hill 1938; White 1943). While drying does not significantly affect the nutritional content of meat (Wing and Brown 1979), it does make it highly storable and portable. The probability that the population was greater than the resources available and that the canyon continued to be inhabited for a long span of time makes the use of dried meat as a staple food a reasonable supposition. Procurement of these resources would have necessitated travel, suggesting interaction with the surrounding region from a least Basketmaker III times.

In general terms, utilization of small body sizes is heaviest at the beginning of the time spectrum. Jochim (1976) concludes that a small game strategy is less risky because small mammals are relatively more abundant and spatially more predictable than larger game. Traditional agriculturalists prefer more costly but secure strategies to those that involve more risk. Alternatively, Speth and Scott (1984b:31) suggest that there is a relationship between the percent of contribution of larger species (as compared to smaller species) and the reliance on horticulture.

A number of the early assemblages are dominated by small mammal fauna; deer do not occur in a number of the Basketmaker III sites. Either these populations were less horticultural than later groups and were able to provide sufficient meat by hunting primarily small mammals and/or the most readily available of the large mammals were hunted outside the area. Elk was found only in the earlier deposits suggesting that some long-distance hunting or trade had taken place.

The early Pueblo II faunal assemblages suggest that the larger body size animals were increasingly utilized and that deer became the primary game animal. The change in utilization from smaller to larger body sizes is just beginning to be examined by Southwestern archeologists. Speth and Scott (1984a, 1984b) suggest that the change to larger prey species is a result of "horticultural communities becoming larger, more residentially stable, and more dependent on the products of cultivation." They argue that by virtue of these conditions a more logistic mobility strategy, where scheduling of hunting activities must conform with horticultural activities, is initiated. Thus it is changes in the socioeconomic system that result in the change in body size utilization.

Wing and Brown (1979) point out that maintenance of dense concentrations of people requires extra human effort. In such instances either the productivity of the land must be increased or the area available to support the communities must be expanded. This can be done in a number of ways, among them trade, tribute, and taxes. Scheduling, whether it is for hunting or trading parties, is probably the crucial factor.

A Regional Perspective

We should be able to look at faunal resources and remains from other areas of the San Juan Basin, especially the outlying sites, and learn more about the movement of resources in the system. Most of these are either untested or, if they have been excavated, they are not reported or are reported in a manner that does not allow comparisons. While a regional perspective is not feasible at this point in time, there are observations that can be made.

Although neither of the reports on the fauna from Salmon Ruin (Beezley 1975; Harris 1980) divides the fauna into primary (or Chacoan) and secondary occupations, mountain sheep appear to have been relatively rare. This suggests that, unlike Judd's (1954) Navajo informants, mountain sheep were not procured north of the San Juan River or we would expect more from Salmon Ruin. Their constant presence throughout the time spectrum at Chaco suggests a closer source, e.g., Chacra Mesa.

More interesting is the age distribution of artiodactyls from Guadalupe (Pippin 1979) and Bis sa'ani (Bertram and Draper 1982). While only 8% of the postcranial artiodactyl bones from Guadalupe were immature, a number of mandibles were recovered and aged. The distribution for deer included nine mandibles from individuals that were one to four weeks old, eight that were two to three months old, one that was four to five months old, and two that were over a year old. The pronghorn mandibles included one from an individual that was one to four weeks old, and there were two from mountain sheep of the same age. Identifiable artiodactyl elements were rare in the assemblage with deer and pronghorn accounting for 1% and mountain sheep 2% for both the Chacoan and secondary occupations. The variety of ages found in this relatively small sample suggests that artiodactyl hunting was done from late spring through at least fall. At Bis sa'ani fully one sixth of the identified artiodactyl elements were from very young individuals. Of these 6 deer (summed MNI's), 3 pronghorn, and 10 unidentified artiodactyls were listed as neonate or very young.

The evidence of such young kills contrasts with the Chaco samples where only four sites contained late spring/summer killed individuals. Table 7.40 gives the percentage of these for each site. The evidence of immature pronghorns at Pueblo Alto could represent as few as one individual and the deer two. The pronghorn were in deposits dating before or to the construction of the pueblo, suggesting that some late spring/early summer hunting was done to provide for the builders. The immature deer elements are primarily from the trash mound with one element from the early deposit in Plaza Grid 30. The unknown artiodactyl immature elements are mainly from the same locations as the immature pronghorn and deer elements and only three elements occurred in other portions of the site.

The immature pronghorn elements from 29SJ 628 come from two pithouses and may represent two individuals (skeletally only one is indicated). The deer from 29SJ 627 are represented by phalanges (three) scattered throughout the roomblock and an innominate fragment from a kiva. Two bones representing a very young pronghorn were found at 29SJ 633.

The relative lack of immature artiodactyl elements in the Chaco assemblages suggests that hunting was primarily a fall or winter strategy, though an occasional pronghorn was taken during the year. More important, it may suggest organizational differences between Chaco and the two outliers that probably result from the Anasazi's traveling farther to hunt or trade for animal resources. Such scheduling is also reasonable for the transport of fresh meat. Cooler temperatures would slow down the rate of spoilage and animals are in their best condition in late summer-early fall.

Other observations can be made from comparisons with sites in different locations. Given that Chaco is in a relatively poor location for artiodactyl procurement, we might expect that the overall frequencies would be lower than at sites in more favorable areas. Those sites with very large amounts of artiodactyl remains should also be looked at from the perspective of collection practices. As two of the Chaco sites demonstrate, non-screening practices where only the larger bones were recovered heavily biases a sample toward artiodactyls and carnivores.

Many sites in or near favorable hunting locations have relatively small percentages of artiodactyl elements. In the Dolores, Colorado area, Nemetz (1977) reports that the Chacoan outlier, Escalante, located just a few miles from the San Juan National Forest, had 27.6% artiodactyl compared with 33.4% rabbit elements. Neusius, working on smaller sites in the Dolores area, found that artiodactyls made up between 15.8 and 16.5% and small mammals 62.5 and 62.9% of the elements (Neusius and Phagan 1983). A small sample from Salmon Ruin (Beezley 1975) resulted in 13.5% artiodactyls; Long House at Mesa Verde (Cattanach 1980) had only 3.5% of the mammals identified as artiodactyls. At Guadalupe (Pippin 1979), where

Table 7.40 Percent of the Immature Elements for the Artiocadtyls

Site	Deer	Pronghorn	Artiodactyl sp.
Pueblo Alto	.5	20.9	1.1
29SJ 627	2.2		.3
29SJ 628		7.9	3.9
29SJ 633		50.0	

Note: Includes elements coded as very immature and immature.

hunters may have utilized Mesa Chivato, artiodactyls comprised 43% of the elements in the Chacoan deposits and 31% in the secondary ones. They comprised 49.41% at Gran Quivira (McKusick 1981). Collection bias is possible at the latter two.

Relatively low frequencies of artiodactyl elements are not unusual in other more favorable areas, which could be interpreted as the result of butchering practices where much is "left in the field" or as a seasonal strategy even in better environments (Neusius and Phagan 1983).

Scheduling for Hunt or Trade

Since the number of artiodactyl elements is not a good indication of local procurement, other means of evaluating the possibilities are necessary. Elk, bear, tassel-eared squirrels, snowshoe hares, and eastern cottontails are long-distance imports to Chaco and suggest exchange or procurement from at least 60 to 70 km. Some of the pronghorn and deer could have been taken closer, but travel would still be required to get to more protective areas.

Trade was the more likely alternative for the Anasazi. Wing and Brown (1979) suggest a round trip of over 10 km is too costly in energy expenditure for food procurement. Lightfoot (1978) maintains that a 16 to 32 km distance for fresh meat and an 80 km radius for more concentrated foods are the maximum for regular and efficient transport. Drennan (1984) suggests 275 km is the absolute maximum distance profitably to export food overland. The more productive areas of the San Juan basin are at distances where trade would be more efficient than procurement.

The movement of goods is more easily demonstrated with other kinds of archeological materials such as sherds and lithics. Changes in the direction and flow of these materials and construction activities may also suggest the direction of trade in faunal resources. One of the most noteworthy changes in faunal patterning occurred between ca. A.D. 950 and 1000 when artiodactyl use surpassed that of the small economic mammals (rabbits and prairie dogs). During the same time, pronghorn, which had been the most utilized of the artiodactyls (prior to ca. 920 - 950) began to be supplanted by deer. (This change possibly occurred slightly earlier at the greathouse than village sites.) There appear to be no ceramic or lithic correlations with the change in body size utilization, although greathouse construction had begun and gray wares from the Red Mesa Valley reached their peak at this time. It appears to be a period of transition, but little else can be suggested. The change in body size utilization is more likely the result of the aggregation, organization, and scheduling coupled with a depletion of local small mammal resources (cf. Speth and Scott 1984a, 1984b). Ceramic imports from the south may suggest some pronghorn was coming from that direction.

The peak in deer frequencies (A.D. 1050 to 1120) corresponds with the maximum use of Washington Pass Chert (Cameron 1984), the most construction activity and tree felling (Dean and Warren 1983; Lekson 1984), and large-scale ceramic consumption at Pueblo Alto (Toll 1984). Of these, the use of Washington Pass Chert and increases in deer occur in both greathouse and village sites. It also overlaps with relatively higher frequencies of Chuska graywares. These correlations may suggest that during this time a large portion of the trade and/or interaction was with the Chuska area. Dean and Warren (1983) report that most of the ponderosa pine used in the construction of Chetro Ketl was felled from February through October. While immature deer elements are relatively rare, all but one of those found were from the portion of the Pueblo Alto trash mound dating to this period and may suggest that deer were brought back with the construction timbers. Deer meat is 74% water (Watt and Merril 1963) and when dried would be concentrated and portable food. Small amounts of lithic raw materials, dried meat, and even some fresh meat could have been brought back with construction timbers while ceramic vessels would have been difficult to transport at the same time. In either case it may be that the increased need for scheduling of activities throughout the canyon led to increasing utilization of deer.

The other major shift in faunal utilization involves a significant increase in turkey elements which occurred post-A.D. 1200. This change may be related to an increase in ceramics from the San Juan area (Toll and McKenna 1983). Turkey also increases in the secondary occupation at Guadalupe (Pippin 1979). Percentages at Escalante (Nemetz 1977), as at Chaco, are fairly low (5.2%), but are not given by time period (the site dates from A.D. 1075 to post-A.D. 1200). It is not possible to determine the contribution of turkey at Salmon Ruin from the current reports. Turkey percentages from Long House (post-A.D. 1200) (Cattanach 1980) are approximately 31.6%. It may be that extensive use of turkey in northwestern New Mexico and even southwestern Colorado is a post-A.D. 1200 phenomenon; however, the kind of data needed to evaluate its presence does not appear in the published reports.

Conclusions

If we can assume that the archeological samples reflect past utilization, there are a number of demonstrable changes in the faunal assemblages from the Chaco sites. Three important trends have been recognized: a shift in utilization from primarily small to large body sizes, a change in the aspects of large mammals utilized from pronghorn to deer, and ultimately the use of turkey as the primary food animal. Missing is a sense of scale that would allow us to address the mechanisms behind the changes. Until we have the requisite data, little more than trend recognition is possible.

Faunal reporting should, at bare minimum, include the sample size, the NISP or number of elements for each taxon, and some sense of chronology in long occupied or multicomponent sites. The analyst should address how collection and sampling could have affected the results. Until these basics are included and until archeologists recognize the value of faunal reporting, we will not be able to address broader questions and implications of this data base.

Appendix 1

Provenience Groupings for Species Abundance Tables

The assigned dates are from McKenna (1981) and personal communications with McKenna and Windes.

Una Vida

950-1050	Room 23, Floors 2 through 4: Room 60, Floor 2; Room 64, Floor 2; Room 65; Room 83, Floors 4 and 5.
1050-1220	Room 18; Room 201; Room 21, Floor 1; Room 60, Floor 1; Room 63; Room 64, Floor 1; Room 85, Floors 1 and 2; Room 84.
	(Akins 1982b)

Pueblo Alto

(Akins 1982a:Table 5.1)

Shabik'eshchee Village

(Akins 1981c:Table 2)

29SJ 299

600-700	Pithouses A, C, and D.
780-820	Pithouse E and surface rooms.
920-1020	Kiva B.
	(Akins 1981b)

29SJ 423

(Akins 1981d:Table 2)

29SJ 627

1000-1050	Room 10, Floor 2; Pithouse C, Layer 3 through floor; Kiva F, Layers 5 and 6.
1050-1080	Kiva D, Levels 1 through 10.
1130-1200	Kiva E, Layers 3 through 5.
	(Akins 1981g)

29SJ 628

(Akins 1981f:Table 3)

29SJ 629

850-950	Early Trash; Middle Trash.
975-1040	Pithouse 3 fill, Late Trash, Rooms, Pithouse 2.
1100-1150	Kiva, Room 1.
	(Gillespie 1981a: Table 7) Note: The totals in this table did not include wild birds or herpetological elements.

29SJ 633

1030-1120	subfloors
1220-1250	Rooms 7 and 8 through Floor 1.
	(Gillespie 1981b:Table 2)

29SJ 721

(Gillespie 1979:Table 1)

29SJ 724

(Akins 1981a:Table 2)

29SJ 1360

(Akins 1981e:Table 2)

Appendix 2

Number of Elements and MNIs for Chaco Sites.

Pueblo Alto

	Site			A.D. 920-1020		A.D. 1020-1120		A.D. 1120-1220		Mixed		Estimated
Taxon	NISP		MNI	NISP	MNI	NISP	MNI	NISP	MNI	NISP	MNI	MNI
Myotis californicus	4	[4]	4					4	4			4
Sylvilagus cf. *auduboni*	5909	[20]	131	1006	81	3234	192	1435	122	234	33	428
Sylvilagus nutalli	1		1			1	1					1
Lepus californicus	4798	[1]	69	697	54	2417	145	1471	86	213	18	303
Lepus americanus	1		1			1	1					1
Ammospermophilus leucurus	10		3	3	1	2	1	4	3	1	1	6
Spermophilus variegatus	2		1					1	1	1	1	2
squirrel sp.	4		2			2	2	2	2			4
Cynomys gunnisoni	2616	[3]	116	178	37	992	126	1379	121	67	16	300
Sciurus aberti	8		2			6	4	2	2			6
Thomomys bottae	118		27	10	7	21	13	83	27	4	4	51
Perognathus sp.	14		2			5	3	9	3			6
Dipodomys ordii	134	[3]	16	14	6	61	21	55	20	4	4	51
Dipodomys spectabilis	18		3	1	1	14	2	2	2	1	1	6
Reithrodontomys sp.	3	[1]	2					3	2			2
Peromyscus sp.	739	[76]	135	51	24	596	126	88	38	4	3	191
Onychomys sp.	3		3					3	3			3
Neotoma sp.	55	[2]	2			26	8	23	10	6	3	21
Neotoma cinerea	12	[1]	2	1	1	4	3	6	5	1	1	10
Neotoma stephensi	3		1			2	2	1	1			3
Neotoma albigula	4		2			1	1	2	1	1	1	3
Microtus mexicanus	1	[1]	1							1	1	1
Erethizon dorsatum	1		1							1	1	1
Canis sp.	37		2	11	2	6	3	19	4	1	1	10
Canis latrans	16		2	13	5			1	1	2	2	8
Canis lupus	2		1	1	1	1	1					2
Canis familiarus	11		2			1	1	1	1	9	2	4
Urocyon cinereoargenteus	1		1			1	1					1
Ursus arctos	1		1							1	1	1
Taxidea taxus	8		2			1	1	7	2			3
Felis rufus	13		2	9	7	2	1	1	1	1	1	10
Cervus elaphus	1		1			1	1					1
Odocoileus hemionus	572		9	30	15	361	59	142	33	39	7	114
Antilocapra americana	167		4	50	15	45	22	63	18	9	5	69
Ovis canadensis	145		5	21	7	40	26	74	22	10	5	60
Ovis/Capra	23		2					5	2	18	4	6
Anas platyrhynchos	3		1	2	1			1	1			2
FALCONIFORMES	1			1								
Accipitridae	10			10	1							1
Buteo sp.	120			110	2	7	3	2	2	1	1	8
Buteo lagopus	1		1	1	1							1
Buteo regalis	3		1	2	1	1	1					2
Buteo jamaicensis	126		11	109	12	15	3	2	2			17
Buteo swainsoni	6		1	6	1							1
Aguila chrysaetos	82		4	72	19	8	7	2	4			30
Falco sparverius	14		2			6	2	7	3	1	1	6
Callipepla sp.	4							4				
Callipepla squamata	3		1			2	2	1	1			3
Meleagris gallopavo	987		18	3	3	68	21	878	49	38	6	79
Grus canadensis	1		1					1	1			1
Zenaida macroura	4		1			2	2	2	2			4
Otus asio	3		1	1	1	1	1	1	1			3
Colaptes auratus	3		1			2	2	1	1			3
Trochilidae	1		1			1	1					1
PASSERIFORMES	16			1	1	4	2	11	7			10
Eremophilia alpestris	17	[1]	3	4	3	9	6	4	4			13
Hirundinindae	1		1					1	1			1
Icteridae	7		4					7	4			4
Corvidae	1			1	1							1
Gymnorhinus cyanocephalus	7		1	6	2			1	1			3
Pica pica	12		3	1	1	4	4	4	1	3	1	7
Corvus corax	11		2	7	3	4	3					6
Sialia sp.	1			1	1							1
Silia mexicana	1		1					1	1			1
Sialia currucoides	1		1					1	1			1
Laniidae	1		1	1	1							1
Lanis ludovicianus	2	[2]	2					2	2			2
Fringillidae	7			1	1	6	3					4
Junco hyemalis	1		1			1	1					1
Pipilo chlorura	1		1			1	1					1
Pipilo erythrophthalmus	1		1			1	1					1
Spea sp.	1		1			1	1					1
Iguanidae	1					1	1					1
Sceloporus undulatus	24		2			23	6	1	1			7
Phrynosoma douglassi	2		1					2	1			1
Cnemidophorus velox	2		1					2	1			1
Pituophus melanoleucus	1		1			1	1					1
Gila sp.	1		1					1	1			1
rodent	171											
small to medium mammal	7104											
medium mammal	61											
medium to large mammal	2636											
artiodactyl	2328											
Aves	427											
unknown	835											
total unknown	13562			2428		7024		3840		270		
totals	30509		635	4864	320	15037	842	9666	630	942	125	1917
number of provenience divisions			1		50		87		52		10	

29SJ 299

Taxon	NISP		Site MNI	Estimated MNI
Sylvilagus cf. *auduboni*	76		6	10
Lepus californicus	74		4	8
Cynomys gunnisoni	17		3	6
Thomomys bottae	1		1	1
Perognathus sp.	4		1	1
Perognathus flavescens	2	[2]	2	2
Dipodomys ordii	14	[1]	4	6
Dipodomys spectabilis	1		1	1
Peromyscus sp.	2		1	1
Neotoma sp.	1			1
Neotoma cinerea	1		1	1
Canis sp.	1		1	1
Canis latrans	1		1	1
Canis familiarus	4	[2]	3	3
Taxidea taxus	2		1	2
Antilocapra americana	4		2	2
Ovis canadensis	1		1	1
Ovis/Capra	1		1	1
Meleagris gallopavo	10	[3]	5	7
Corvus corax	1		1	1
Spea sp.	5		4	4
Spea bombifrons	1	[1]	1	1
rodent	2			
small to medium mammal	59			
medium to large mammal	11			
artiodactyl	7			
Aves	5			
unknown	10			
totals	318		45	62
number of provenience divisions				9

29SJ 423

Taxon	NISP	Site MNI	Estimated MNI
Sylvilagus cf. *auduboni*	589	11	25
Lepus californicus	97	4	11
Cynomys gunnisoni	6	1	1
Perognathus sp.	1	1	1
Dipodomys ordii	5	2	3
Peromyscus sp.	6	2	2
Neotoma sp.	6	2	5
Neotoma cinerea	1	1	1
Canis sp.	9		
Canis latrans	10	3	5
Canis familiarus	2	1	2
Urocyon cinereoargenteus	2	1	2
Ursus arctos	1	1	1
Felis rufus	3	1	3
Cervus elaphus	2	1	1
Odocoileus hemionus	3	1	3
Antilocapra americana	11	2	5
Ovis canadensis	4	1	3
Anas sp.	1	1	1
Buteo sp.	2	1	2
Falco sp.	1	1	1
quail sp.	1	1	1
Sceloporus undulatus	1	1	1
rodent	6		
small to medium mammal	909		
medium mammal	22		
medium to large mammal	211		
artiodactyl	30		
Aves	2		
unknown	20		
totals	1964	41	80
number of provenience divisions			11

Una Vida

Taxon	NISP	Site MNI	Estimated MNI
Sylvilagus cf. *auduboni*	629	22	48
Legus californicus	543	10	34
Cynomys gunnisoni	266	9	24
squirrel sp.	10	4	8
Sciurus aberti	3	1	2
Thomomys bottae	33	7	14
Perognathus sp.	7	3	5
Dipodomys ordii	47	3	9
Peromyscus sp.	500	[11] 54	62
Onychomys sp.	2	1	1
Neotoma sp.	4	1	
Neotoma cinerea	5	1	5
Canis sp.	6	1	3
Canis latrans	13	1	1
Felis rufus	9	2	3
Odocoileus hemionus	22	2	5
Ovis canadensis	34	1	5
Aquila chrysaetos	1	1	1
eagle	1		1
Meleagris gallopavo	17	2	5
PASSERIFORMES	6		1
Ermophilia alpestris	2	1	2
Icteridae	2	1	1
Fringillidae	3	1	1
Spea sp.	16	[2] 4	5
Spea multiplicata	3	[1] 2	3
SERPENTES	1		
Crotalus virdis	2	1	1
rodent	62		
small to medium mammal	596		
medium mammal	4		
medium to large mammal	287		
artiodactyl	161		
Aves	54		
unknown	23		
totals	3374	136	250
number of provenience divisions			25

Shabik'eshchee Village

Taxon	NISP	Site MNI	Estimated MNI
Sylvilagus cf. *auduboni*	103	6	10
Lepus californicus	36	2	7
Cynomys gunnisoni	4	1	3
Thomomys bottae	16	3	4
Dipodomys ordii	1	1	1
Peromyscus sp.	1	1	1
Neotoma sp.	2	2	2
Neotoma cinerea	5	1	1
Canis sp.	4	1	1
Canis familiarus	2	1	2
Ursus arctos	1	1	1
Felis rufus	4	1	2
Odocoileus hemionus	5	2	2
Antilocapra americana	29	4	6
Ovis canadensis	4	2	3
Meleagris gallopavo	1	1	1
Eremophilia alpestris	1	1	1
Corvus corax	1	1	1
small to medium mammal	37		
medium mammal	2		
medium to large mammal	20		
artiodactyl	58		
Aves	1		
unknown	1		
totals	339	32	49
number of provenience divisions			5

29SJ 627

Taxon	NISP		Site MNI	Estimated MNI
Sylvilagus cf. *auduboni*	992		35	99
Lepus californicus	1345		33	87
Cynomys gunnisoni	355	[1]	18	56
squirrel sp.	2		1	2
Thomomys bottae	24		5	12
Perognathus sp.	5		1	3
Dipodomys ordii	32	[1]	4	10
Dipodomys spectabilis	8		3	6
Peromyscus sp.	27	[8]	11	17
Neotoma sp.	23		1	8
Neotoma cinerea	7	[1]	3	6
Canis sp.	? 33			6
Canis latrans	53		2	15
Canis lupus	3		1	3
Canis familiarus	89	[2]	6	14
Urocyon cinereoargenteus	1		1	1
Vulpes vulpes	2		1	1
Taxidea taxus	3		1	2
Felis rufus	12		2	5
Cervus elaphus	5		1	5
Odocoileus hemionus	224		6	33
Antilocapra americana	65		3	13
Ovis canadensis	73		4	15
Buteo sp.	6			
Buteo regalis	2		1	2
Aquila chrysaetos	6		1	6
Meleagris gallopavo	190	[8]	19	42
Bubo virginianus	2		1	1
Eremophilia alpestris	1		1	1
Corvus corax	1		1	1
Spea sp.	24	[2]	5	13
Spea bombifrons	2		2	2
Spea multiplicata	3	[2]	3	3
Bufo sp.	1		1	1
Bufo woodhousei	2	[2]	2	2
Phrynosoma douglassi	1		1	1
rodent	49			
small to medium mammal	1013			
medium mammal	65			
medium to large mammal/artiodactyl	1561			
Aves	125			
unknown	315			
totals	6752		181	497

29SJ 628

Taxon	NISP	Site MNI	Estimated MNI
Sylvilagus cf. *auduboni*	2042	86	95
Lepus californicus	1717	35	47
Cynomys gunnisoni	175	19	19
squirrel sp.	2	1	2
Spermophilus variegatus	2	1	1
Thomomys bottae	33	8	10
Perognathus sp.	4	1	1
Dipodomys ordii	10	2	5
Dipodomys spectabilis	6	2	3
Neotoma sp.	6		
Neotoma cinerea	7	1	5
Neotoma c.f. *stephensi*	3	2	2
Canis sp.	60		
Canis latrans	35	2	5
Canis familiarus	15	2	4
Urocyon cinereoargenteus	5	1	2
Ursus americanus	1	1	1
Taxidea taxus	31	2	4
Felis rufus	7	2	3
Cervus elaphus	1	1	1
Odocoileus hemionus	16	1	5
Antilocapra americana	63	5	9
Ovis canadensis	30	2	5
Buteo sp.	3		
Buteo regalis	51	2	2
Buteo jamaicensis	39	2	2
Circus cyaneus	4	1	1
Meleagris gallopavo	24	[2] 2	3
Grus canadensis	2	1	1
Corvus corax	3	1	1
rodent	15		
small to medium mammal	172		
medium mammal	54		
medium to large mammal	74		
artiodactyl	233		
Aves	7		
lost Aves	41		
unknown	4		
totals	4997	186	239
number of provenience divisions			11

29SJ 629

Taxon	NISP	Site MNI	Estimated MNI
Sylvilagus cf. *auduboni*	381	15	48
Lepus californicus	395	13	46
Cynomys gunnisoni	225 [1]	13	46
Ammospermophilus leucurus	15 [1]	2	4
Spermophilus variegatus	1	1	1
Thomomys bottae	55	7	17
Perognathus sp.	54 [17]	19	23
Dipodomys ordii	37 [10]	11	19
Dipodomys spectabilis	3	2	3
Peromyscus sp.	30 [3]	9	13
Onychomys leucogaster	10	2	2
Neotoma sp.	16	4	8
Erethizon dorsatum	4	2	3
Canis sp.	32		6
Canis latrans	28	3	9
Canis lupus	2	1	2
Canis familiaris	67	14	24
Taxidea taxus	1	1	1
Felis concolor	1	1	1
Felis rufus	1	1	1
Cervus canadensis	1	1	1
Odocoileus hemionus	22	3	12
Antilocapra americana	8	1	5
Ovis canadensis	7	2	6
Buteo sp.	12		8
Buteo jamaicensis	2	1	1
Aquila chrysaetos and cf. *Aquila*	11	2	6
Meleagris gallopavo	54	7	16
Grus canadensis	1	1	1
cf. *Corvus Corax*	1	1	1
Spea sp.	3	3	3
Spea multiplicata	5	5	5
Spea bombifrons	2	2	2
Sceloporus undulatus	1	1	1
Sceloporus graciosus	1	1	1
rodent	96		
small mammal	542		
medium mammal	55		
medium to large mammal	223		
artiodactyl	94		
Aves	39		
unknown	280		
totals	2818	152	346
number of provenience divisions			38

29SJ 633

Taxon	NISP	Site MNI	Estimated MNI
Sylvilagus cf. *auduboni*	1101	37	60
Lepus californicus	351	11	25
Cynomys gunnisoni	160	11	26
cf. *Spermophilus spilosoma*	1	1	1
Thomomys bottae	9	2	5
Perognathus sp.	7	1	4
Dipodomys ordii	19	3	9
Dipodomys spectabilis	6	1	3
Reithrodontomys megalotis	1	1	1
Peromyscus sp.	73	5	12
Onychomys leucogaster	2	1	2
Neotoma sp.	36	7	9
Canis sp.	4	1	3
Taxidea taxus	2	1	1
Felis rufus	2	1	2
Odocoileus hemionus	1	1	1
Antilocapra americana	4	2	3
Ovis canadensis	1	1	1
Anatidae	1	1	1
Buteo so.	5	2	3
Aquila chrysaetos	1	1	1
Callipepla squamata and cf. *Callipepla*	12	2	2
Meleagris gallopavo	766	12	28
Bubo virginianus	2	1	1
Eremophilia alpestris	1	1	1
Pipilo chlorura and cf. *Pipilo*	2	1	1
Corvus corax	1	1	1
Pituophus melanoleucus	1 [1]	1	1
SERPENTES	4		
rodent	36		
small mammal	1139		
medium mammal	11		
medium to large mammal	34		
artiodactyl	2		
Aves	3		
unknown	103		
totals	3904	111	209
number of provenience divisions			unknown

29SJ 721

Taxon	NISP	Site MNI	Estimated MNI
Sylvilagus cf. *auduboni*	8		2
Lepus californicus	4		2
Cynomys gunnisoni	1		1
rodent	3		
small mammal	8		
large mammal	1		
unknown	1		
totals	26		5
number of provenience divisions			8

29SJ 724

Taxon	NISP		Site MNI	Estimated MNI
Antrozous pallidus	1		1	1
Sylvilagus cf. *auduboni*	133	[1]	10	14
Lepus californicus	178		5	8
Cynomys gunnisoni	18		2	5
Thomomys bottae	4	[1]	3	3
Perognathus sp.	1			
Perognathus flavescens	1		1	1
Dipodomys ordii	2		1	2
Peromyscus sp.	5	[1]	1	1
Neotoma sp.	2			
Neotoma cinerea	1		1	1
Canis sp.	1			1
Canis latrans	4		2	2
Urocyon cinereoargenteus	1		1	1
Felis rufus	1		1	1
Antilocapra americana	2		1	1
FALCONIFORMES	1			
Buteo sp.	5			
Buteo regalis	18		2	2
Buteo jamaicensis	3		1	1
Aquila chrysaetos	2		1	1
Haliaeetus leucocephalus	1		1	1
Meleagris gallopavo	1		1	1
Sialia sp.	1		1	1
rodent	5			
small to medium mammal	64			
medium to large mammal	6			
Aves	4			
unknown	4			
totals	470		37	49
number of provenience divisions				10

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Taxon	NISP	Site MNI	Estimated MNI
Sylvilagus cf. *auduboni*	39	4	14
Lepus californicus	145	7	17
Cynomys gunnisoni	25	9	11
Thomomys bottae	1	1	1
Dipodomys ordii	4	1	1
Canis sp.	12		2
Canis latrans	13	2	7
Canis familiarus	60 [2]	10	18
Taxidea taxus	1	1	1
Odocoileus hemionus	14	2	3
Antilocapra americana	52	4	11
Ovis canadensis	6	1	3
Buteo sp.	3	1	1
Falco cf. *mexicanus*	1	1	1
Meleagris gallopavo	18	2	8
Ara cf. *macao*	5	1	1
Corvus corax	1	1	1
small to medium mammal	32		
medium mammal	9		
medium to large mammal	56		
artiodactyl	171		
Aves	29		
unknown	11		
totals	708	48	101
number of provenience divisions			19

[ ] number of articulated skeletons

Appendix 3

Meat Weight Estimates

William B. Gillespie

Lyman (1979) and Binford (1978) have recently presented convincing reasons for not continuing the common practice of calculating meat weight values on the simple basis of Minimum Numbers of Individuals represented. This stems from the growing recognition that the MNI meat weight method (identified with White [1953b]) can lead to vast overestimation of the meat weight represented by the remains of larger taxa and marked distortion of the relative abundance of different taxa.

Between the two of them, Binford (1978) and Lyman (1979) indicated three techniques which might be profitably used to give more accurate and reliable estimates of consumed meat weight. These are (1) skeletal portion (Lyman), (2) butchering portion (Lyman), and (3) individual element (Binford). In each case, the method is to sum the usable weight represented by the anatomical portion recovered. "Skeletal portion" and "major anatomical segment" refers to the division of the body into five parts, the axial skeleton, two front limbs and two hind limbs (Binford 1978). Both Binford and Lyman give figures of the meat weight present in each portion for various species of artiodactyls.

It is also deemed reasonable to modify the meat weight calculations for the next largest set of animals, the carnivores, in an effort to reduce overestimation of their dietary importance. If one attempts to gain more realistic meat weight estimates for artiodactyls by considering only the anatomical portions represented, but calculates carnivore meat weight on the basis of individuals represented, the result is a clear overestimation of the importance of the latter group. High estimates of meat value for carnivores are particularly suspect in view of indications that several carnivores were often procured for reasons other than food value. Similarly, there is only limited evidence at most sites that domestic dogs were eaten.

In order to produce what are thought to be more realistic meat weight estimates, carnivore remains can be handled in a manner similar to the artiodactyls; however, detailed comparative data on the meat weights represented by specific skeletal parts are not as readily available as for the larger artiodactyls. In lieu of such data, carnivores are divided only in basic skeletal portions--axial skeleton, front legs, rear legs --and the relative meat weight contribution of each is based on Binford's (1978) sheep data. Using these values and following Binford rather than Lyman for definitions of the major skeletal portions (i.e., cranium, mandible, pelvis, and sacrum are included with the axial skeleton), the guidelines used for estimating consumed weight represented by carnivores are given in Table 1.

"Butchering portion" is a more appealing categorization involving the division of the body into more refined anatomical sections which (presumably) have a more integral relationship to how a large animal might have been cut up and distributed. Lyman gives meat weight value for the butchering portions which were standard for the early twentieth century (e.g., "hotel racks," "chunks," and "briskets," etc.). While these are appropriate to his study of the historic use of domestic animals, there are two aspects which make application of his butchering units to prehistoric remains inappropriate. First, with his Euro-American bias, such an integral part of the body as the skull is omitted. Second, some of the butchering portions require a saw or minimally an axe/cleaver, and thus do not correspond to anatomical portions which result from dismemberment by simpler tools.

Binford (1978) carries the reduction further by considering only the meat weight represented by each individual element. This technique is required for Binford's complicated manipulations designed to assess variability in the relative abundance of each element and is suited to his Nunamiut collections where faunal remains are quite abundant. However, in situations where large game elements are not so abundant, it appears that estimating consumed meat weight simply by figuring the amount of meat attached to each element present could lead to noticeable underestimation of the actual meat weight present.

The approach adopted here combines data presented by Binford with the basic methodology outlined by Lyman. Eight anatomical sections which Binford identifies as basic butchering units and a ninth category of "feet" are established and the relative meat weight of each calculated from Binford's data on sheep elements (Table 2). The relative amounts of meat weight for each section are then used to estimate values for different live weights of the different artiodactyl species. This involves the assumption that skeletal proportions of the species in question are equivalent or nearly so. Figures given by Binford for sheep and caribou suggest that this assumption is not completely appropriate, i.e., that artiodactyl species do show differences in skeletal proportions and distribution of usable meat. In lieu of comparable data for the three taxa, the proportions determined by Binford (1978:16) for a mature domestic sheep are used with the recognition that the resultant estimates are not as precise as they would be with better comparative data. One should also recognize the great amount of <u>intra</u>-specific variability in meat weight amounts with such factors as age, sex, and season. Still, it is thought that these estimates of <u>consumed</u> meat amounts (as opposed to <u>available</u> meat) are more accurate and relevant than the estimates derived from White's method. Table 3 gives the average live weights of several common southwestern taxa.

Table 1. Values for Calculation of Consumed Meat Weight of Carnivore Major Skeletal Portions.

	Estimated % of Available Meat Weight
axial skeleton cranium, vertebrae, ribs sternum, pelvis, sacrum	58.2
front leg (each) scapula, humerus, radius ulna, metacarpals, carpals, phalanges	9.6
rear leg (each) femur, tibia, fibula, metatarsals, tarsals, patella, phalanges	11.2

Relative amounts are based on Binford's (1978) data for sheep.

Table 2 Meat Weight Estimates for Artiodactyls Equating Binford's (1978) Gross Weight with the Butchered Dressed Weight used by Wildlife Biologists

	% Total Meat Weight	Meat Weight as % of Gross Weight	*Ovis canadensis* and *Odocoileus hemionus* Grams	*Antilocapra americana* Grams
estimated average live weight			75,000	45,000
estimated dressed weight (53% of live weight			39,750	23,850
head	9.9	8.3	3,300	1,980
cervical vertebrae	7.4	6.3	2,500	1,500
thoracic vertebrae	8.7	7.3	2,900	1,740
lumber vertebrae, and pelvis	11.6	9.7	3,860	2,320
sternum (ventral ribs)	10.7	9.0	3,570	2,140
ribs (dorsal parts)	9.7	8.1	3,210	1,930
front leg (each)	8.7	7.3	2,900	1,740
rear leg (each)	10.3	8.6	3,430	2,060
feet (each)	0.9	0.8	310	180
totals	99.6	83.7	33,240	19,930

Table 3. Estimated Average Live Weights of Chaco Area Mammals and Available Meat Weights.

Taxon	Live Weight Grams	% Usable Meat	Meat Weight Grams
Perognathus flavus	8	-	-
Perognathus flavescens	0	-	-
Reithrodontomys megalotis	10	-	-
Peromyscus crinitus	17	-	-
P. maniculatus, boylii, truei	25	-	-
Microtus mexicanus	30	-	-
Onychomys leucogaster	32	-	-
Dipodomys ordii	70	0.4	28
Ammospermophilus leucurus	100	0.4	40
Spermophilus spilosoma	110	0.4	44
Thomomys bottae	170	0.4	68
Dipodomys spectabilis	175	0.4	70
small *Neotoma*	175	0.4	90
large *Neotoma*	275	0.4	110
Spermophilus variegatus	800	0.4	320
Cynomys gunnisoni	925	0.4	370
Sylvilagus auduboni	995	0.4	382
Lepus californicus	2,750	0.4	1,100
Urocyon cinereoargenteus	4,500	0.5	2,250
Erethizon dorsatum	6,000	0.4	2,400
Canis familiarus	7,000	0.5	3,500
Taxidea taxus	10,000	0.5	5,000
Felis rufus	10,000	0.5	5,000
Canis latrans	11,000	0.5	5,500
Canis lupus	27,000	0.5	13,500
Antilocapra americana	45,000	0.4	19,930
Odocoileus hemionus	75,000	0.4	33,240
Ovis canadensis	75,000	0.4	33,240
Ursus americanus	90,000	0.5	45,000
Cervus elapus	590,000	0.4	120,000

Taxa arranged by increasing size. Live weight values from Armstrong (1972), Lecheitner (1969), Bailey (1931), and White (1953b).

Appendix 4

Economic Contribution Based on MNIs and Butchering Portion

Pueblo Alto (Samples - See Note)

	A.D. 920-1020				A.D. 1020-1120				A.D. 1120-1200				A.D. 1200-1250			
	Available		Consumed		Available		Consumed		Available		Consumed		Available		Consumed	
			g	%	g	%	g	%	g	%	g	%	g	%	g	%
cottontail	1146	1.8	1146	5.1	7258	2.7	7528	8.8	4966	2.9	4996	6.4	1528	1.8	1528	5.3
jack rabbit	3300	5.2	3300	14.8	17600	6.5	17600	21.3	14300	8.3	14300	18.3	4400	5.3	4400	15.3
prairie dog	370	0.6	370	1.7	3700	1.4	3700	4.5	11100	6.4	11100	14.2	740	0.9	740	2.6
economic rodent	246	0.4	246	1.1	934	0.3	934	1.1	1250	0.7	1250	1.6	68	0.1	68	0.2
carnivore	5000	7.9	2910	13.0					19500	11.3	5080	6.5				
deer	33240	52.6	3520	15.7	166200	61.3	24720	30.0	66480	38.5	23780	30.4	33240	40.2	3520	12.3
pronghorn	19930	31.5	2160	9.7	39860	14.7	7960	9.7	19300	11.2	5720	7.3				
mountain sheep					33240	12.2	11820	14.3	33240	19.3	3830	4.9	33240	40.2	310	1.1
unknown artiodactyl			8690	38.9			6085	7.4			5712	7.3			8700	30.3
turkey					2350	0.9	2350	2.8	2350	1.4	2350	3.0	9400	11.4	9400	32.8
total grams	63232		22342		271142		82427		172486		78118		82616		28666	
sample size		916				4514				2688				470		

A.D. 920-1020: Plaza Grid 8 trash deposit with predominately Red Mesa B/W ceramics
A.D. 1020-1120: Trash Mound booths 4,5, and 6 with Gallup B/W ceramics
A.D. 1120-1200: Kiva 10 trash fill, Layers 15 through 27 with carbon paint ceramics
A.D. 1200-1250: Rooms 142 and 146, materials recorded as roof fall but may be trash, also with carbon paint ceramics

Una Vida

	Site MNI				Estimated MNI			
	Available		Consumed		Available		Consumed	
	g	%	g	%	g	%	g	%
cottontail	8404	5.7	8404	10.9	18336	4.1	19336	10.7
jack rabbit	11000	7.4	11000	14.3	37400	8.3	37400	21.9
prairie dog	3300	2.2	3300	4.3	8880	2.0	8880	5.2
economic rodent	1127	0.8	1127	1.5	4982	1.1	4982	2.9
carnivore	20000	13.5	8750	11.4	34000	7.6	12524	7.3
deer	66480	44.8	19390	25.2	166200	37.1	39730	17.4
mountain sheep	33240	22.4	13460	17.5	166200	37.1	16710	9.8
unknown artiodactyl			6760	8.8			30580	17.9
turkey	4700	3.2	4700	6.1	11750	2.6	11750	6.9
total grams	148281		76921		447748		170892	
total calories	185351		96151		559685		213615	
man years	2.5		1.3		7.7		2.9	

Shabik'eshchee Village

	Site MNI				Estimated MNI			
	Available		Consumed		Available		Consumed	
	g	%	g	%	g	%	g	%
cottontail	2292	0.8	2292	3.6	3820	1.0	3820	5.4
jack rabbit	2200	0.8	2200	3.5	7700	2.1	7700	10.9
prairie dog	370	0.1	370	0.6	1100	0.3	1100	1.5
economic rodent	482	0.2	482	0.8	550	0.1	550	0.8
carnivore	57500	20.7	12652	20.0	66000	18.0	12652	17.8
deer	66480	23.9	2962	4.7	66480	18.1	2962	4.2
pronghorn	79720	28.7	14880	23.5	119580	32.6	15060	21.2
mountain sheep	66480	23.9	12530	19.8	99720	27.1	12350	17.4
unknown artiodactyl			12620	19.9			12333	17.4
turkey	2350	0.8	2350	3.7	2350	0.6	2350	3.3
total grams	277874		63338		367300		70877	
total calories	347342		79172		459125		88596	
man years	4.9		1.1		6.3		1.2	

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	Site MNI				Estimated MNI			
	Available		Consumed		Available		Consumed	
	g	%	g	%	g	%	g	%
cottontail	2292	2.3	2292	7.6	3820	3.3	3820	8.7
jack rabbit	4400	4.4	4400	14.6	8800	7.5	8800	20.0
prairie dog	1110	1.1	1110	3.7	2220	1.9	2220	5.0
economic rodent	442	0.4	442	1.5	478	0.4	478	1.1
carnivore	14000	14.0	3636	12.1	19000	16.3	3636	8.2
pronghorn	39860	39.8	7840	26.0	39860	34.1	7940	17.8
mountain sheep	33240	33.2	2900	9.6	33240	28.4	2900	6.6
unknown artiodactyl			2822	9.4			4952	11.2
turkey	4700	4.7	4700	15.6	9400	8.0	9400	21.3
total grams	100044		30142		116818		44046	
total calories	125055		37677		146022		55057	
man years	1.7		0.5		2.0		0.7	

29SJ 423

	Site MNI				Estimated MNI			
	Available		Consumed		Available		Consumed	
	g	%	g	%	g	%	g	%
cottontail	4202	1.4	4202	9.0	9550	1.8	9550	11.2
jack rabbit	4400	1.4	4400	9.5	12100	2.2	12100	14.2
prairie dog	370	0.1	370	0.8	370	0.1	370	0.4
economic rodent	346	0.1	346	0.7	644	0.1	644	0.7
carnivore	72250	23.4	8260	17.8	99000	18.3	18550	21.7
elk	120000	39.0	1080	2.3	120000	22.2	1080	1.3
deer	33240	10.8	6510	14.0	99720	18.4	6510	7.6
pronghorn	39860	12.9	7140	15.3	99650	18.4	9180	10.7
mountain sheep	33240	10.8	3210	6.9	99720	18.4	3520	4.1
unknown artiodactyl			10970	23.6			23845	27.9
total grams	307908		46488		540754		85349	
total calories	384885		58110		675942		106686	
man years	5.2		0.8		9.2		1.5	

29SJ 627

	Site MNI				Estimated MNI			
	Available		Consumed		Available		Consumed	
	g	%	g	%	g	%	g	%
cottontail	13370	2.0	13370	5.3	37818	1.3	37818	5.1
jack rabbit	36300	5.5	36300	14.5	95700	3.3	95700	12.9
prairie dog	6290	1.0	6290	2.5	20720	0.7	20720	2.8
economic rodent	1240	0.2	1204	0.5	3416	0.1	3416	0.5
carnivore	58250	8.9	30575	12.2	229750	7.9	101044	13.6
elk	120000	18.4	25080	10.0	600000	20.5	37800	5.1
deer	199440	30.5	59850	24.0	1096920	37.5	129540	17.4
pronghorn	59790	9.1	14710	5.9	259090	8.9	27270	3.7
mountain sheep	132960	20.3	36400	14.6	498600	17.1	60930	8.2
unknown artiodactyl							148510	20.0
turkey	25850	3.9	25850	10.3	79900	2.7	79900	10.7
total grams	653454		249629		2921914		742648	
total calories	816817		312036		3652392		928310	
man years	11.2		4.3		50.0		12.7	

29SJ 628

	Site MNI				Estimated MNI			
	Available		Consumed		Available		Consumed	
	g	%	g	%	g	%	g	%
cottontail	32852	7.0	32852	18.9	36290	4.4	36290	13.5
jack rabbit	38500	8.2	38500	22.1	51700	6.3	51700	19.2
prairie dog	7030	1.5	7030	4.0	7030	0.8	7030	2.6
economic rodent	1570	0.3	1570	0.9	2560	0.3	2560	0.9
carnivore	85250	18.2	25478	14.6	126000	15.2	46475	17.3
elk	120000	25.6	11640	6.7	120000	14.5	11640	4.3
deer	33240	7.1	6420	3.7	166200	20.1	13330	5.0
pronghorn	83706	17.9	23524	13.5	147482	17.9	32604	12.1
mountain sheep	66480	14.2	27080	15.5	166200	20.1	31860	11.8
unknown artiodactyl							33062	12.3
turkey					2350	0.3	2350	0.9
total grams	468628		174094		825812		268901	
total calories	585910		217617		1032265		336126	
man years	8.0		3.0		14.1		4.6	

References Cited

Adams, Richard N.
1951 Half House: A Pithouse in Chaco Canyon New Mexico. Papers of the Michigan Academy of Science, Arts and Letters 35:273-279.

Akins, Nancy J.
1981a Analysis of the Faunal Remains from 29SJ 724. Ms. on file, Division of Cultural Research, National Park Service, Albuquerque.

1981b The Faunal Remains from 29SJ 299. Ms. on file, Division of Cultural Research, National Park Service, Albuquerque.

1981c The Faunal Remains from Shabik'eshchee Village (29SJ 659). Ms. on file, Division of Cultural Research, National Park Service, Albuquerque.

1981d An Analysis of the Faunal Remains from 29SJ 423. Ms. on file, Division of Cultural Research, National Park Service, Albuquerque.

1981e The Faunal Remains from 29SJ 1360. Ms. on file, Division of Cultural Research, National Park Service, Albuquerque.

1981f The Faunal Remains from 29SJ 628. Ms. on file, Division of Cultural Research, National Park Service, Albqquerque.

1981g An Analysis of the Faunal Remains from 29SJ 627. Ms. on file, Division of Cultural Research, National Park Service, Albuquerque.

1982a Analysis of the Faunal Remains from Pueblo Alto, Chaco Canyon. Ms. on file, Division of Cultural Research, National Park Service, Albuquerque.

1982b Analysis of the Faunal Remains from Recent Excavations at Una Vida. Ms. on file, Division of Cultural Research, National Park Service, Albuquerque.

1982c Perspective on Faunal Resource Utilization, Chaco Canyon, New Mexico. Newsletter New Mexico Archeological Council 4(5&6):23-29, Albuquerque.

1984 Temporal Variation in Faunal Assemblages from Chaco Canyon. In Recent Research in Chaco Prehistory, edited by W.J. Judge and John D. Schelberg, pp. 225-240, Reports of the Chaco Center, no. 8, Division of Cultural Research, National Park Service, Albuquerque.

Akins, Nancy J., and William B. Gillespie
1979 Summary Report of Archeological Investigations at Una Vida, Chaco Canyon, New Mexico. Ms. on file, Division of Cultural Research, National Park Service, Albuquerque.

Anthony, Robert G.
1976 Influence of Drought on Diet and Numbers of Desert Deer. Journal of Wildlife Management 40:140-144.

Bailey, Vernon
1931 Mammals of New Mexico. North American Fauna no. 53.

Beaglehole, Ernest
1936 Hopi Hunting and Hunting Ritual. Yale University Publications in Anthropology no. 4. New Haven.

Beezley, John A.
1975 Faunal Analysis of the Salmon Site, LA8846, San Juan Valley, New Mexico. Paper submitted to Cynthia Irwin-Williams. Ms. on file, Department of Anthropology, Eastern New Mexico University, Portales.

Bent, Arthur Cleveland
1932 Life History of North America Gallinaceous Birds. Smithsonian Institute, U.S. National Museum Bulletin 162. Washington.

Bertram, Jack B., and Neal Draper
1982 The Bones from the Bis sa'ani Community: A Sociotechnic Archeofaunal Analysis, vol. 3. In Bis sa'ani: A Late Bonito Phase Community on Escavada Wash, Northwest New Mexico, edited by Cory Dale Breternitz, David E. Doyel, and Michael P. Marshall, pp. 1015-1065. Navajo Nation Papers in Anthropology no. 14.

Binford, Lewis R.
1978 Nunamiut Ethnoarchaeology. Academic Press, New York.

1981 Bones: Ancient Men and Modern Myths. Academic Press, New York.

Bradfield, Richard Maitland
1973 A Natural History of Associations, vol. 2. Duckworth, London.

Bradley, Zorro A.
n.d. The Excavation of Bc 236. In Excavations in Three Small House Sites, Chaco Canyon National Monument, New Mexico, edited by Charles B. Voll, pp. 3-55. Archive no.529. Ms. on file, Division of Cultural Research, National Park Service, Albuquerque

Brand, D.D., F.M. Hawley, and F.C. Hibben
1937 Tseh So, A Small House Ruin, Chaco Canyon, New Mexico, University of New Mexico, Anthropological Series, vol. 2, no. 2, Albuquerque.

29SJ 629

	Site MNI				Estimated MNI			
	Available		Consumed		Available		Consumed	
	g	%	g	%	g	%	g	%
cottontail	5730	1.6			18340	1.8	18340	6.3
jack rabbit	14300	4.0			50600	5.1	50600	17.3
prairie dog	4810	1.3			17020	1.7	17020	5.8
economic rodent	6040	1.7			9960	1.0	9960	3.4
carnivore	16500	4.6			49500	5.0	18640	6.4
elk	120000	33.3			120000	12.1	1270	0.4
deer	99720	27.7			398880	40.2	37970	13.0
pronghorn	19930	5.5			99650	10.0	8640	3.0
mountain sheep	66480	18.4			199440	20.1	16960	5.8
unknown artiodactyl							83910	28.8
turkey	7050	2.0			28200	2.8	28200	9.7
total grams	360560				991590		291510	
total calories	450700				1239487		364387	
man years	6.2				17.0		5.0	

29SJ 633

	Site MNI				Estimated MNI			
	Available		Consumed		Available		Consumed	
	g	%	g	%	g	%	g	%
cottontail	14134	7.8	14134	17.8	22920	8.5	22920	15.0
jack rabbit	12100	6.7	12100	15.2	27500	10.2	27500	18.0
prairie dog	4070	2.2	4070	5.1	9620	3.6	9620	6.3
economic rodent	964	0.5	964	1.2	1360	0.5	1360	0.9
carnivore	15500	8.5	9599	12.1	31500	11.7	14837	9.7
deer	33240	18.3	2900	3.6	33240	12.4	2900	1.9
pronghorn	39860	22.0	3940	5.0	43600	16.2	3940	2.6
mountain sheep	33240	18.3	310	0.4	33240	12.4	310	0.2
unknown artiodactyl			3210	4.0			3210	2.1
turkey	28200	15.5	28200	35.5	65800	24.5	65800	43.1
total grams	181308		79427		268780		152397	
total calories	226635		99284		335975		190496	
man years	3.1		1.4		4.6		2.6	

29SJ 724

	Site MNI				Estimated MNI			
	Available		Consumed		Available		Consumed	
	g	%	g	%	g	%	g	%
cottontail	3438	6.8	3438	20.2	4966	8.1	4966	21.5
jack rabbit	5500	10.9	5500	32.3	8800	14.4	8800	38.1
prairie dog	740	1.5	740	4.3	1850	3.0	1850	8.0
economic rodent	274	0.5	274	1.6	302	0.5	302	1.3
carnivore	18250	36.1	2808	16.5	22750	37.3	2888	12.5
pronghorn	19930	39.5	1920	11.3	19930	32.7	1920	8.3
turkey	2350	4.6	2350	13.8	2350	3.8	2350	10.2
total grams	50482		17030		60948		23076	
total calories	63102		21287		76185		28845	
man years	0.9		0.3		1.0		0.4	

29SJ 1360

	Site MNI				Estimated MNI			
	Available		Consumed		Available		Consumed	
	g	%	g	%	g	%	g	%
cottontail	1528	0.7	1528	1.9	5348	1.0	5348	3.9
jack rabbit	7700	3.3	7700	9.4	18700	3.5	18700	13.8
prairie dog	3330	1.4	3330	4.1	4070	0.8	4070	3.0
economic rodent	96		96	0.1	96		96	
carnivore	33500	14.5	14384	17.7	64500	12.2	14218	10.5
deer	66480	28.9	9970	12.2	99720	18.8	10590	7.8
pronghorn	79720	34.6	22140	27.2	219230	41.3	27680	20.5
mountain sheep	33240	14.4	9970	12.2	99720	18.8	10280	7.6
unknown artiodactyl			7637	9.4			25350	18.7
turkey	4700	2.0	4700	5.8	18880	3.6	18880	14.0
total grams	230294		81455		530264		135212	
total calories	287867		101818		662830		169015	
man years	3.9		1.4		9.1		2.3	

Buechner, Helmut K.
1950 Pronghorn Antelope in Trans-Pecos Texas. American Midland Naturalist 43:257-345.

Bullen, Ripley P.
1941 Preliminary Report Bc 54, Chaco Canyon, New Mexico. Ms. on file, Division of Cultural Research, National Park Service, Albuquerque. Archive no. 2086.

Cameron, Catherine M.
1982 The Chipped Stone of Chaco Canyon, New Mexico. Ms. on file, Division of Cultural Research, National Park Service, Albuquerque.

1984 A Regional View of Chipped Stone Raw Material Use in Chaco Canyon. Recent Research in Chaco Prehistory, edited by W.J. Judge and John D. Schelberg, Reports of the Chaco Center no. 8. Division of Cultural Research, National Park Service, Albuquerque.

Castro, Jose I.
1983 The Sharks of North American Waters. Texas A. and M. University Press, College Station.

Cattanach, George S.
1980 Long House, Mesa Verde National Park, Colorado. Publications in Archeology 7H, National Park Service, Washington.

Cornwall, I.W.
1956 Bones for the Archaeologist. Macmillan Co., New York.

Dasmann, William
1971 If Deer are to Survive. Stackpole Books, Harrisburg, Pa.

Davis, James T.
1960 An Appraisal of Certain Speculations on Prehistoric Puebloan Subsistence. Southwest Journal of Anthropology 16:15-21.

Dean, Jeffrey S., and Richard L. Warren
1983 Dendrochronology. In the Architecture and Dendrochronology of Chetro Ketl, Chaco Canyon, New Mexico, edited by Stephen H. Lekson, pp. 105-240. Reports of the Chaco Center no. 6. Division of Cultural Research, National Park Service, Albuquerque.

Drennan, Robert D.
1984 Long-Distance Movement of Goods in the Mesoamerican Formative and Classic. American Antiquity 49(1):27-43.

Dutton, Bertha P.
1938 Leyit Kin, A Small House Ruin, Chaco Canyon, New Mexico. University of New Mexico, Bulletin 333. Albuquerque.

Emslie, Steven

n.d. Species Identifications. Ms. on file, Division of Cultural Research, National Park Service, Albuquerque.

1978 Dog Burials from Mancos Canyon, Colorado. The Kiva 43:167-182.

1983 Cultural and Climatic Implications in Anasazi Faunal Exploitation: A Review and Perspectives. In The Proceedings of the Anasazi Symposium, 1981, edited by Jack E. Smith, pp. 119-122. Mesa Verde Museum Association.

Fagerstone, Kathleen A., Keith Lavoie, and Richard E. Griffith, Jr.

1980 Black-tailed Jack Rabbit Diet and Density on Rangeland and Near Agricultural Crops. Journal of Range Management 33(3):229-233.

Findley, James S., Arthur H. Harris, Don E. Williams, and Clyde Jones

1975 Mammals of New Mexico. University of New Mexico Press, Albuquerque.

Flinders, Jerran T., and Richard M. Hansen

1975 Spring Population Responses of Cottontails and Jackrabbits to Cattle Grazing Shortgrass Prairie. Journal of Range Management 28(4):290-293.

Gehlback, F.R., and R.R. Miller

1961 Fishes from Archaeological Sites in Northern New Mexico. Southwestern Naturalist 6(1):2-8.

Geist, Valerius

1971 A Study in Behavior and Evolution. University of Chicago Press, Chicago.

Gillespie, William B.

1979 Faunal Remains from 29SJ 721. Ms. on file, Division of Cultural Research, National Park Service, Albuquerque.

1981a Faunal Remains from 29SJ 629. Ms. on file, Division of Cultural Research, National Park Service, Albuquerque.

1981b Faunal Remains from 29SJ 633. Ms. on file, Division of Cultural Research, National Park Service, Albuquerque.

1981c Ecological Implications of Faunal Remains from Archaeological Sites in Chaco Canyon, New Mexico. Paper presented at the 46th Annual Meeting of The Society for American Archaeology, San Diego.

Goodwin, Derek,

1967 Pigeons and Doves of the World. British Museum of Natural History, London.

Grayson, Donald K.
1981 The Effects of Sample Size on Some Derived Measures in Vertebrate Faunal Analysis. Journal of Archaeological Science 8:89-98.

Guilday, John E., Paul W. Paramalee, and Donald P. Tanner
1962 Aboriginal Butchering Techniques at the Eschelman Site (36 La 12), Lancaster County, Pennsylvania. Pennsylvania Archaeologist 32(2):59-83.

Haley, Tom
1965 Trans-Pecos Antelope. In Proceedings of the First Annual Antelope States Workshop, pp. 49-53. Santa Fe, New Mexico.

Hansen, Charles G.
1980 Habitat. In The Desert Bighorn: Its Life History, Ecology and Management, edited by Gale Monson and Lowell Sumner, pp. 52-63. University of Arizona Press, Tucson.

Hargrave, Lyndon L.
n.d. Arche-ornithology File. Ms. on file, Division of Cultural Research, National Park Service, Albuquerque. Archive no. 2137g.

1959a Bird Bones from #Bc 236. Memos Southwest Archeological Center. May 20, 1959 and June 15, 1959. On file, Southwest Archeological Center, Tucson.

1959b Bird Bones from Talus Unit, Chaco Canyon National Monument, Chaco Canyon National Monument. Memos Southwest Archeological Center, July 6, August 13, October 8, and October 14. On file, Southwest Archeological Center, Tucson.

1960a Report on Bird Bones from Chetro Ketl. Memo Southwest Archeological Center, February 17, 1960. On file, Southwest Archeological Center, Tucson.

1960b Report on Bird Bones from Tseh So, Chaco Canyon National Monument, New Mexico. Memo Southwest Archeological Center, May 23, 1960. On file, Southwest Archeological Center, Tucson.

1960c Bird Bone Artifacts from Bc 51. Memo Southwest Archeological Center, June 29, 1960. On file, Southwest Archeological Center, Tucson.

1961 Wild Birds Identified from Bones from Una Vida in Chaco Canyon National Monument. Memo Southwest Archeological Center, February 14, 1961. On file, Southwest Archeological Center, Tucson.

1962 Report on Some Archeological Bird Bones from Pueblo Bonito, Chaco Canyon National Monument, New Mexico. Memo from Southwest Archeological Center, November 16, 1961. On file, Southwest Archeological Center, Tucson.

1963 A Report on Bird Bones from Kin Kletso, A Pueblo in Chaco Canyon, New Mexico. Memo Southwest Archeological Center, January 3, 1963. On file, Southwest Archeological Center, Tucson.

1964a Bird Bones, Chaco Canyon National Monument. Memo Southwest Archeological Center, November 25, 2964. On file, Southwest Archeological Center, Tucson.

1964b Bones from Chaco. Memo Southwest Archeological Center, June 29, 1964. On file, Southwest Archeological Center, Tucson.

1965 Turkey Bones from Wetherill Mesa. Memoirs of the Society for American Archaeology 31(2):161-166.

1970 Mexican Macaws: Comparative Osteology and Survey Remains from the Southwest. Anthropology Papers of the University of Arizona no. 20, Tucson.

Hargrave, Lyndon L., and D.N. Dodgen

1962 Bird Bones from Leyit Kin, Chaco Canyon. Memo Southwest Archeological Center, June 1962. On file, Southwest Archeological Center, Tucson.

Harris, Arthur H.

1963 Ecological Distribution of Some Vertebrates in the San Juan Basin, New Mexico. Museum of New Mexico Papers in Anthropology no. 8, Santa Fe.

1980 Faunal Materials from Salmon Ruins, San Juan Valley, New Mexico. In Investigations at the Salmon Site: The Structure of Chacaon Society in the Northern Southwest, edited by Cynthia Irwin-Williams and Phillip H. Shelly, pp. 27-44; 219-224. Final Report to Funding Agencies.

Hayes, Alden C.

1981 A Survey of Chaco Canyon Archeology. In Archeological Surveys of Chaco Canyon, by Alden C. Hayes, David M. Brugge, and W. James Judge, pp. 1-68. Publications in Archeology 18A, Chaco Canyon Studies. National Park Service, Washington.

Hayes, Alden C., and James A. Lancaster

1975 Badger House Community, Mesa Verde National Park, Colorado. Publications in Archeology 7E, National Park Service, Washington.

Helwig, Jane T., and Kathryn A. Council (editors)

1979 SAS User's Guide, 1979 Edition. SAS Institute, Inc. Cary, North Carolina.

Hempworth, Bill
Investigation of Pronghorn Antelope in Wyoming. Proceedings of the First Annual Antelope State Workshop, April 14-15, 1965, pp. 1-12. Santa Fe.

Henderson, Junius, and John Peabody Harrington
1914 Ethnozoology of the Tewa Indians. Bureau of American Ethnology 56, Washington.

Hibben, Frank C.
1937 Mammal and Bird Remains. In Tseh So, A Small House Ruin, Chaco Canyon, New Mexico, by Donald D. Brand, Florence M. Hawley, Frank C. Hibben, et al., pp. 100-106. University of New Mexico, Anthropology Series vol. 2, no. 2.

Hill, W.W.
1938 The Agricultural and Hunting Methods of the Navajo Indians Yale University Publications in Anthropology 18. New Haven.

1982 An Ethnography of Santa Clara Pueblo, New Mexico. University of New Mexico Press, Albuquerque.

Hubbard, John P.
1978 Revised Check-List of the Birds of New Mexico. New Mexico Ornithological Society Publication, no.6.

Jochim, Michael A.
1976 Strategies for Survival: Cultural Behavior in an Ecological Context. Academic Press, New York.

Jones, Kirkland L.
1970 An Ecological Survey of the Reptiles and Amphibians of Chaco Canyon National Monument, San Juan County, New Mexico. Unpublished Master's Thesis, Department of Biology, University of New Mexico, Albuquerque.

Judd, Neil M.
1954 The Material Culture of Pueblo Bonito. Smithsonian Institution, Miscellaneous Collections, 124. Washington.

1959 Pueblo del Arroyo, Chaco Canyon, New Mexico. Smithsonian Institute, Miscellaneous Collections 138 (1). Washington.

Kluckhohn, Clyde, and Paul Reiter
1939 Preliminary Report on the 1937 Excavations, Bc 50-51, Chaco Canyon, New Mexico. University of New Mexico, Anthropology Series, vol. 3, no. 2.

Lechleitner, R.R.
1969 Wild Mammals of Colorado. Pruett Publication Co., Boulder.

Lekson, Stephen H.
1984 Standing Architecture at Chaco Canyon and Interpretation of Local and Regional Organization. In *Recent Research in Chaco Prehistory*, edited by W.J. Judge, and John D. Schelberg, pp. 55-73. Reports of the Chaco Center no 8. Division of Cultural Research, National Park Service, Albuquerque.

Lightfoot, Kent G.
1978 Food Redistribution in the Prehistoric Southwest. Paper presented at the 43rd Annual Meeting of the Society for American Archeology, Tucson.

Lyman, R. Lee
1979 Available Meat From Faunal Remains. *American Antiquity* 44:536-554.

1982 Archaeofaunas and Subsistence Studies. In *Advance in Archaeological Method and Theory*, vol. 5, edited by Michael B. Schiffer, pp. 331-393. Academic Press, New York.

Manville, Richard H.
1980 The Origin and Relationships of American Wild Sheep. In *The Desert Bighorn: Its Life History, Ecology and Management*, edited by Gale Monson and Lowell Sumner. University of Arizona Press, Tucson.

Mathien, Frances Joan
1981 Ornaments and Minerals from Chaco Canyon. Ms on file, Division of Cultural Research, National Park Service, Albuquerque.

Maxon, James C.
n.d. The Excavation of Bc 192. In *Excavations in Three Small House Sites, Chaco Canyon National Monument, New Mexico*, edited by Charles B. Voll, pp. 56-81. Ms on file, Division of Cultural Research, National Park Service, Albuquerque.

McKenna, Peter J.
1981 Chacoan Primer: Village Excavations in Chaco Canyon 1973-1978. Ms. on file, Division of Cultural Research, National Park Service, Albuquerque.

1984 The Architecture and Material Culture of 29SJ 1360 Chaco Canyon, New Mexico. *Reports of the Chaco Center* no 7. Division of Cultural Research, National Park Service, Albuquerque.

McKusick, Charmion R.
n.d. Worksheets and Notes Forwarded by McKusick to Alden Hayes. On file, Division of Cultural Research, National Park Service, Albuquerque. Archive no. 2020-2026.

1971a Avian Remains from Bc 288. Ms. on file, Division of Cultural Research, National Park Service, Albuquerque.

1971b Mammalian Remains from Bc 288. Ms. on file, Division of Cultural Research, National Park Service, Albuquerque.

1981 The Faunal Remains of Las Humanas. In *Contributions to Gran Quivira Archeology, Gran Quivira National Monument, New Mexico,* edited by Alden C. Hayes, pp. 39-65. Publications in Archeology 17, National Park Sevice. Washington.

Nemetz, Judith A.
1977 *Archaeological Investigations at the Escalante Site, Dolores, Colorado 1975 and 1976*. Unpublished Master's Thesis, Department of Anthropology, University of Colorado, Boulder.

Neusius, S.W., and C.J. Phagan
1983 Patterns of Large and Small Game Procurement Among the Dolores Anasazi A.D. 600-950. Paper presented at the 1983 Anasazi Symposium, Aztec, New Mexico.

Pepper, George H.
1920 *Pueblo Bonito*. Anthropology Papers of the American Museum of Natural History, no. 23.

Pippin, Lonnie Corlett
1979 *The Prehistory and Paleoecology of Guadalupe Ruin, Sandoval County, New Mexico*. Unpublished Ph.D. Dissertation, Department of Anthropology, Washington State University.

Reed, Erik K.
1955 Bison Beyond the Pecos. *Texas Journal of Science* VII: 130-136. San Marcos.

Roberts, Frank H.H., Jr.
1929 *Shabik'eshchee Village: A Late Basket Maker Site in Chaco Canyon, New Mexico*. Bureau of American Ethnology 92. Washington.

Schorger, A.W.
1966 *The Wild Turkey*. University of Oklahoma Press, Norman.

Schroeder, Albert H.
1968 *Birds and Feathers in Documents Relating to Indians of the Southwest*. Papers of the Archaeological Society of New Mexico 11:95-115.

Scurlock, Dan
n.d. A Checklist of the Birds of Chaco Canyon National Monument. Ms. on file, Division of Cultural Research, National Park Service, Albuquerque.

Senter, Donovan
1939 Excavation Report, Chaco Canyon, Bc 50, Season 1939. Ms. on file, Division of Cultural Research, National Park Service, Albuquerque. Archive no. 20.

Speth, John D., and Susan L. Scott

1984a Late Prehistoric Subsistence Change in Southeastern New Mexico: The Faunal Evidence from the Sacramentos. *The Artifact*, in press.

1984b The Role of Large Mammals in Late Prehistoric Horticultural Adaptions: The View From Southeastern New Mexico. Paper presented at the 17th Annual Meeting of the Canadian Archaeological Association, Victoria, B.C.

Thomas, David H.

1969 Great Basin Hunting Patterns: A Quantitative Method for Treating Faunal Remains. *American Antiquity* 34:392-401.

Toll, H. Wolcott

1984 Trends in Ceramic Import and Distribution in Chaco Canyon. In *Recent Research in Chaco Prehistory*, edited by W.J. Judge, and John D. Schelberg, pp. 115-136. Reports of the Chaco Center no. 8. Division of Cultural Research, National Park Service, Albuquerque.

Toll, H. Wolcott, and Peter McKenna

1983 The Ceramography of Pueblo Alto. Ms. on file, Division of Cultural Research, National Park Service, Albuquerque.

Udvardy, Miklos D.F.

1977 *The Audubon Society Field Guide to North American Birds: Western Region*. Alfred A. Knopf, Inc., New York.

U. S. Government, Department of the Interior, Bureau of Reclamation

1976 *Final Environmental Statement: Proposed Modifications to the Four Corners Powerplant and Navajo Mine, New Mexico*, vol. 1.

Vivian, Gordon, and Thomas W. Mathews

1965 *Kin Kletso: A Pueblo III Community in Chaco Canyon, New Mexico*. Southwest Parks and Monuments Association Technical Series 6(1).

Voll, Charles B.

n.d. The Excavation of Bc 362. In *Excavations in Three Small House Sites, Chaco Canyon National Monument, New Mexico*, edited by Charles B. Voll, pp. 82-153. Ms. on file, Division of Cultural Research, National Park Service, Albuquerque. Archive no. 529.

Watt, Bernice K., and Annabel L. Merril

1963 Handbook of the Nutritional Contents of Foods. *Agricultural Handbook* no. 8. United States Department of Agriculture.

White, Leslie A.

1943 New Material from Acoma. *Bureau of American Ethnology* 136. Washington.

Appendix A

Checklist of Plants, Chaco Canyon National Monument

by

Anne C. Cully

Appendix A

Checklist of Plants Chaco Culture National Historical Park

Family	Scientific Name	Common Name	Collection
Agavaceae	*Yucca* sp.	Soapweed	2
Amaranthaceae	*Amaranthus graecizans* L.	Pigweed	1,2,5
	Amaranthus hybridus L.	Pigweed	5
	Amaranthus Powellii Wats.	Pigweed	5
	Tidestromia lanuginosa (Nutt.) Standl.		1
Anacardiaceae	*Rhus trilobata* Nutt.	Three-leaf sumac	1,3,5
Asclepidaceae	*Asclepias macrotis* Torr.	Milkweed	1
Berberidaceae	*Berberis fendleri* A. Gray	Fendler's barberry	5
Boraginaceae	*Cryptanthe crassisepale* (Torr. & Gray) Greene	Hidden-flower	2,5
	Cryptantha flava (A. Nels.) Payson	Hidden-flower	3,5
	Cryptantha fulvocanescens (Wats.) Payson		5
	Cryptantha Jamesii (Torr.) Payson		1,3,4,5
	C. Jamesii var. *setosa* Johnst.		5
	Cryptantha micrantha (Torr.) Johnst.		3
	Lappula Redowskii (Hornem.) Greene	Stick-seed	5
	L. Redowskii var. *desertorum* (Greene) Johnst.	Stick-seed	2,3
Cactaceae	*Opuntia Whipplei* Englm. & Bigel.		5
Capparidaceae	*Cleome serrulata* Pursh.	Rocky Mountain beeplant	1,2,3,4
Caryopyllaceae	*Arenaria confusa* Rydb	Sandwort	5
	Arenaria Fendleri Gray	Fendler sandwort	1,3
	Silene Scoulari Hook.	Catchfly, campion	5
Chenopodiaceae	*Atriplex argentea* Nutt.	Saltbush	4,5

White, Theodore E.
  1953a Observations on the Butchering Technique of Some Aboriginal Peoples, no. 2. American Antiquity 19:160-164.

  1953b A Method of Calculating the Dietary Percentages of Various Food Animals Utilized by Aboriginal Peoples. American Antiquity 18:390-396.

Wing, Elizabeth S., and Antoinette B. Brown
  1979 Paleonutrition: Method and Theory in Prehistoric Foodways. Academic Press, New York.

Family	Scientific Name	Common Name	Collection
Chenopodiaceae (cont'd.)	*Atriplex canescens* (Pursh) Nutt.	Fourwing saltbush	1,2,3,4,5
	Atriplex confertifolis (Torr. & Frem.) Wats.	Shadscale	2,4,5
	Atriplex Jonesii Standl.	Saltbush	4
	Atriplex obovata Moq.	Broadscale	4,5
	Atriplex Powellii Wats.	Ribscale	3,4,5
	Chenopodium Berlandieri Moq.	Goosefoot	5
	Chenopodium incanum (S. Wats.) A. Heller	Goosefoot	5
	Chenopodium leptophyllum Nutt.	Goosefoot	2,3,5
	Chenopodium Watsoni A. Nels	Goosefoot	5
	Eurotia lanata (Pursh) Moq.	Winterfat	3,4,5
	**Kochia scoparia* (L.) Roth	Summer cypress	5
	**Salsola Kali* L.	Tumbleweed	1,3,4,5
	Sarcobatus vermiculatus (Hook.) Torr	Greasewood	1,3,4,5
	Suckleya suckleyana (Torr.) Tydb.		5
	Sueda torreyana Wats.	Torry seepweed	1,5
Compositae	*Antennaria marginata* Greene	Pussytoes	1
	Artemesi Biglovii Gray	Sagebrush	5
	Artemesia dracunculoides Pursh	False terragon	4,5
	Artemesia filifolia Torr.	Sand sagebrush	1,3,5
	Artemesia frigida Willd.	Estafiata	1,3,5
	Artemesia ludoviciana Nutt.	Anisote, sagebrush	3,5
	A. ludoviciana ssp. *redolens* (Gray) Keck		5
	Artemesia nova A. Nels.	Sagebrush	1
	Artemesia tridentata Nutt.	Big sagebrush	1,4,5
	Bahia neomexicana Gray		5
	Brickellia californica (Torr. & Gray) Gray	Brickle-bush	5
	Brickellia scabra (Gray) A. Nels.	Brickle-bush	2,5
	Chrysopsis canescens (DC.) Torr. & Gray	Golden aster	5
	Chrysopsis foliosa Nutt.	Golden aster	4,5
	Chrysopsis villosa (Pursh.) Nutt. ex DC.	Golden aster	3,5
	Chrysothamnus Greenei (Gray) Greene	Slenderleaf Rabbitbush	4,5
	C. Greenei ssp. *fillifolius* (Rybd.) H. & C.		5
	Chrysothamnus neuseousus ssp. *Biglovii* (Gray) H. & C.	Bigelow rabbitbush	5

Family	Scientific Name	Common Name	Collection
Compositae (cont'd.)	C. nauseousus ssp. gnaphalodes (Greene) Hall	Rabbitbush	5
	Chrysothamnus Parryi (Gray) Greene	Rabbitbush	5
	Chrysothamnus viscidiflorus (Hook.) Nutt	Rabbitbush	3,5
	C. viscidiflorus ssp. visciciflorus	Rabbitbush	5
	Cirsium pulchellum (Greene) Woot. & Standl.	Thistle	1,5
	Cirsium wheeleri (Gray) Petrak	Thistle	3,5
	*Conyza canadensis (L.) Cronq.		5
	Conyza Coulteri Gray		5
	Erigeron divergens Torr. & Gray	Spreading fleabane	3,5
	Erigeron nudiflorus Buckl.	Fleabane	5
	Franseria acanthicarpa (Hook.) Cov.	Bur-weed	1,2,5
	Grindelia squarrosa var. nuda (Wood) Gray	Gum-weed	5
	Gutierrezia microcepala (DC.) Gray	Snakeweed	5
	Gutierrezia sarothrae (Pursh) Britt. & Rusby	Snakeweed	4,5
	Haplopeppus ameroides (Nutt.) Gray	Goldenweed	5
	Helianthus annuus L.	Sunflower	5
	Helianthus petiolaris ssp. fallax Heiser	Sunflower	1,5
	Hymenopappus filifolius Hook.		1,2,4
	Hymenoxys Ivesiana (Greene) K.F. Parker	Bitterweed	1,2,3,5
	Hymenoxys odorata DC.	Bitterweed	5
	Leuceiene ericoides (Torr.) Greene		1,3
	Lygodesmia grandiflora (Nutt.) Torr. & Gray	Skeleton plant	1,3
	Machaeranthera boltoniae (Greene) Turner & Horne	Aster	5
	Machaeranthera canescens (Pursh) Gray	Aster	5
	Machaeranthera tanacetifolia (H.B.K.) Nees	Aster	5
	Senecio multicapitatus Greene.	Groundsel	5
	Senecio multilobatus Torr. & Gray	Groundsel	1,3
	Solidago missouriensis Nutt.	Goldenrod	5
	Solidago petradoria Blake	Goldenrod	5
	Stephanomeria exigua Nutt.	Wire-lettuce	1,3,5
	Stephanomeria pauciflora (Torr.) A. Nels.	Wire-lettuce	5
	Tetradymis canescens DC.	Horse-brush	1,4
	Thelesperma megapotamicum (Spreng.) Kuntze	Hopi tea, green-thread	1,3,5
	Townsendia annua Beaman	Townsend's aster	5
	Townsendia incana	Townsend's aster	3

Family	Scientific Name	Common Name	Collection
Compositae (cont'd.)	*Townsendia strigosa* Nutt.	Easter daisy	3
	**Tragopogon dubius Scop.*	Goat's beard	3
	Verbesina encelioides (Cav.) Benth. & Hook.	Grownbeard	2,5
	Xanthium saccharatum Waller.	Cocklebur	1
Convovulaceae	*Cuscuta campestris* Yuncker.	Dodder	5
Cruciferae	*Arabis lignifera* A. Nels.	Rock-cress	5
	Arabis perrenans Wats.	Rock-cress	5
	Descuraninia pinnata ssp. *halictorum* (Cockll.) Detting	Pinnate tansy-mustard	2,3,5
	Dithyrea Wislenzii Englm.	Spectaclepod	1,2,3,4,5
	Erysimum capitatum (Dougl.) Greene	Western wallflower	2,3,5
	Lesquerella Fendleri (Gray) Wats.	Bladder-pod	2,3,4,5
	Rorippa microtites (Robins.) Rollins	Cress	1,3
	Sisymbrium altissimum L.		2
	Stanleya pinnate (Pursh.) Britton	Desert plume	1,3,5
	Streptanthella longirostris (Wats.) Rydb.		3,5
	Streptanthus cordatus Nutt.	Twistflower	3
Cupressaceae	*Juniperus monosperma* (Englm.) Sarg.	One-seed juniper	1,3,5
Cyperaceae	*Cerax.* sp.	Sedge	4
	Carex filifolia Nutt.	Hair sedge	1
Ephedracae	*Ephedra Cutleri* Peebles	Joint-fir	5
	Ephedra Torreyana Wats.	Joint-fir	2,3,4,5
	Ephedra viridis Coville	Joint-fir	2,3,5
Euphobiuceae	*Croton texensis* (Klotz.) Muel.	Dove-weed	1
	Euphorbia Fendleri Torr. & Gray.	Spurge	3,5
	E. Fendleri var. *chaetocalyx* Boiss.	Spurge	5
	Euphorbia glyptosperma Englm.	Spurge	5
	Euphorbia micromera Boiss.	Spurge	5
	Euphorbia serpens H.B.K.	Spurge	5

FAMILY	Scientific Name	Common Name	Collection
Geraniaceae	*Erodium cicutarium (L.) L'Her	Filaree, alfilaria	3
Gramineae	*Agropyron repens (L.) Beauv	Wheatgrass	5
	Agropyron Smithii Rydb.	Western wheatgrass	1,3,4,5
	Agropyron subsecundum (Link.) Hitchc.	Wheatgrass	5
	Andropogon scoparius Michx.	Little Bluestem	5
	Aristida Fendleriana Steud.	Fendler three-awn	3,5
	Boutelous barbata Lag.	Six-weeks grama	5
	Bouteloua curtipendula (Michx.) Torr.	Side-oats grama	1,5
	Bouteloua gracilis (H.B.K.) Lag	Blue grama	3,4,5
	Broumus anamalous Rupr.	Brome	1
	Bromus ciliatus L.	Fringed brome	2,3
	Bromus tectorum L.	Cheatgrass	2,3,4
	Elymus glacus Buckl.	Blue wild-rye	3
	Eragrostis pectinacea Michx. Nees	Love grass	5
	Festuca octoflora Walt.	Fescue	1,4
	Hilaria Jamesii (Torr.) Benth.	Galleta grass	1,3,4,5
	Hordeum jubatum L.	Fox-tail barley	5
	Hordeum pusillum Nutt.	Little barley	3
	Muhlenbergia pungens Thurb.	Sand-hill muhly	1,3,4,5
	Muhlenbergia racemosa (Michx.) B.S.P.	Muhly	5
	Muhlenbergia rigens (Benth.) Hitchc.	Muhly	5
	Munroa squarrosa (Nutt.) Torr.	False buffalo-grass	5
	Oryzopsis hymenoides (Roem. & Schult.) Ricker	Indian ricegrass	1,2,3,4
	Phleum pratense L.	Timothy	5
	Phragmites communis Trin.	Reed	3
	Piptochaetium fimbriatum (H.B.K.) Hitchc.	Pinyon ricegrass	3
	Poa fendleriana (Steud.) Vasey	Mutton grass	2,5
	*Setaria viridis (L.) Beauv.	Bristle grass	5
	Sitanion hystrix (Nutt.) J.G. Smith	Bottle brush	1,3,4,5
	Sporobolus airoides Torr.	Alkali sacaton	4,5
	Sporobolus contractus Hitchc.	Spike dropseed	5
	Sporobulus cryptandrus (Torr.) Gray	Sand dropseed	3,5
	Stipa comata Trin. & Rupr.	Needle & thread grass	3
	Stipa neomexicana (Thurb.) Scribn.	New Mexican porcupine grass	1,2
	Stipe speciosa Trin. & Rupr.	Desert needle grass	3

Family	Scientific Name	Common Name	Collection
Hydrophyllaceae	*Nama hispidum* Gray		3
	Phacelia crenulata Torr.	scorpion-weed	1,2,3,5
	Phacelia Ivesiana Torr.		5
	Phacelia neomexicana Thurb.		1,3
Labiatea	*Hedeoma Drummondii* Benth.	False pennyroyal	1,3,5
	**Marrubium vulgare* L.	Horehound	5
	Moloavica perviflora (Nutt.) Britton	Dragonhead	5
Leguminoseae	*Astragalus amphioxys* Gray	Milk-vetch	5
	Astragalus calycosus Torr. var. *saposus* (Gray) Jones	Milk-vetch	5
	Astragalus lentiginosus Dougl.	Blue locoweed	1
	Astragalus mollismus Torr. var. *Thompsonae*		3,5
	Astragalus praelongus Sheld. var. *praelongus*		3
	Astragalus proximus (Rydb.) Woot. & Standl.		3,5
	Dalea terminalis Jones	Spreading indigo-bush	1,4
	Lathyrus eucosmus Butters & St. John	Bush peavine	2,3
	Lupinus Kingii Wats.	Lupine	4,5
	Lupinus pusillus Pursh.	Rusty lupine	3
	Melilotus officinalis (L.) Lam.	Yellow sweetclover	3
	Petalostemum candidum (Willd.) Mich.	White prairieclover	5
	Psoralea lanceolata Pursh.	Lemon scurfpea	1,3,4
Liliaceae	*Allium macropetalum* Rydb.	Wild onion	5
Linaceae	*Linum aristatum* Engelm.	Flax	4
	Linum Lewisii Pursh.	Flax	3
	Linum puberulum (Englm.) Heller	Flax	1,3
Loasaceae	*Mentzelia albicaulis* Dougl.	White-stem blazing-star	3,5
	Mentzelia pumila (Nutt.)	Blazing-star	2,5

Family	Scientific Name	Common Name	Collection
Malvaceae	*Sphaeralcea coccinea* (Pursh.) Rydb. var. *coccinea*	Globemallow	1,5
	Sphaeralcea emoryi Torr.	Globemallow	4,5
	Sphaeralcea Fendleri Gray	Globemallow	1,3,4
	S. Fendleri Gray var. *fendleri*	Globemallow	5
	Sphaeralcea incana Torr. var. *cuneata* Kearney	Globemallow	5
	Sphaeralcea incana Torr. var. *incana*	Globemallow	5
	Sphaeralcea parvifolia A. Nels.	Globemallow	5
Nyctaginaceae	*Abronia elliptica* A. Nels.	Sandverbena	1,2,3
	Abronia fragrans Nutt.	Sandverbena	5,2
	Mirabilis multiflora (Torr.) Gray	Wild four-O'clock	5,1,3
	Mirabilis oxybaphoides Gray		1,3
	Oxybaphus glaber (Wats.)		5
	Oxybaphus pumilus (Standl.) Standl.		5
	Tripterocalyx Wootonii Standl.		5,3
Oleaceae	*Forestieria neomexicana* Gray	Ironwood, New Mexico olive	1,5
Onagraceae	*Oenothera albicaulis* Pursh	Prairie evening primrose	5,1,2,3
	Oenothera caespitosa Nutt.	Tufted evening primrose	1,3
Pinaceae	*Pinus edulis* Englm.	Pinon pine	3
Plantaginaceae	*Plantago Purshii* Roem. & Schult.	Indian Wheat	5,4,3
Polemoniaceae	*Ipomopsis aggregata* (Pursh) V. Grant	Skyrocket	5,1,3
	Ipomopsis longiflora (Torr.) V. Grant		5,1,2,3
	Ipomopsis multiflora (Nutt.) V. Grant		5,1
	Ipomopsis pumila (Nutt.) V. Grant		3
Polygonaceae	*Eriogonum alatum* Torr.	Wild buckwheat	3,4,5
	Eriogonum cernuum Nutt.	Wild buckwheat	5
	Eriogonum corymbosum Benth. var *velutinum*	Wild buckwheat	1,3,4
	Eriogonum effusum Nutt.	Wild buckwheat	4

Family	Scientific Name	Common Name	Collection
Polygonaceae (cont'd.)	*Eriogonum Jamesii* Benth.	Wild buckwheat	1,5
	E. Jamesii var. *flavescens*	Wild buckwheat	5
	Eriogonum leptophyllum (Torr.) Woot. & Standl.	Wild buckwheat	1,4,5
	Eriogonum microthecum Nutt. var. *foliosum* (Torr.) Reveal	Wild buckwheat	5
	Rumex hymenosepalus Torr.	Canaigre, wild rhubarb	3,5
Polypodiaceae	*Cheilanthes Feei* Morre	Lip-fern	1,5
Portulacaceae	*Portulaca oleracea* L.	Purslane	5
Ranunculaceae	*Clematis ligusticifolia* Nutt.	Virgin's bower	1,5
	Dephinium scaposum Greene	Larkspur	1,2,3
Rosaceae	*Cerocarpus montanus* Raf.	Mountain mahogany	1,2,3,4
	Cowainia Stansburiana Torr.	Cliffrose	1,3,4
	Fallugia paradoxa (D. Don) Endl.	Apache plume	5
	Prunus virginiana L. var. *melanocarpa* (A. Nels.) Rydb.	Chokecherry	1,2,3
Santallaceae	*Comandra pallida* A. DC.	Bastard toad-flax	1,2,3
Salicaceae	*Populus* X *acuminata* Rydb.	Lanceleaf cottonwood	1,3,5
	Populus angustifolia James	Narrowleaf cottonwood	1
	Populus Fremontii Wats.	Fremont cottonwood	1,3,5
	Salix exigua Nutt.	Coyote willow	1,4,5
	Salix Goodingii Ball	Gooding willow	5
	Salix lasiandra Benth.	Pacific willow	5
	Salix lutea Nutt.	Yellow willow	5
	Salix taxifolia H.B.K.	Yew-leaf willow	3
Saxifragaceae	*Ribes areum* Pursh	Golden currant	1,3,5
	Ribes cereum Dougl.	Currant	5
	Ribes inebrians Lindl.	Currant	1,3
Scrophulariaceae	*Castillega integra* Gray	Paintbrush	1

FAMILY	Scientific Name	Common Name	Collection
Scrophulariaceae (cont'd.)	Castilleja linariaefolia Benth.	Paint brush	1,3,5
	Orobanche multiflora Nutt.	Broom-rape	5
	Penstemon angustifolius Nutt.	Beardtongue	1,3,4
	P. angustifolius Nutt. ssp. caudatus (Heller) Keck	Beardtongue	5
	Penstemon barbatus (Cav.) Roth.	Beardtongue	1,5
	P. barbatus (Cav.) Roth ssp. trichander (Gray) Keck	Beardtongue	5
	*Verbascum Thapsus L.	Mullein	5
Solanaceae	Chamaesaracha coronopus (Dunal) Gray	False tomatoe	1,3
	Datura meteloides DC.	Jimson weed	1
	Lycium pallidum Myers	Pale wolfberry	3,5
	Physalis hederafolia var. cordifoila (Gray) Waterfall	Ground cherry	1,2,3,5
	Solanum Jamesii Torr.	Wild potatoe	1,2,5
	Solanum triflorum		1
Tamaricaceae	*Tamarix pentandra Pall.	Tamarisk	1,3,4,5
Typhaceae	Typha latifolia L.	Cattail	5
Umbelliferae	Aletes Macdougali Coult. & Rose		5
	Cymopterus bulbosus A. Nels		5,3
	Cymopterus Fendleri Gray		5
	Cymopterus montanus (Nutt.) Torr. & Gray		5,1,3
Vitaceae	Partheoncissus inserta (Kerner) K. Fritsch	Virginia creeper	1,3,5

Collections

1. Herbarium, Chaco Culture National Historical Park. Collection made by Ora M. Clark, in approximately 1945.

2. Herbarium, Chaco Culture National Historical Park. Collections made by various people, all subsumed here under Hastings and Benson, from approximately 1935-1939.

3. Herbarium, Chaco Culture National Historical Park. Collections made by Ron Bronitsky, 1972, in conjunction with Ecology of Chaco Canyon, Loren D. Potter, 1974.

4. Herbarium, University of New Mexico. Collections made by Mollie Struever and Anne Cully, in conjunction with Pollen and Flotation Analysis in Relation to Archeology, Chaco Canyon.

5. Herbarium, University of New Mexico, and Chaco Culture National Historical Park. Collections made by Anne Cully in conjunction with Pollen Analysis at 29SJ 627, Chaco Canyon, and Check-list of Plants at Chaco Canyon National Monument, New Mexico.

* Indicates plant introduced.

Appendix B

An Annotated List of the Birds of Chaco Canyon National Monument

by

Jack F. Cully, Jr.

During the period 17 October 1978 to 31 July 1980, I conducted extensive field work on wildlife populations at Chaco Canyon National Monument, New Mexico. One hundred and nineteen days were spent in the field recording birds and trapping small mammals. This bird list includes birds censused along five 1.6-km long strip transects in four habitats as well as opportunistic observations in the monument and reference to records of bird observations maintained at the monument headquarters. A list of birds is never complete and additional species will be added in the future. I did not spend any time in the monument during midwinter, thus, the most serious deficiency of the list is inadequate accounting for wintering birds. Birds were observed in the monument as late as mid-November and as early as mid-March, most of which were probably wintering species.

One goal was to identify breeding bird species at Chaco Canyon. The breeding activity of 29 species was observed and 12 additional species that probably breed in the monument at least occasionally were identified. Because of the scope of work on various aspects of wildlife biology at the monument I was not able to spend as much time looking for nests and indications of breeding activity as I would have liked. For purposes of this report, I consider that definite evidence of breeding is sighting (1) birds at nest; (2) adults feeding begging dependent young; (3) adult birds carrying nest material and; (4) adults carrying food. The most common evidence of breeding was adult birds feeding dependent fledglings. Breeding species are identified by an asterisk after their common name. Likely breeders are those species that are resident throughout the breeding season but for which reproductive activity was not observed. These species are identified by an asterisk followed by a question mark; e.g., "Great-horned Owl*?."

Figure 2.1 shows the habitats identified in the list and location of the bird transects. Habitats are described in the attached report on avian ecological relationships at Chaco Canyon (Cully this volume). Status, frequency of occurrence, and numbers are treated according to Hubbard (1978). Resident implies that a species is present year-round; migrant species are present for short periods during spring and/or fall; summer or winter residents are present for longer periods in the specified season. Regular species can be found every year in the right season; irregular species, every other year; occasional, every 3 - 5 years and casual, less often than occasional. Numbers are treated subjectively. Abundant birds are conspicuous and numerous when present in an area. Common birds are always to be found with a modicum of effort; uncommon birds will be present in a habitat at a given time but considerable looking may be required to find them. Rare species may not be present in the monument at a given time. Describing density in this way is not particularly accurate since conspicuous species will be more easily found at low densities than will secretive species at higher densities, but this method should indicate which species are most likely to be seen, and how much effort must be expended to see them.

Common Loon (Gavia immer) One was reported banded in 1938 in NPS records. The record is not the original and there is no further information. Loons are probably not justified on this list.

Canada Goose (Branta candensis) Casual migrant. Reported "just outside the monument" in April 1962. NPS personnel also reported seeing a flock of migrating Canada geese flying over the monument during spring 1979, but there was no written record of this sighting.

Snow Goose (Chen caerulescens) Casual migrant. Reported during October 1951 by F.H. Elmore. There is no further information about this sighting.

Mallard (Anas platyrhynchos) Casual migrant. Reported in October 1968 in the park records. Mallards are common migrants in the San Juan Basin where they can be seen on stock tanks. I have not observed them in the monument.

Turkey Vulture (Cathartes aura) Regular common summer resident. Turkey vultures roost at Chaco Canyon in the cottonwoods in the Wash 200 m south of Casa Chiquita ruin from April to September. During 1979 and 1980 there were from 18-22 turkey vultures present. They may nest in the cliffs at Chaco Canyon, but I have not seen any signs of breeding in the monument.

Sharp-shinned Hawk (Accipiter striatus) Irregular migrant. One was seen once flying over the Pinyon-juniper woodland on Chacra Mesa.

Cooper's Hawk (Accipiter cooperii) Regular uncommon migrant. Cooper's hawks may be seen occasionally along the Wash during both spring and fall migration.

Red-tailed Hawk* (Buteo jamaicensis) Regular year-round resident. During 1979 I did not observe red-tailed hawks breeding at Chaco Canyon. During 1980 there were two red-tailed hawk nests on the cliffs. One of these nests fledged at least one baby, and the other had two nestlings in May, but their fate is unknown.

Ferruginous Hawk (Buteo regalis) Uncommon regular to irregular resident. Ferruginous hawks have been sighted in the monument occasionally since 1955. I have seen ferruginous hawks along the north entrance road within 1 km of the monument, but not in the monument itself.

Golden Eagle (Aquila chrysaetos) Regular uncommon migrant. Golden eagles were seen rarely during the winters of 1978-79 and 1979-80. During summer 1980 there were two or three seen over the monument regularly. During fall of 1980 there were possibly as many as five seen throughout the period of late September to early November. Three of these birds (all sub-adults) were often seen over Cly's Canyon. The other observations were of an adult or adults.

Bald Eagle (Haliaeetus leucocephalus) Rare migrant. Although I have seen bald eagles at other locations in the San Juan Basin, I have not seen them at Chaco Canyon National Monument. They probably do occur there occasionally during migration, however.

Northern Harrier (Circus cyaneus) Regular uncommon migrant and winter resident. Northern harriers may be seen soaring over any habitat at Chaco Canyon, but they are most common over grassland.

Prairie Falcon* (Falco mexicanus) Regular uncommon year-round resident. There have been as many as four prairie falcon nests at Chaco Canyon during a single year. During the 1979 breeding season there were two nesting attempts and fledglings were being fed on 20 July 1979. During 1980 I only observed one nest and the fate of the babies is unknown. They appeared to be about two weeks old at the end of May.

Peregrine Falcon (Falco peregrinus) There have been unverified reports of peregrine falcons, but they may be misidentifications of the more common prairie falcon.

American Kestrel* (Falco sparverius) Regular common summer resident. Like the other hawks observed nesting at Chaco Canyon, American Kestrels nest in the cliffs. During 1979 there were several nests on the north side of the canyon near Cly's Canyon and west of Casa Chiquita. During 1980 these nests were not occupied and although American kestrels were present, I did not observe any nesting efforts.

Scaled Quail* (Callipepla squamata) Uncommon to common resident. Scaled quail were uncommon during 1979, but by 1980 they were fairly common. They are most often seen among the greasewood and fourwing saltbush along the floodplain. I did occasionally see scaled quail on the Bench above Casa Chiquita. Scaled Quail do breed at Chaco Canyon. I saw a pair with three small birds near Wijiji Ruin during May 1980.

Snowy Egret (Egreta thula) Casual migrant. One was reported in September1959. Snowy egrets are uncommon migrants during spring and fall; I have seen them at Lake Valey and at Orphan Annie Lake.

Killdeer (Charadrius vociferus) Regular uncommon migrant. I heard killdeer migrating overhead at night during spring 1979. Killdeer were previously reported during 1962, 1963, and 1969.

Mountain Plover (Charadrius montanus) Irregular uncommon migrant. Mountain plovers frequent barren areas in the San Juan Basin during both spring and fall migration. National Park Service personnel described a mountain plover that was on the road in the residence area in August 1980.

Long-billed Curlew (Numenius americanus) Irregular uncommon fall migrant. During August 1980 I observed two of these birds on the south entrance road 1 km south of the monument boundary. They are regularly reported from the San Juan Basin outside of Chaco Canyon National Monument.

Mourning Dove (Zenaida macroura) Regular abundant summer resident. Mourning doves nest in all habitats at Chaco Canyon. I have found their nests in the wash on the ground, in trees and shrubs, on the floodplain in shrubs and in shrubs on the ground in the shrub grassland of the Bench and Pinyon-juniper. They are the most abundant breeding bird in the Wash.

Yellow-billed Cuckoo (Coccyzus americanus) Casual. One was reported in the monument during August 1977. There are no further data.

Greater Roadrunner (Geococcyx californianus) Occasional. Roadrunners were reported in 1944, April 1955, May 1956, February 1957, September 1964, September 1968, August 1970, and May 1973. I have not observed roadrunners in the San Juan Basin.

Great-horned Owl*? (Bubo virginianus) Regular uncommon year-round resident. Great-horned Owls can be heard calling at night from the cliffs in the monument. Their numbers range from common to uncommon depending on the year, but there are always some in the monument. In 1979, I rarely saw them, but in 1980 they were regularly seen in the wash. Although I have not seen any evidence of their breeding in the monument, it is almost certain that they do breed there.

Northern Pigmy Owl (Glaucidium gnoma) Irregular migrant. During August 1979 I flushed one from a juniper tree on Chacra Mesa south of Wijiji.

Long-eared Owl* (Asio otus) Regular uncommon summer resident. Long-eared owls are occasionally flushed out of hiding in densely vegetated rincons or from the cottonwoods along the wash. In June 1979 I observed three or four owls that appeared to be fledglings flying over the campground. I was not able to get a good look at them because it was too dark, but they were the right size for long-eared owls. In 1980 a pair nested near Pueblo Bonito and the fledglings were seen in the ruin for several days. Ken Mabery was able to photograph both juveniles and adults.

Common Poor-will* (Phaelaenoptilus nuttallii) Common summer resident. Poor-wills can often be seen during the summertime when they fly up from roads in automobile headlamps. They can also be heard calling at night, especially in the fall. Poor-wills are known to hibernate, so they may winter in the monument. I found one nest on Chacra Mesa during May 1981.

Common Nighthawk*? (Chordeiles minor) Uncommon summer resident. I have flushed common nighthawks from their roosts under bushes in the Pinyon-juniper woodland on Chacra Mesa. Although I have found common nighthawk nests in other places in the San Juan Basin, I have not yet found any at Chaco Canyon. They probably do breed in the monument, however.

White-throated Swift* (Aeronautes saxatalis) Common summer resident. White-throated swifts roost, and probably nest, in crevices in the cliffs. I have located summer roosts in the campground and behind Pueblo Bonito. During the daytime in June 1979 I watched birds entering and leaving these crevices, presumably feeding babies.

Black-chinned Hummingbird*? (Archilochus alexandri) Regular common summer resident. Black-chinned hummingbirds are most common along the floodplain sites and in the Wash, where they probably breed.

Broad-tailed Hummingbird*? (Selasphorus platycercus) Common summer resident. Broad-tailed hummingbirds are most common in the Pinyon-juniper habitat on Chacra Mesa and around some seeps on the north side of Chacra Mesa. Although they probably breed in the monument, I have no direct evidence of this.

Rufous Hummingbird (Selasphorus rufus) Regular uncommon fall migrant. Rufous hummingbirds are found on Chacra Mesa and in the rincons on the north side of Chacra Mesa during August and early September. They probably do not breed at Chaco Canyon.

Belted Kingfisher (Ceryle alcyon) Causal migrant. One was reported in September 1969. There is no further information on this record.

Common Flicker (Colaptes auratus) Regular uncommon migrant and winter resident. During fall, winter, and spring, flickers can often be heard or seen in the Wash or in the Pinyon-juniper woodland on Chacra Mesa.

Lewis Woodpecker (Melanerpes lewis) Casual. Lewis woodpeckers were reported during May and September 1969.

Yellow-bellied Sapsucker (Sphyrapicus varius) Irregular uncommon migrant. I have one observation of yellow-bellied sapsuckers during fall 1979 and one during spring 1980 in a cottonwood in the Wash. There are no other records for the monument, but I have seen them at other locations in the San Juan Basin.

Hairy Woodpecker (Picoides villosus) Regular uncommon winter resident. Hairy woodpeckers frequent trees along the Wash and in the Pinyon-juniper during fall, winter, and early spring. They are never common.

Downy Woodpecker (Picoides pubescens) Irregular rare migrant. I saw downy woodpeckers along the Wash once during spring and once during fall 1980. There are no other records at Chaco Canyon for this species.

Western Kingbird* (Tyrannus verticalis) Regular uncommon summer resident. There was one western kingbird nest in the cottonwoods during June 1979 and again in June 1980. The 1979 nest produced four fledglings, but none was observed during 1980.

Cassin's Kingbird* (Tyrannus vociferans) Regular common summer resident. During both 1979 and 1980 there were numerous Cassin's Kingbird nests in the Wash. During 1979 nesting success was high for this species. During 1980 I did not observe fledglings, although pairs were common.

Ash-throated Flycatcher* (Myiarchus cinerascens) Regular common migrant and summer resident. During 1979 I observed a pair of ash-throated flycatchers carrying nesting material into a juniper tree on Chacra Mesa. The nesting effort there had been abandoned when I returned two weeks later. Later that summer, however, I did see a group of four, probably a family group, 0.5 km south of the attempted nest. Ash-throated flycatchers were observed carrying nest material in the Wash and on the floodplain near Pueblo Bonito during summer 1980.

Say's Phoebe* (Sayornis saya) Common year-round resident. Say's phoebes nest in holes in the side of the wash, in sandstone, at the Visitor Center and in niches in the ruins. They are common and not shy. During 1979 a nest in a niche at Pueblo Bonito was located directly over one of the self-guided trail markers. I watched this bird incubating her eggs apparently unconcerned, as a Park Ranger led a guided tour past the nest.

Dusky Flycatcher (Empidonax oberholseri) Rare migrant. I saw one near Pueblo Bonito during August 1979.

Gray Flycatcher (Empidonax wrightii) Common spring migrant. Gray flycatchers are common during May near Pueblo Bonito and in the Pinyon-juniper woodland on Chacra Mesa. They are uncommon along the Wash.

Western Flycatcher (Empidonax difficilis) Rare migrant. I observed one along the Wash in late May 1979.

Western Wood Pewee (Contopus sordidulus) Irregular uncommon spring migrant. I observed western wood pewees along the Wash in May and September 1979.

Horned Lark*? (Eremophila alpestris) Regular abundant year-round resident. Horned larks are abundant in the shrub grassland on top of the mesas and surrounding Chaco Canyon. Horned larks are the most abundant bird in the San Juan Basin, but they are rarely seen in the canyon itself. I have only encountered horned larks on transects twice on the bench. I frequently heard them flying over all of my other transects, especially during the winter, but they never occurred on the ground at those locations.

Barn Swallow (_Hirundo rustica_) Regular spring migrant. Barn swallows are a transient species at Chaco Canyon occurring in small numbers in migration during April.

Cliff Swallow* (_Hirundo pyrrhonota_) Regular abundant summer resident. Cliff swallows can be seen flying overhead in any habitat in Chaco Canyon. They are most common over the floodplain and the Wash. Large numbers of cliff swallows nest under overhangs in the south-facing cliffs on the north side of the canyon.

Tree Swallow (_Tachycineta bicolor_) Regular spring migrant. Tree swallows are usually the first swallows to migrate through the San Juan Basin during spring. They can be seen during April over the floodplain. They do not occur at Chaco Canyon during the breeding season.

Violet Green Swallow (_Tachycineta thalassina_) Occasional spring migrant. I saw one violet green swallow in the Wash during June 1979.

Bank Swallows (_Riparia riparia_) Occasional migrant. I observed several bank swallows during June 1979 over the floodplain and in an arroyo between Chetro Ketl and Hungo Pavi, which I thought might be nesting in holes in the arroyo bank. A week later they were not present.

Steller's Jay (_Cyanocitta stelleri_) Casual winter. A Steller's jay was reported by Lloyd Pierson in November 1955. They may occasionally enter the monument during mid-winter when servere weather forces them down from Mt. Taylor.

Scrub Jay*? (_Aphelocoma coerulescens_) Uncommon resident. Scrub jays are most common in the Pinyon-juniper woodland of Chacra Mesa during all seasons. They are occasionally seen along the Wash or floodplains during winter. I have not seen reproductive activity among scrub jays, but they almost surely breed on Chacra Mesa.

Black-billed Magpie (_Pica pica_) Casual winter. One was reported at Chaco Canyon during November 1958. Black-billed magpies are fairly common along the San Juan River and young dispersing birds might occasionally appear at Chaco Canyon.

Chihuahuan Raven* (_Corvus corax_) Common year-round resident. Ravens occur at Chaco Canyon in loose flocks during fall and winter. During spring they form pairs and nest in cavities in the cliffs. Their densities are fairly low; there are probably no more than five or six breeding pairs in the monument. Because they are conspicuous and wide-ranging, however, they appear to be more abundant than they actually are.

White-necked Raven (Corvus cryptoleucus) David Niles reported hearing a call from a raven in July 1964 that he thought was too high-pitched for a common raven. He suggested that it might have been a whitenecked raven. The frequency range of raven calls is wide, however, and I have heard the same bird produce high and low-pitched calls. The bird that he heard was probably a young common raven.

American Crow (Corvus brachyrhynchos) Irregular winter wanderer. Douglas Warnock reported crows at Chaco Canyon during November 1956. I observed a flock of 20 crows about 10 km south of the monument during April 1979, but have not observed them in the monument.

Pinyon Jay* (Gymnorhinus cyanocephalus) Common year-round resident. Pinyon jays occur most abundantly in the Pinyon-juniper woodland during all seasons. I have observed adults feeding fledglings from April to June. During fall and winter, flocks of pinyon jays were occasionally seen on the Bench and flying over the canyon.

Mountain Chickadee (Parus gambeli) Common fall migrant. During fall 1978 mountain chickadee were very common along the Wash. They were present during fall 1979 and 1980, but their numbers were considerably lower than in 1978.

Plain Titmouse* (Parus inornatus) Locally common summer resident. Plain titmice can be found on Chacra Mesa from April through September. I have not observed them carrying food or nesting material, but the presence of groups of four to seven birds during August suggests that they do breed there.

Bushtit (Psaltriparus minimus) Irregular migrant. I observed a flock of about 20 Bushtits on the floodplain 1 km west of Casa Chiquita during October 1978 and in the Pinyon-juniper woodland during spring 1979. They have been irregularly reported in the monument during winter since 1956.

White-breasted Nuthatch (Sitta carolinensis) Irregular rare migrant. I observed one white-breasted nuthatch west of Casa Chiquita on 31 July 1980. There were no other records of this species in the monument.

Red-breasted Nuthatch (Sitta canadensis) Irregular rare migrant. I observed one red-breasted nuthatch in a cottonwood in the Wash on 4 September 1979. There are no other records of this species in the monument.

House Wren (Troglodytes aedon) Regular uncommon fall migrant. I observed house wrens during September 1979 in the Wash and on Chacra Mesa in the Pinyon-juniper woodland. I also saw house wrens at Chaco Canyon near Pueblo Bonito and in the Wash in October 1980.

Bewick's Wren*? (Thryomanes bewickii) Common fall and spring migrant. Bewick's wrens are noisy and conspicuous small wrens with long tails. They are common during spring migration in the Pinyon-juniper and during the fall along the floodplains.

Canyon Wren* (Catherpes mexicanus) Uncommon resident except during winter when they are common. Canyon wrens occur around Chacra Mesa in small numbers all year. In the rest of the monument they are likely to be seen or heard along the cliffs from October-April. During spring 1981, I observed an adult canyon wren feeding fledglings on Chacra Mesa.

Rock Wren* (Salpinctes obsoletus) Abundant summer resident. Rock wrens were the most common breeding bird species on the Bench during 1979. They also are abundant along the cliffs of the canyon, the vertical banks of the Wash and on Chacra Mesa. This species appears to be one of the most successful birds in the monument.

Northern Mockingbird* (Mimus polyglottos) Summer, regular, common. Mockingbirds are common in the shrubs of the floodplain and Wash and uncommon in the Pinyon-juniper. In 1979 I observed two adults carrying food to a fledgling in some greasewood west of Pueblo Bonito. In 1980 there appeared to be at least four pairs in or adjacent to the Wash along the transect there.

Gray Catbird (Dumetella carolinensis) Casual migrant. Hubbard (1978) lists this species for Chaco Canyon, and although I have a record during October 1980 from the San Juan Basin, I could find no other record of catbirds being seen in the monument.

Brown Thrasher (Toxostoma rufum) Casual? Hubbard (1978) again cites the Chaco Canyon Bird List (1975), which indicates that brown thrashers occur here during fall. I did not find any recorded observations for Chaco Canyon and have not seen this species in the San Juan Basin.

Bendire's Thrasher* (Toxostoma bendirei) Migrant and summer, uncommon and regular. Bendire thrashers occur in the shrubby habitat along the floodplain during spring migration. In June 1980 I observed a pair of Bendire thrashers feeding fledglings along the monument boundary in Gallo Wash.

Crissal Thrasher (Toxostoma dorsale) Summer, regular, uncommon. Crissal thrashers are secretive; however, their long curved bill, clear breast and reddish brown crissum are distinctive. I have observed Crissal thrashers in the shrubby habitat along the floodplain as well as in Kim-me-ni-oli Wash 15 km to the west. I have seen no evidence of breeding although I have heard these birds singing in April and May.

Sage Thrasher (Oreoscoptes montanus) Regular spring migrant. Sage thrashers are most common in the shrubby floodplain habitats. I frequently saw them along the Pueblo Bonito and Casa Chiquita transects during April and May. Although I have not observed sage thrashers during the fall, they have been recorded during the period August-November. I observed a sage thrasher nest near Star Lake in a sagebrush.

American Robin (Turdus migratorius) Occurs regularly during migration and is uncommon. Robins were seen in the wash and on the floodplain during November and April.

Hermit Thrush (Catharus guttatus) Regular uncommon fall migrant. Hermit thrushes were seen during fall in the Wash and in the Pinyon-juniper habitat on top of Chacra Mesa.

Western Bluebird (Sialia mexicana) Occasional rare migrant. Western bluebirds were reported at the monument during March 1957 and for March in another, unidentified, year. No specimens were seen during this study.

Mountain Bluebird* (Sialia currucoides) Common regular winter resident and uncommon summer resident. I have found two mountain bluebird nests, in small holes in rocks, at Chaco Canyon: one in 1979 in Mockingbird Canyon about 6 m high in a cliff, and one about 1 km west of Wijiji in a large boulder during 1980. There were several other pairs present during summer 1980, as well, but I was not able to locate their nests.

Townsend's Solitaire (Myadestes townsendi) Common regular winter resident in Pinyon-juniper woodland. Townsend solitaires were seen during fall and spring on top of Chacra Mesa and along the Wash during April 1980.

Blue-gray Gnatcatcher*? (Polioptila caerulea) Common migrant and summer resident along the floodplain and in the Wash. Although I saw no evidence of this species nesting at Chaco Canyon, its presence throughout the breeding season suggest that it breeds in the monument, probably in the Wash.

Ruby-crowned Kinglet (Regulus calendula) Uncommon, regular migrant along the Wash and in the Pinyon-juniper.

Bohemian Waxwing (Bombycilla garrulus) Casual in winter. One was reported during December 1968. Hubbard (1978) reports that this species is expanding its range into New Mexico and has become a regular winter visitor. They were not seen at Chaco Canyon during this study, but I have not worked in the canyon during mid-winter.

Loggerhead Shrike* (Lanius ludovicianus) Common resident along the floodplain. Loggerhead shrikes were present on every trip that I made to Chaco Canyon. I did not find nests, but I saw parents feeding babies during May and June in Gallo Wash, in Chaco Wash near Wijiji and along the floodplain from Chetro Ketl to Peñasco Blanco. Clutches usually numbered four fledglings.

European Starling (Sturnus vulgaris) Uncommon, regular migrant or wanderer. During spring 1979 I saw one flock of four starlings fly down Chaco Wash. During May 1980 it appeared that three pairs were attempting to nest in holes in the sandstone cliffs behind the residence area. At that time, the park was sprinkling as part of its sewage processing and the water appeared to make it possible for this species to nest. When a new sewage treatment method was initiated and the water was no longer available, the starlings disappeared from the monument. This suggest an interesting management dilemma. Since water seems to be such a limiting factor on biological communities in the San Juan Basin, it is tempting to think that adding water to an area will enhance its value to wildlife. What might in fact happen is that the additional water will make it possible for aggressive exotic species that are excluded by the present xeric conditions to become established and drive out more delicate native species--a situation that is not desirable in a National Park.

Hutton's Vireo (Vireo huttoni) One Hutton vireo was reported at Chaco Canyon during October 1956, but there is no additional detail; therefore I concur with Hubbard (1978) that the record is questionable.

Solitary Vireo (Vireo solitarius) Rare irregular migrant. One was seen during September 1979 in cottonwoods along the Wash. Solitary vireos may be regular migrants; the lack of previous reports may be because this species is not conspicuous during migration.

Warbling Vireo (Vireo gilvus) Rare occasional fall migrant. One warbling vireo was seen along the wash in September 1979. This species is secretive and may occur more regularly during migration, but the monument had no other records of this species.

Orange-crowned Warbler (Vermivora celata) Regular common to uncommon fall migrant along the Wash and floodplain.

Virginia's Warbler (Vemivora virginiae) Casual to irregular migrant. I observed one Virginia warbler in the Wash during May 1979. One other record exists at the monument for September 1969. I have seen this species at other locations during May in the San Juan Basin, but it was never common.

Yellow Warbler (Dendroica petechia) Occasional migrant. I have not observed yellow warblers at Chaco Canyon, but records are on file for observations of this species during August 1963 and May 1969 and 1973.

Yellow-rumped Warbler (Dendroica coronata) Regular common migrant. Audubon warblers can be seen during May, June, and September along the Wash, the floodplain, and in the Pinyon-juniper woodland. Myrtle warblers are a far less common subspecies. I saw one in the Pinyonjuniper woodland on Chacra Mesa during September 1979.

Black-throated Gray Warbler (Dendroica nigrescens) Irregular, fall migrant. I observed one black-throated gray warbler in the Pinyon-juniper woodland on top of Chacra Mesa during August 1979.

Townsend's Warbler (Dendroica townsendi) Casual fall migrant. A Townsend's warbler was seen in the Wash during October 1978. I did not find any other record of this species in the monument, and I have not seen it at other locations in the San Juan Basin.

MacGillivray's Warbler (Oporonis tolmiei) Regular uncommon to common migrant along the Wash and floodplain. Previous to this study MacGillivray warblers have been reported during fall since 1950.

Wilson's Warbler (Wilsonia pusilla) Irregular, uncommon migrant. Wilson's warblers were seen during May and September 1979 along the Wash and on the floodplain. They have been previously reported in the monument during May 1955, August 1962, and September 1969 and 1972.

House Sparrow (Passer domesticus) Occasional during all seasons. During this study no house sparrows were seen at the monument. They have been reported occasionally since 1954, the most recent record being from winter 1969. There are resident local populations of house sparrows at numerous other locations in the basin, including at Star Lake, Lake Valley, and Crownpoint. The absence of dependable water at Chaco Canyon may be responsible for their absence here.

Western Meadowlark* (Sturnella neglecta) Regular uncommon resident except during winter. Western meadowlarks breed on the floodplain along Chaco Wash in low numbers. During April and May their song is common early in the morning. Their nesting density seems to be less than one pair per linear mile of floodplain.

Yellow-headed Blackbird (Xanthocephalus xanthocephalus) Occasional spring migrant. Yellow-headed Blackbirds are uncommon but regular spring migrants throughout the San Juan Basin. I have not seen them at Chaco Canyon, but they were reported there during spring 1963 and June 1965.

Red-wing Blackbird (Agelaius phoeniceus) Occasional to casual spring migrant. I observed a flock of red-wing blackbirds flying over the monument during May 1979. The only other observation on record at the monument is a banding record from 1938. They are regular migrants over the San Juan Basin, but they probably do not often stop at the monument because of the lack of water.

Scott's Oriole (Icterus parisorum) Casual fall migrant. David Niles reported Scott's orioles during July 1964. I saw an adult pair and a flock of young Scott's orioles 30 km south of the monument during July 1980, but have seen no others in the San Juan Basin.

Northern Oriole* (Icterus galbula) Common summer breeding resident in the cottonwoods along the Wash. The race at Chaco Canyon is the Bullock's oriole. Where the habitat is available these birds nest in large numbers during May and June. They are generally gone from the monument by the end of July.

Brewer's Blackbird (Euphagus cyanocephalus) Irregular, uncommon migrant. I saw two Brewer blackbirds at the wash during May 1980. They were previously recorded during spring, summer and fall of 1969.

Brown-headed Cowbirds* (Molothrus ater) Regular common late spring and summer breeding resident. Brown-headed cowbirds are most common along the Wash and floodplain. This species is a nest-parasitic species at Chaco Canyon; in late July 1980 I observed four different pairs of black-throated sparrows feeding fledging cowbirds. I have often seen Bullock's orioles chasing cowbirds, so they probably parasitize that species as well. Brown-headed cowbirds are known to parasitize more than 100 species of birds.

Western Tanager (Piranga ludoviciana) Regular locally common spring migrant. During May and early June western tanagers are fairly common along the Wash.

Rose-breasted Grosbeak (Pheucticus ludovicianus) Casual spring migrant. One rose-breasted grosbeak record exists at the monument during spring 1963. I have not encountered this species in the San Juan Basin.

Black-headed Grosbeak (Pheucticus melanocephalus) Regular, uncommon spring migrant. Black-headed grosbeak are most common during May along the Wash in cottonwood trees.

Blue Grosbeak* (Guiraca caerulea) Regular, uncommon summer breeding resident. Blue grosbeaks can occasionally be seen along the floodplains, but they are most common in the Wash where they breed. I have not found nests, but I have watched a female feeding fledglings and during June there are quite a few males singing.

Indigo Bunting (Passerina cyanea) Casual. One Indigo bunting is included in the National Park Service records from spring 1963. No examples were seen during this study.

Lazuli Bunting (Passerina amoena) Irregular uncommon migrant. I saw one Lazuli bunting in the Wash during May 1979. This species has been previously reported in spring and summer 1963, April 1965, and May 1973.

Evening Grosbeak (Coccothraustes vespertinus) Casual. One was reported in July 1977. None was seen during this study.

House Finch* (Carpodacus mexicanus) Abundant regular resident. House finches can be found in all habitats during the summer season, but are most common in the Wash where they breed in tamarisk and willows and along the floodplain. During the winter, they are most often found in flocks near fourwing saltbush along the floodplain.

Pine Siskin*? (Carduelis pinus) Regular common resident. Pine siskins are most common during fall when they occur in flocks along the Wash, probably foraging on rabbitbrush seeds. I have not observed any reproductive behavior for this species at Chaco Canyon, but their presence during the breeding season makes it possible that pine siskins do breed at the monument.

Lesser Goldfinch (Carduelis psaltria) Regular uncommon migrant and irregular during summertime. Lesser goldfinches and pine siskins are often found together in flocks along the Wash. I have seen and heard this species mostly during fall but there are other records from the monument throughout the period March through November.

Green-tailed Towhee (Pipilo chlorurus) Regular uncommon migrant. Green-tailed towhees are most common in shrubby area of the Wash and on the floodplain.

Rufous-sided Towhee (Pipilo erythrophthalmus) Regular uncommon migrant and possible winter resident. I have found rufous-sided towhees in all habitats at Chaco Canyon during spring and fall. The species is secretive while in the monument and usually has to be flushed at close range before being seen. Prior to this study there was only one record of rufous-sided Towhees from Chaco Canyon (October 1969).

Brown Towhee* (Pipilo fuscus) Common resident. Brown towhees are common birds in the rocks along the talus slopes bordering the floodplain. Although I have not found active brown towhee nests at Chaco Canyon I have seen adults with short-tailed fledglings. Brown towhees are one of the most conspicuous birds in the residence area and campground.

Lark Bunting (Calamospiza melanocorys) Irregular rare migrant. I observed two lark buntings at Chaco Canyon during late May 1980. I have seen them at other locations in the San Juan Basin every spring since 1978 and near Star Lake and just south of Blanco Trading Post in June and July.

Savannah Sparrow (Passerculus sandwichensis) Casual or irregular migrant. Two savanna sparrows were seen in the Wash in September 1979.

Vesper Sparrow (Pooecetes gramineus) Regular uncommon migrant. Vesper sparrows were most often seen during April and May in the grassland areas along the floodplain west of Casa Chiquita.

Lark Sparrow (Chondestes grammacus) Irregular uncommon migrant. Lark sparrows are regular and breed in the San Juan Basin near Hospah (personal observation), but I only saw them at Chaco Canyon during May and July 1980. There is one other record at the monument (September 1969).

Black-throated Sparrow* (Amphispiza bilineata) Abundant summer resident. Black-throated sparrows breed in all habitats at Chaco Canyon and are most common in the saltbush and greasewood along the floodplain. This is probably the most abundant breeding species in the monument.

Sage Sparrow (Amphispiza belli) Common to uncommon resident. Sage sparrows are most common along the floodplain during winter when they seem to have a strong association with pale wolfberry. Although they probably breed in the sagebrush around Star Lake, they are uncommon at Chaco Canyon during summertime and I have seen no evidence of sage sparrows breeding at Chaco canyon.

Dark-eyed Junco (Junco hyemalis) Common winter resident. Dark-eyed juncos usually appear in October and stay through April. They are most common in the Wash but also occur on the floodplain and in the Pinyon-juniper.

Gray-headed Junco (Junco caniceps) Irregular migrant and possible winter resident. Gray-headed juncos are far less common than dark-eyed juncos, with which they often occur. The gray-headed juncos that I have seen have all been in the Wash or along the floodplains.

Chipping Sparrow (Spizella passerina) Regular uncommon migrant. Chipping sparrows occur most commonly during fall in the Pinyon-juniper but they occur in all the other habitats as well during both fall and spring.

Clay-colored Sparrow (Spizella pallida) Rare, casual migrant. I observed one clay-colored sparrow singing in the top of a greasewood near Casa Chiquita in May 1979. There are no other records for the monument.

Brewer's Sparrow*? (Spizella breweri) Regular common migrant. Brewer sparrows are most common during May and June when they occur in flocks. They also occur during fall as late as November, but in smaller numbers. Brewer Sparrows could breed in the monument, although I have no evidence of this.

White-crowned Sparrow (Zonotrichia leucophrys) Common winter resident. White-crowned sparrows are most common along the floodplain during late fall, probably winter, and early spring. Near Pueblo Bonito during late fall and early spring, this species accounts for more than half of all birds seen.

Lincoln Sparrow (Melospiza lincolnii) Irregular to casual migrant. I observed one Lincoln sparrow on Chacra Mesa during September 1979 where it was picking seeds from a rabbitbrush.

Song Sparrow (Melospiza melodia) Regular uncommon migrant along the wash and floodplain during early spring and fall. This species may nest near Hospah, but I have seen no evidence of breeding at Chaco Canyon.

This list includes 132 species of birds that I have seen or that have otherwise been reported at Chaco Canyon National Monument. At least 29 species and perhaps as many as 41 breed at the monument. The majority of species that occur at the monument are migrants. In a detailed study of the various habitats at Chaco Canyon, the largest number of species at the monument occurred in the Wash, where vegetation consists of cottonwood trees, willows, and tamarisk (J. Cully, this volume). The second most important habitat was the floodplain, where 45 species were observed at each of two transects, followed by Pinyon-juniper woodland (41 species) and rock grassland (12 species).

Bird diversity at Chaco is higher than in other areas of the San Juan Basin south of the San Juan River, largely because of the presence of the trees in the wash. These trees act as an oasis for migrating birds that stop briefly as they cross the surrounding desert. Schmidt (1976) studied breeding birds along the San Juan River and attributed breeding status to 105 species, of which 98 were native. His criteria for breeding were less rigorous, since he counted song as a breeding activity. Since many birds sing during migration, I considered song as insufficient evidence for breeding. His numbers and Hubbard's for the Gila River (in Schmidt 1976) are in close agreement, however. I suspect that the relatively low diversity of breeding bird species at Chaco Canyon is a result of the lack of water at the monument.

Along the San Juan River, Schmidt (1976) found 45 species that were limited to restricted riparian or primary riparian habitat, both closely associated with water along the river. Hubbard found a similar pattern in the Gila Valley. If restricted riparian and primary riparian are excluded from their lists, the results of this study are very comparable to theirs. These results seem to indicate that the presence of wet riparian habitats creates a highly significant effect on the numbers of species to be found in an area.

Because of the mining activity that is planned or underway, wet riparian habitats may become more common in the San Juan Basin. If the coal mines upstream from the monument provide a permanent source of water in the Chaco River, one could argue that as many as 50 new species of breeding birds could become established at the monument. For the reasons argued in the Starling account, such an optimistic view should be treated with a good deal of skepticism. If the variety of riparian habitats similar to those that exist along the San Juan and Gila rivers cannot establish themselves because of edaphic or other factors, the community will probably not respond in so positive a fashion.

References Cited

Hubbard, J.P.
1978 Revised Checklist of the Birds of New Mexcio. New Mexico Ornithological Society Publication no. 6. Albuquerque.

Schmidt, C.G.
1976 Summer Birds of the San Juan Valley, New Mexico. New Mexico Ornithological Society Publiction no. 4. Albuquerque.

Appendix C

Suggested Readings

compiled by
Frances Joan Mathien

The intent of this appendix is to provide the reader with the opportunity to evaluate the adaptations of the prehistoric Anasazi using the broadest data base possible. A comprehensive report on environment and subsistence within a single volume was beyond the scope of investigation of the Chaco Project. The reader is, therefore, directed to these suggested readings, which indicate additional reports pertaining to the environment and subsistence of other prehistoric sites and natural science studies in the San Juan Basin.

Allan, William C.
1977 Present and Past Climate. In *Settlement and Subsistence Along the Lower Chaco River: The CGP Survey*, edited by C.A. Reher, pp. 127-137. University of New Mexico Press, Albuquerque.

Antevs, Ernest
1954 Climate of New Mexico During the Last Glacial-pluvial. *Journal of Geology* 62:182-191.

Applegarth, John S.
1980 Analysis of Archeofaunal Remains Recovered by the Little Water Project (Museum of New Mexico) in San Juan County, New Mexico. Ms. on file, Museum of New Mexico, Santa Fe.

Baltz, E.H.
1967 *Stratigraphy and Regional Tectonic Implications of Part of Upper Cretaceous and Tertiary Rocks, East-Central San Juan Basin, New Mexico*. United States Geological Survey Professional Paper 552.

Bandoian, C.A.
1968 *Geomorphology of the Animas River Valley, San Juan County, New Mexico*. Unpublished Master's thesis, University of New Mexico, Albuquerque.

Bannister, Bryant
1960 *Southwestern Dated Ruins VII*. Tree-ring Bulletin 23(1-4). University of Arizona, Tucson.

Beaumont, E.C., J.W. Shoemaker, and W.J. Stone (editors)
1976 *Guidebook to Coal Geology on Northwest New Mexico*. New Mexico Bureau of Mines and Mineral Resources Circular 154.

Bent, A.M., and H.E. Wright, Jr.
1963 Pollen Analysis of Surface Materials and Lake Sediments from the Chuska Mountains, New Mexico. GSA Bulletin 74:81-500.

Betancourt, Julio L.
1979 Inventory and Provenience Check of Tree-ring Specimens from Chaco Canyon, New Mexico. Laboratory of Tree-ring Research, University of Arizona, Tucson.

1980 The Holocene Environments in Chaco Canyon, New Mexico: The Midden Record Packrat. Arizona-Sonora Desert Museum. Ms. submitted to Division of Cultural Research, National Park Service, Albuquerque.

Betancourt, Julio L., Paul S. Martin, and Thomas R. Van Devender
1983 Fossil Packrat Middens from Chaco Canyon, New Mexico: Cultural and Ecological Significance in Chaco Canyon Country. In A Field Guide to the Geomorphology, Quaternary Geology, Paleoecology, and Environmental Geology of Northwestern New Mexico, edited by S.G. Wells, D.W. Love, and T.W. Gardner, pp. 207-217. American Geomorphology Field Group.

Blagbrough, J.W.
1965 Quaternary Geology of the Northern Chuska Mountains and Red Rock Valley, Northeastern New Mexico. Unpublished Ph.D. Dissertation, University of New Mexico, Albuquerque.

Bohrer, Vorsila L., and Karen R. Adams
1977 Ethnobotanical Techniques and Approaches at the Salmon Ruin, New Mexico. San Juan Valley Archaeological Project, Technical Series 2. Eastern New Mexico Contributions in Anthropology 8(1).

Bryan, Kirk
1941 Pre-Columbian Agriculture in the Southwest, as Conditioned by Periods of Alluviation. Association of American Geographers Annals 31:219-242.

Bryan, Kirk, and F.P. McCann
1943 Sand Dunes and Alluvium Near Grants, New Mexico. American Antiquity 8:281-290.

Buge, David E., and James Schoenwetter
1977 Pollen Studies at Chimney Rock Mesa, Colorado. Appendix B in Archaeological Investigations at Chimney Rock Mesa: 1970-1972, by Frank W. Eddy. Memoirs of the Colorado Archaeological Society no. 1.

Castetter, E.F.
1956 The Vegetation of New Mexico. New Mexico Quarterly 26:257-288.

Clary, Karen H.

1981 Summary of Botanical Remains (Pollen and Flotation) from the Little Water Archaeological Sites, the Chuska Valley, New Mexico. Castetter Laboratory for Ethnobotanical Studies Technical Series Report 45. Ms. on file, Department of Biology, University of New Mexico, Albuquerque.

Cully, Anne C.

1981 Pollen Analysis at 29SJ 629: A Comparison of Two Village Sites in Marcia's Rincon, Chaco Canyon, New Mexico. Laboratory for Ethnobotanical Studies Technical Series Report 48. Ms. on file, Department of Biology, University of New Mexico, Albuquerque.

1982 Prehistoric Subsistence at Bis sa'ani Ruin and Associated Small Sites: Evidence from Pollen Analysis. Castetter Laboratory for Ethnobotanical Studies Technical Series Report 65. Ms. on file, Department of Biology, University of New Mexico, Albuquerque.

1983 Prehistoric Subsistence at Chaco Canyon: Evidence from Pollen Analysis. Ms. on file, Division of Cultural Research, National Park Service, Albuquerque.

1984 The Distribution of Corn Pollen at Three Sites in Chaco Canyon. In Recent Research on Chaco Prehistory, edited by W. James Judge, and John D. Schelberg, pp. 251-264. Reports of the Chaco Center no. 8. Division of Cultural Research, National Park Service, Albuquerque.

Cully, Anne C., and Loren D. Potter

1976 Relation of Pollen and Flotation Analysis to Archeological Excavations, Chaco Canyon. Department of Biology, University of New Mexico. Ms. submitted to Division of Cultural Research, National Park Service, Albuquerque.

Dane, C.H.

1936 Geology and Fuel Resources of the San Juan Basin, New Mexico. Part 3: The La Ventana-Chaco Mesa Coal Field. United States Geological Survey Bulletin 860-C, pp. 81-166.

De Angelis, J.M.

1972 Physical Geography of the Chaco Canyon Country. Ms. on file, Division of Cultural Research, National Park Service, Albuquerque.

Doebley, John F.

1976 A Preliminary Study of Wild Plant Remains Recovered by Flotation at Salmon Ruin, New Mexico. Unpublished Master's thesis, Eastern New Mexico University, Portales.

Doebley, John F., and Vorsila L. Bohrer

A Report on the Maize Remains from Salmon Ruin, New Mexico. Ms. on file, Eastern New Mexico University, Portales.

Durrant, S.D., and N.K. Dean
1961 Mammals of the Navajo Reservoir Basin in Colorado and New Mexico, 1960. University of Utah Anthropological Papers 55:155-182.

Ebert, James I., and Galen N. Brown
1981 Geomorphic Process Affecting the Visibility and Integrity of Cultural Resources at Chaco Culture National Historical Park. Ms. on file, Division of Cultural Research, National Park Service, Albuquerque.

Eddy, Frank W.
1983 Upland Anasazi Settlement Adaptations at Chimney Rock Mesa, Southern Colorado. In Proceedings of the Anasazi Symposium 1981, compiled and edited by Jack E. Smith, pp. 141-152. Mesa Verde National Park, Colorado. Mesa Verde Museum Association.

Fassett, James E.
1977 Geology of the Point Lookout Cliff Sandstones of the San Juan Basin, New Mexico and Colorado. New Mexico Geological Society Guidebook 28th Field Conference, San Juan Basin III, edited by J.E. Fassett, pp. 193-197.

Fassett, James E., and Jim S. Hinds
1971 Geology and Fuel Resources in the Fruitland Formation and Kirtland Shale of the San Juan Basin, New Mexico and Colorado. Geological Survey Professional Paper 676.

Faulkner, David P., Niels L. Martin, and James R. Martin
1976 San Juan-Chaco Area: Forage Productions and Proper Use Date. Rangeland Resources International, Inc. Ms. submitted to Bureau of Land Management.

Fletcher, J.E.
1961 Climate and Soil of the Southwest. In Bioecology of the Arid and Semiarid Land of the Southwest. New Mexico Highlands University Bulletin 212:2-14

Gillespie, William B.
1977 Preliminary Analysis of Faunal Remains for Site 29SJ 1613. Ms. on file, Division of Cultural Research, National Park Service, Albuquerque.

1981 Summary of Osteological Remains from Chaco Coprolites. Ms. on file, Division of Cultural Research, National Park Service, Albuquerque.

1984 The Environment of the Chaco Anasazis. In New Light on Chaco Canyon, edited by David Grant Noble, pp. 37-44. School of America Research Press, Santa Fe.

Gough, L.P., and R.C. Severson
1981 Biogeochemical Variability of Plants at Native and Altered Sites, San Juan Basin, New Mexico. Geological Survey Professional Paper 1134-D, Washington.

Gutierrez, Alberto A.

1980 *Channel and Hillslope Geomorphology at Badlands in the San Juan Basin, New Mexico*. Unpublished Master's thesis, University of New Mexico, Albuquerque.

Hall, Stephen A.

1975 *Stratigraphy and Palynology of Quaternary Alluvium at Chaco Canyon, New Mexico*. Unpublished Ph.D. dissertation, University of Michigan, Ann Arbor.

1980 Snails from Quaternary Valley Fill at Chaco Canyon, New Mexico. *The Nautilus* 94(2).

1983 Holocene Stratigraphy and Paleoecology of Chaco Canyon. In *Chaco Canyon Country*. *A Field Guide to the Geomorphology, Quaternary Geology, Paleoecology, and Environmental Geology of Northwestern New Mexico*, edited by S.G. Wells, D.W. Love, and T.W. Gardner, pp. 219-226. American Geomorphological Field Group.

Hansen, B.S., and E.J. Cushing

1973 Identification of Pine Pollen of Late Quaternary Age from the Chuska Mountains, New Mexico. *GSA Bulletin* 84:1181-1200.

Harris, Arthur H.

1963 *Vertebrate Remains and Past Environmental Reconstruction in the Navajo Reservoir District*. Museum of New Mexico, Publication in Anthropology, no. 13.

1970 Past Climate of the Navajo Reservoir District. *American Antiquity* 35:374-377.

1977 Faunal Remains from Chimney Rock Mesa. Appendix A in *Archaeological Investigation at Chimney Rock Mesa: 1970-1972*, by Frank W. Eddy. Memoirs of the Colorado Archaeological Society no. 1.

Harshbarger, J.W., and C.A. Repenning

1954 *Water Resources of the Chuska Mountains Area, Navajo Indian Reservation, Arizona and New Mexico*. United States Geological Survey Circular 308.

Hayes, Alden C.

1975 A Cache of Gardening Tools: Chaco Canyon. In *Collected Papers in Honor of Marjorie Ferguson Lambert*, edited by A.H. Schroeder, pp. 73-84. Papers of the Archaeological Society of New Mexico, no. 3.

Hodges, W.K.

1974 Arroyo and Wash Development in the Chaco Canyon Country. Project Report. Ms. on file, Division of Cultural Research, National Park Service, Albuquerque.

Hunter, William C.
1978 Indications from Rabbit Mandible Bone Regarding Forestation at Chaco Canyon between A.D. 750 and 1200. Ms. on file, Division of Cultural Research, National Park Service, Albuquerque.

Kelley, Klara B.
1982 Navajo Farming in the Vicinity of the Gallo Wash Mine Lease. Working Papers of the Navajo Nation Cultural Resources Management Program, no. 8.

Kelley, V.C.
1951 Tectonics of the San Juan Basin. New Mexico Geological Society Guidebook 2:124-131.

Kosse, Alan
1983 Anasazi Influence on the Environment. In Proceedings of the Anasazi Symposium 1981, compiled and edited by Jack E. Smith, pp. 115-118. Mesa Verde National Park, Mesa Verde Museum Association.

Lagasse, Peter F., Kenneth J. Eggert, and Keith A. Yarborough
1983 Geomorphic and Hydraulic Analysis for Erosion Control. In Chaco Canyon Country. A Field Guide to the Geomorphology, Quaternary Geology, Paleoecology, and Environmental Geology of Northwestern New Mexico, edited by S.G. Wells, D.W. Love, and T.W. Gardner, pp. 227-236. American Geomorphological Field Group.

Leopold, L.B., E.B. Leopold, and R. Wendorf
1963 Some Climatic Indicators in the Period A.D. 1200-1400 in New Mexico. In Changes of Climate. Proceedings of the Rome Symposium UNESCO.

Loose, Richard W.
1977 Pre-Pleistocene Geology. In Settlement and Subsistence along the Lower Chaco River: The CGP Survey, edited by Charles A. Reher, pp. 139-148. University of New Mexico Press, Albuquerque.

1978 Physiography/Geology. In Western Area Survey, pp. 15-34. Public Service Company of New Mexico, Albuquerque.

Love, David W.
1977 Quaternary Geology and Geomorphology. In Settlement and Subsistence along the Lower Chaco River: The CGP Survey, edited by Charles A. Reher, pp. 149-164. University of New Mexico Press, Albuquerque.

1979 Quaternary Fluvial Geomorphic Adjustments in Chaco Canyon, New Mexico. In Adjustments of the Fluvial System, edited by D.D. Rhodes and G.P. Williams, pp. 277-308. Kendall and Hunt, Dubuque.

1983 Quaternary Facies in Chaco Canyon and Their Implications for Geomorphic-Sedimentologic Models. In Chaco Canyon Country. A Field Guide to the Geomorphology, Quaternary Geology, Paleoecology, and

Environmental Geology of Northeastern New Mexico, edited by S.G. Wells, D.W. Love, and J.W. Gardner, pp. 195-206. American Geomorphological Field Group.

Love, David W., and Jerry Schultz
1980 Surficial Geology and Geomorphology Related to Mitigation of Archeological Sites of the UII Lease. In Human Adaptations in a Marginal Environment: The UII Mitigation Project, edited by James L. Moore, and Joseph C. Winter, pp. 29-39. Office of Contract Archaeology, Albuquerque.

Lyons, Thomas R., Robert R. Hitchcock, and Basil G. Pouls
1972 The Kin Bineola Irrigation Study: An Experiment in the Use of Aerial Remote Sensing Techniques in Archaeology. In Proceedings of the Third Annual Conference on Remote Sensing in Arid Lands, pp. 266-283. Tucson Office of Arid Lands Studies, University of Arizona. Also in Remote Sensing Experiments on Cultural Resource Studies, assembled by T.R. Lyons, pp. 103-114. Reports of the Chaco Center, no. 1. National Park Service and University of New Mexico, Albuquerque.

Miller, John
1980 Settlement and Subsistence in the UII Area. In Human Adaptation in a Marginal Environment: The UII Mitigation Project, edited by James L. Moore and Joseph C. Winter, pp. 437-482. Office of Contract Archaeology, Albuquerque.

Molenaar, C.M.
1977 Stratigraphy and Depositional History of Upper Cretaceous Rocks of the San Juan Basin Area, New Mexico and Colorado, with a Note of Economic Resources. In San Juan Basin III, edited by J.E. Fassett, pp. 159-166. New Mexico Geological Society Guidebook 28.

Moore, James L., and Catherine Harlow
1980 The UII Lease as a Marginal Enviroment. In Human Adaptations in a Marginal Enviroment: The UII Mitigation Project, edited by James L. Moore and Joseph C. Winter, pp. 15-28. Office of Contract Archaeology, Albuquerque.

Nash, Thomas H. III, Milton R. Sommerfeld, and Loren L. Sigal
1979 Preliminary Study on the Lichens of Chaco Canyon National Monument. Ms. on file, Division of Natural Resources, National Park Service, Santa Fe.

Neller, Earl
n.d. Botanical Analysis in Atlatl Cave, Preliminary Report. Ms. on file, Division of Cultural Research, National Park Service, Albuquerque.

Nichols, R.
1975 Archaeomagnetic Study of Anasazi Related Sediments of Chaco Canyon, New Mexico. Unpublished Master's thesis, University of Oklahoma, Norman.

O'Sullivan, Robert B., Glenn R. Scott, and David L. Weide
1979 Preliminary Geologic Map of the Kin Klizhin Ruins Quadrangle, San Juan County, New Mexico. United States Geological Survey Miscellaneous Field Studies Map MF-1094.

Pastouzak, R.A.
1968 Geomorphology of Part of the La Plata and San Juan Rivers, San Juan County, New Mexico. Unpublished Master's thesis, University of New Meixco, Albuquerque.

Potter, Loren D., and L.E. Kelly
1980 Aerial Photo Interpretation of Vegetation of Chaco Canyon National Monument. In Cultural Resources Remote Sensing, edited by Thomas R. Lyons, and Frances Joan Mathien, pp. 87-104. Cultural Resources Management Division, National Park Service, Washington.

Potter, Loren D., and Richard Young
1977 Indicator Plants and Archaeological Sites, Chaco Canyon National Monument. Ms. on file, Biology Departament, University of New Mexico, Albuquerque.

Powell, J.S.
1972 The Gallegos Sandstone (formally Ojo Alamo Sandstone) of the San Juan Basin, New Mexico. Unpublished Master's thesis, University of Arizona, Tucson.

Reher, Charles A., and Daniel E. Witter
1977 Archaic Settlement and Vegetative Diversity. In Settlement and Subsistence along the Chaco River: The CGP Survey, edited by C.A. Reher, pp. 113-126. University of New Mexico Press, Albuquerque.

Ross, J.R.
1978 A Three-dimensional Facies Analysis of the Canyon Alluvial Fill Sequence, Chaco Canyon, New Mexico. Unpublished Master's thesis, University of New Mexico, Albuquerque.

Roybal, F. Eileen, and others
1983 Hydrology of Area 60, Northern Great Plains, and Rocky Mountain Coal Provinces, New Mexico, Colorado, Utah and Arizona. United States Geological Survey, Water Resources Investigations, Open File Report 83-203, United States Department of the Interior, Albuquerque.

Schelberg, John D.
1982 The Development of Social Complexity in Chaco Canyon. New Mexico Archeological Council Newsletter 4(5 and 6):15-20.

Schneider, Gary B., David L. Weide, James W. Myttan, and Glenn R. Scott
1979 *Geologic Map of the Pueblo Bonito, New Mexico Quadrangle, San Juan County, New Mexico*. United States Geological Survey Miscellaneous Field Studies Map MF-1117.

Schoenwetter, James
1965 A Re-evaluation of the Navajo Reservoir Pollen Chronology. *El Palacio* 73:19-26.

Schultz, J.D.
1980 *Geomorphology, Sedimentology, and Quaternary History of the Eolian Deposits, West-Central San Juan Basin, Northwest New Mexico*. Unpublished Master's thesis, University of New Mexico, Albuquerque.

Short, Susan K.
1975 Pollen Analysis at Chimney Rock, Colorado, 5AA88. Appendix H in *1972 Archaeological Explorations at the Ravine Site, Chimney Rock, Colorado* by Marcia L. Truell. Unpublished Master's thesis, University of Colorado, Boulder.

Siemers, C.T., and N.R. King
1974 Macroinvertebrate Paleoecology of a Transgressive Marine Sandstone, Cliff House Sandstone (Upper Cretaceous), Chaco Canyon, Northwestern New Mexico. In *New Mexico Geological Social Guidebook, 25th Field Conference, Ghost Ranch (Central-Northern New Mexico)*, pp. 267-279. Albuquerque.

Simmons, Alan H.
1984 *Archaic Prehistory and Paleoenvironments in the San Juan Basin, New Mexico: The Chaco Shelters Project*. University of Kansas, Museum on Anthropological Project Report Series No. 53. Lawrence.

Simmons, Li, and Associates, Inc.
1982a Erosion Study at Chaco Culture National Historical Park, New Mexico. Ms. on file, Southwest Region, National Park Service, Santa Fe.

1982b Flood Plain Maps for Chaco Culture National Historical Park, New Mexico. Ms. on file, Southwest Region, National Park Service, Santa Fe.

1982c Soil Piping Study in the Vicinity of Pueblo Bonito, Chaco Culture National Historical Park, New Mexico. Ms. on file, Southwest Region, National Park Service, Santa Fe.

Smith, L.N.
1983 *Late Cenozoic Fluvial Evolution in the Northern Chaco River Drainage Basin, Northwestern New Mexico*. Unpublished Master's thesis, University of New Mexico, Albuquerque.

Stone, W.J., F.P. Lyford, P.F. Frenzel, N.H. Mizell, and E.T. Padgett

1983 *Hydrogeology and Water Resources of the San Juan Basin, New Mexico*. New Mexico Bureau of Mines and Mineral Resources Hydrologic Report 6.

Struever, Mollie, and Paul J. Knight

1979 Analysis of Flotation Samples and Macrobotanical Materials: Block III Mitigation, Navajo Indian Irrigation Project. Ms. on file, Ethnobotany Laboratory, Department of Biology, University of New Mexico, Albuquerque.

Sublette, J.E.

1977 Aquatic Fauna Inventory of the La Plata and Animas Rivers in New Mexico. Ms. on file, Natural Sciences Research Institute, Natural History Museum, Eastern New Mexico University, Portales.

Toll, Mollie S.

1984 Taxonomic Diversity in Flotation and Macrobotanical Assemblages from Chaco Canyon. In *Recent Research on Chaco Prehistory*, edited by W. James Judge and John D. Schelberg, pp. 241-250. Reports of the Chaco Center no. 8. Division of Cultural Research, National Park Service, Albuquerque.

Treshaw, Michael

1979 A Study for the Possible Adverse Effects on Vegetation Due to Air Pollutants in the Chaco Canyon National Monument, New Mexico, Interim Report. Ms. on file, Division of Natural Resources, National Park Service, Southwest Region, Santa Fe.

1980 A Study for the Possible Adverse Effects on Vegetation Due to Air Pollutants in the Chaco Canyon National Monument, New Mexico, Concluding Report. Ms. on file, Division of Natural Resources, National Park Service, Southwest Region, Santa Fe.

Weaver, Donald E., Jr.

1978 *Prehistoric Population Dynamics and Environmental Exploitation in the Manuelito Canyon District, Northwestern New Mexico*. Unpublished Ph.D. dissertation, Arizona State University, Tempe.

Weide, David L., Gary B. Schneider, James W. Myttan, and Glenn R. Scott

1979 *Geologic Map of the Sargeant Ranch Quadrangle, San Juan County, New Mexico*. United States Geological Survey Miscellaneous Field Studies Map MF-1120.

Wells, Stephen G.

1981 *Geomorphology and Surface Hydrology Applied to Landscape Reclamation in the Strippable Coal Belts of Northwestern New Mexico*. Ms. submitted to New Mexico Energy and Mineral Department and New Mexico Enerty Institute, New Mexico Institute of Mining and Technology.

Wells, Stephen G., and Alberto A Gutierrez
1982 Quaternary Evolution of Badlands in the Southeastern Colorado Plateau. In *Badland Geomorphology and Piping*, edited by R. Bryan and A. Yair, pp. 239-258. Geobook (Geoabstracts Ltd.) Norwich, England.

Wells, Stephen G., David W. Love, and Thomas W. Gardner (editors)
1983 *Chaco Canyon Country. A Field Guide to the Geomorphology, Quaternary Geology, Paleoecology, and Environmental Geology of Northwestern New Mexico*. American Geomorphology Field Group.

West, S.W.
1957 *Possibility of Developing a Ground-Water Supply at the Chaco Canyon National Monument, San Juan County, New Mexico*. United States Geological Survey, open-file report.

Windes, Thomas C.
1977 Dwellers of the Wood ("Say, Who Are Those Turkeys?"): A Preliminary Eggshell Report. Ms. on file, Division of Cultural Research, National Park Service, Albuquerque.

Winter, Joseph C.
1980 Human Adaptations in a Marginal Environment. In *Human Adaptions a Marginal Enviroment: The UII Mitigation Project*, edited by James L. Moore, and Joseph C. Winter, pp. 483-520. Office of Contract Archaeology, Albuquerque.

Witter, D.C.
1977 Vegetative Ecology. In *Settlement and Subsistence along the Lower Chaco River: The CGP Survey*, edited by Charles A. Reher, pp. 165 189. University of New Mexico Press, Albuquerque.

Woodbury, A.M., S. Flowers, and H.H. Hall
1961 *Ecological Studies of the Flora and Fauna of the Navajo Reservoir Basin, Colorado and New Mexico*. University of Utah Anthropological Papers no. 55.

Woodward, L.A., and J.F. Callender
1977 Tectonic Framework of the San Juan Basin. *New Mexico Geological Society Guidebook* 28:209-212.

Young, Richard, and Loren D. Potter
1975 Correlation of Indicator Plants and Archeological Sites, Chaco Canyon National Monument. Final report to National Park Service. Contract CX-700040179. Ms. on file, Division of Cultural Research National Park Service, Albuquerque.

Publications in Archeology

1 Archeology of the Bynum Mounds, Natchez Trace Parkway, Mississippi.
By John L. Cotter and John M. Corbett. 1951. (PB 177 061)*
2 Archeological Excavations in Mesa Verde National Park, Colorado, 1950.
By James A. Lancaster et al. 1954. (PB 177 062)*
3 Archeology of the Funeral Mound, Ocmulgee National Monument, Georgia.
By Charles H. Fairbanks. 1956. (PB 177 063)*
4 Archeological Excavations at Jamestown, Virginia.
By John L. Cotter. 1935. (PB 177 064)*
5 The Hubbard Site and Other Tri-wall Structures in New Mexico and Colorado.
By R. Gordon Vivian. 1959. (PB 230 988/AS)*
6 Search for the Cittie of Ralegh, Archeological Excavations at Fort Raleigh National Historic Site, North Carolina.
By Jean Carl Harrington. 1962.
7A The Archeological Survey of Wetherill Mesa, Mesa Verde National Park, Colorado.
By Alden C. Hayes. 1964. (PB 234 542/AS)*
7B Environment of Mesa Verde, Colorado.
By James A. Erdman et al. 1969. (PB 234 541/AS)*
7C Big Juniper House, Mesa Verde National Park, Colorado.
By Jervis D. Swannack, Jr. 1969. (PB 234 537/AS)*
7D Mug House, Mesa Verde National Park, Colorado.
By Arthur H. Rohn. 1971. (PB 234 539/AS)*
7E Badger House Community, Mesa Verde National Park, Colorado.
By Alden C. Hayes and James A. Lancaster. 1975.
7F Skeletal Remains from Mesa Verde National Park, Colorado.
By Kenneth A. Bennet. 1975.
7G Orthopedic Problems of the Wetherill Mesa Populations.
By James S. Miles, M.D. 1975.
7H Long House, Mesa Verde National Park, Colorado.
By George S. Cattanack, Jr. et al. 1980.
8 Excavations in a 17th-Century Jumano Pueblo, Gran Quivira, New Mexico.
By R. Gordon Vivian. 1964.
9 Excavations at Tse-Ta'a, Canyon de Chelly National Monument, Arizona.
By Charlie R. Steen. 1966. (PB 234 540/AS)*
10 Ruins Stabilization in the Southwestern United States.
By Roland Von S. Richert and R. Gordon Vivian. 1974.
11 The Steamboat Bertrand: History, Excavation, and Architecture.
By Jerome E. Petsche. 1974.
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By Ronald R. Switzer. 1974.
13 Investigations in Russell Cave, Russell Cave National Monument, Alabama.
By John W. Griffin et al. 1974.
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By Lee H. Hanson and Dick Ping Hsu. 1975.
15 Woodland Complexes in Northeastern Iowa.
By Wilfred D. Logan. 1976.
16 Excavations at Mound 7, Gran Quivira National Monument, New Mexico.
By Alden C. Hayes. 1981.
17 Contributions to Gran Quivira Archeology, Gran Quivira National Monument, New Mexico.
By Alden C. Hayes. 1981.
18A Archeological Surveys of Chaco Canyon, New Mexico.
By Alden C. Hayes, David M. Brugge, and W. James Judge. 1981.

18B Great Pueblo Architecture of Chaco Canyon, New Mexico.
By Stephen H. Lekson, 1984.

18E Environment and Subsistence in the Chaco Area, New Mexico.
By Frances Joan Mathien, 1985.

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