

PLANT REMAINS FROM THE CLEARWATER SITE, AZ BB:13:6 (ASM), AND THE TUCSON PRESIDIO, AZ BB:13:13 (ASM)

*Michael W. Diehl
Desert Archaeology, Inc.*

The archaeological effort associated with the Rio Nuevo Archaeology project resulted in the recovery and analysis of plant remains from 274 flotation samples. The data collected from this project provided an opportunity to test previous studies that document a series of trends in plant use spanning an interval of approximately 3,200 years. The plant assemblage discussed in this report substantiates earlier findings that Early Agricultural period (2100 B.C.-A.D. 50) subsistence efforts incorporated a wide range of wild plant taxa in an effort to minimize risks associated with floodplain farming. During the first millennium A.D., crops quickly displaced wild foods as subsistence efforts became highly focused on floodplain farming, reducing or eliminating the use of previously important wild plants. Upon the arrival of colonizing Spaniards and, later, emigrating Euro-Americans and Chinese, a host of new crops, ornamental trees, and weeds were brought in. These newly introduced Old World taxa greatly expanded the range of resources available to people living in the Tucson Basin.

QUANTIFICATION AND METHODS

The analyses in the current study compare the established 3,700-year trend in plant use known from prior studies with the new information from the Rio Nuevo project. Changes in the dietary importance of different plant taxa and different groups of plants are examined by considering two characteristics of the plant assemblage—ubiquity and diet breadth—discussed below.

Within the Rio Nuevo assemblage, the ubiquities and diet breadths of the assemblages are based on features from the same temporal component within one site. For example, ubiquity is calculated separately for the Cienega phase (800 B.C.-A.D. 50) assemblage from the Clearwater site, AZ BB:13:6 (ASM), and the Spanish period (A.D. 1694-1821) assemblage from the Mission Gardens locus. The Mission Gardens are, in turn, treated as a distinct entity from

the Spanish period assemblage from the Tucson Presidio, AZ BB:13:13 (ASM).

Together, the ubiquities of taxa and the diet breadths of assemblages provide a way to track changes through time in the kinds of plants preferred by the prehistoric- and historic-era occupants of the Tucson area. To infer that the assemblage reflects preferences in food use, the ubiquity must be assumed to be indicative of the frequency with which a plant was used. Further, changes in diet breadth must be assumed to be driven by concerns about the relative merits of different kinds of resources compared with each other. Each of these assumptions is based on a suite of core principles discussed below.

Ubiquity as an Indicator of Importance

Ubiquity is a commonly used measure of the pervasiveness of a plant in an assemblage (Minnis 1981; Popper 1988). The use of ubiquity as an index for the importance of a particular plant derives from a chain of logical inferences that lead to the following conclusion. All other things being equal, the ubiquity of a plant is directly related to the overall dietary importance of the plant. The ubiquity (U_{taxon}) of a taxon (or plant group) is the proportional frequency of features that contain at least one individual of the taxon, compared with the total number of features that contained any plant taxon (or group). For example, if 10 features contained plant remains and six contained maize, $U_{\text{maize}} = 0.6$.

On any given day, humans consume plants in almost every meal they eat. However, the plant tissues commonly found in archaeological samples, particularly in prehistoric samples, are not the remnants of consumed foods; rather, they are the inedible remnants of things that could not be eaten. Burned foods are inedible; they are also nearly indestructible. Carbon does not rot, nor is it easily dissolved. Carbonized plant remains are inedible, and charring must occur as a result of an accident in processing, storage, or cooking food, or in discarding food waste.

The burned plant remains in an assemblage are assumed to be a sample of the foods that were regularly eaten, randomly generated as a result of the combined effects of, for example, spillage and the effects of charring once spilled food falls in a fire. Preserved plant remains are a random selection of regularly eaten foods; therefore, the relative occurrence of different burned foods is proportional to the frequencies and amounts in which they were eaten. One complicating factor, however, prevents the direct comparison of the ubiquities of different taxa; that is, the seeds of some taxa are so fragile they may be underrepresented in an assemblage. For that and other reasons, certain categories of plants whose frequencies and ubiquities are comparable are recognized. These plant resource groups are discussed in a later section.

Diet Breadth and Optimization

The number of plant types used by a prehistoric group (i.e., diet breadth) is a useful indicator of the roles of different plants or plant groups. Interest in diet breadth derives from an area of inquiry in which the critical questions revolve around the costs and benefits associated with the use of different plants (Kelly 1995; Krebs and Davies 1991; Schiffer 1996). It is sufficient to note that, when people are presumed to maximize their energy intake from the environment, they tend to first use resources that provide the greatest number of Calories for the effort required to obtain them.

Changes in diet breadth through time occur due to changes in the relative merits of different plants or to changes in the perceived need to maximize energy production. When diet breadth is quite broad despite the availability of several overwhelmingly superior resources, two explanations are offered. First is the idea that people have stopped caring about the relative returns for unit of effort; food is so plentiful that people do not worry much about the merits of the marginally profitable resources. An alternative explanation is that the availability of the high-quality foods is, in some way, limited. When diet breadth narrows, it is because some resources have become so superior that using them (and ignoring greatly inferior ones) is the most practical choice.

PLANT RESOURCE GROUPS

Based on commonalities in location, seed size, and the requisite harvesting and processing tool suites, categories of food plants called resource groups are recognized. Justification for the creation and membership among the groups is provided in Diehl and

Waters (2005) and Gregory and Diehl (2002). The categories of plant resources include crops, high-density weeds, low-density weeds, desert tree legumes, cacti, low-density wild grasses, local shrubs, and long-distance resources. Plants assigned to each group share common harvesting, preparation and processing behaviors, and tools. In short, the chain of events that lead to their charring and preservation are similar, and plants within each group are mutually comparable using the ubiquity measure. Plants within each category also offer comparable energy returns. This explains the distinction, for example, between the very low-quality low-density weeds and the higher-quality high-density weeds, despite the fact that the same tools and behaviors are associated with the acquisition of plants in both groups. When diet breadths change, it is useful to determine which plant resource groups are emphasized among the overall range of subsistence practices. The resource groups are described below.

Crops

Crops are deliberately planted cultigens that have been anthropogenically transformed to have large fruits or seeds and that are highly, if not exclusively, dependent on humans for their successful propagation. Maize is the only confirmed cultigen in macrobotanical specimens from pre-San Pedro phase and Early Cienega phase deposits at Clearwater. Samples from other Early Agricultural period sites – most notably from San Pedro phase features at Las Capas, AZ AA:12:111 (ASM), and Late Cienega phase features at Los Pozos, AZ AA:12:91 (ASM) – produced remains tentatively identified as bean cotyledon fragments (cf. *Phaseolus*) and cotton pollen. As Mabry (2005) noted, extant evidence (primarily from pollen samples) hints that maize, beans, squash, and cotton may have arrived as a single crop complex during, or prior to, the Early Cienega phase of the Early Agricultural period.

From A.D. 50 through A.D. 1000, the list of confirmed domesticates expanded to include new varieties of maize (*Zea mays*), several varieties of beans (*Phaseolus acutifolius*, *P. vulgaris*, and *P. lunatus*), at least two varieties of squash (*Cucurbita pepo* and *C. moschata*), and cotton (*Gossypium* sp.) (see Adams 1994; Ford 1981; Galinat 1988; Upham et al. 1987, 1988). Of these, only beans have been confirmed from the Rio Nuevo samples.

Colonizing Spaniards and later, Mexicans, western-migrating Americans, and emigrant Chinese also each introduced new crops. In the Rio Nuevo samples, historically introduced cultigens included apples (*Malus* sp.), black mustard (*Brassica nigra*), clover (*Trifolium* sp.; for animal fodder), oats (*Avena*

sativa), grapes (*Vitis vinifera*), peaches (*Prunus persica*), raspberries (*Rubus* sp.), watermelons (*Citrullus* sp.), wheat (*Triticum* sp.), and white mustard (*Sinapis alba*). In addition, peppers (*Capsicum* sp.), a native cultigen, were observed in Spanish period samples.

High-density Weeds

High-density weeds are wild, nondomesticated plants that thrive in fallow fields, on the margins of active agricultural fields, or in frequently disturbed floodplains. Their locations are predictable, although there is a small search cost associated with their use, and they provided much lower yields per hectare than domesticated plants. Harvesting costs for these plants were higher than for domesticated plants, including more activity to strip or beat seed heads into containers, possibly with attendant losses to scattering. Subsequent processing steps included parching to remove closely fitting glumes, bracts, and capsules, and, in some cases, shelling, prior to subsequent grinding or cooking.

Flotation samples from the Rio Nuevo project produced dropseed (*Sporobolus* sp.), goosefoot (*Chenopodium* sp.), pigweed (*Amaranthus* sp.), indeterminate goosefoot-pigweed (cheno-ams), and tansy mustard (*Descurainia* sp.). The associated tool technology included baskets for collection and storage, as well as parching or winnowing trays. Depending on the strategy, flaked stone tools may have been necessary in the collection process. Where grinding was desired, basin metates and small manos were also used.

Low-density Weeds

Low-density weeds are wild, nondomesticated plants that thrive in fallow fields, on the margins of active agricultural floodplains, in disturbed soils away from floodplains. However, they occur in less pure stands than high-density weeds. Low-density weeds include starchy seed types, such as clammy-weed (*Polansia* sp.), dock (*Rumex* sp.), false purslane (*Trianthema* sp.), purslane (*Portulaca* sp.), ragweed (*Ambrosia* sp.; found only in a nineteenth century context in these samples), ringwing (*Cycloloma* sp.), a smartweed-type seed (*Polygonum* sp.), and nightshade-/chokecherry-type seeds (*Solanum/Physalis*).

Due to their more dispersed growth habits, low-density weed resources provided much lower yields per hectare than high-density weeds because they had higher search and harvesting costs, as well as higher transport costs. The associated suite of tools was the same as that used for the high-density weeds;

therefore, the processing costs were likely similar between the two groups. The search and harvesting costs associated with the use of low-density weeds, however, were much greater than for high-density weeds.

Desert Tree Legumes

In the Rio Nuevo samples, this category is represented only by mesquite (*Prosopis velutina*) pods, although it could also theoretically include screwbeans (*Prosopis pubescens*), acacias (*Acacia* spp.), and palo-verde (*Cercidium* spp.). The requisite technology included heavy stone pestles and mortars made from tree stumps or formed in bedrock outcrops. The processing effort was labor intensive and involved repeated episodes of pounding and winnowing in baskets. The desired product was a meal made from the sweet, starchy mesocarp (a layer of tissue enclosed by the pod that surrounds the hard seeds within the pods). It is generally assumed by Southwestern archaeologists that the seeds, which were protein rich but very hard, were discarded except under circumstances of extreme need. It was common practice among the Pima and Papago in southern Arizona to discard the seeds (Doelle 1976, 1978; Gasser 1982). As with the floodplain weeds, mesquite was locally available on floodplains, alluvial fans, and low terraces on the margins of floodplains.

Cacti

Cactus fruit taxa are common in prehistoric assemblages in southern Arizona, and their persistence from the oldest prehistoric sites to recent history gives evidence of the enduring appreciation for cacti as sources of food. In the Rio Nuevo samples, the taxa include cactus family seeds (Cactaceae), cereus genus seeds (*Cereus* sp.), hedgehog cacti (*Echinocereus* spp.), prickly pear (*Opuntia* spp., "platyopuntia" type), and saguaro (*Carnegiea gigantea*). Most of the cacti can be found concentrated on the rocky slopes of foothills surrounding river basins. During July and August, the energetic costs of unsuccessful long-distance hunting forays (if they were attempted) could have been partially offset by harvesting cactus fruit during the return trip.

Ethnographically documented uses of cacti, especially saguaro, include the harvesting of the fruit with poles, heat treating to singe off the glochids and spines, and subsequent processing in pots (ultimately fermented) or drying on screens (Crosswhite 1980). Saguaro seeds were often dried, parched, ground into a meal, and consumed with other food. The associated cactus fruit harvesting technology included

baskets or vessels for gathering fruit; a fire or other heat source for singeing spines; tongs; sticks, or poles for knocking down fruit; and on some occasions, knives for splitting the fruit prior to seed removal. When the goal of fruit harvesting was to produce a beverage, the fruits were added to water in a ceramic vessel and boiled down to a thick syrup (Crosswhite 1980). Otherwise, fruit could have been dried for storage and consumed later as either a stand-alone food or as an additive in some other preparation. The fruit harvesting technology included task-specific items such as tongs and poles, as well as general-purpose tools such as baskets, vessels, parching and winnowing trays, grinding stones, and stone knives.

Low-density Wild Grasses

Non-floodplain wild grasses are low-density grasses that do not require the more silt-laden and moisture-rich floodplains to thrive. Their definitive characteristic is that they do not occur in very dense or nearly homogeneous stands. Most are not confined to floodplains or their margins, but instead, are dispersed throughout the Tucson Basin and the surrounding foothills and montane regions. Harvesting costs for wild grasses are generally quite high, and they provide low overall energy return rates (Cane 1989; Simms 1987). They could have been obtained and processed using the same suite of tools applied to high- and low-density floodplain weeds. In the Rio Nuevo samples, this group includes indeterminate grasses (Gramineae), bentgrass/muhly (*Agrostis/Muhlenbergia* spp.), little barley (*Hordeum cf. pusillum*), and panic grass (*Panicum* spp.).

Local Shrubs

This category includes locally available woody shrubs (excluding the tree legumes) that produce seeds with an ethnographically documented use as food. Mint family/chia-type seeds (Labiatae/*Salvia* sp.) and sumac (*Rhus* sp.) were the only taxa from this group in the Rio Nuevo macrobotanical assemblage. There is no obvious associated tool technology, although any use of the seeds would almost certainly have entailed parching, winnowing, and grinding. These taxa generally occur away from floodplains on river terraces and alluvial fans, where they often compete with mesquite. Local shrubs may have been gathered as an embedded task during the acquisition of other resources, perhaps only when higher priority resources could not be located.

Distant Resources

This category includes resources that were not generally available along the floodplains, alluvial fans, terraces, or foothills in the intermontane basins, including manzanita (*Arctostaphylos* sp.) and juniper (*Juniperus* spp.). *Juniperus* occurred in only one sample from the undated Feature 529 at Clearwater. Manzanita was observed in Spanish and American period features but not in prehistoric features.

SUBSISTENCE TRENDS IN ARIZONA

The Rio Nuevo project flotation samples enhance current knowledge about resource use in the Tucson Basin because the data add to a growing body of information that may be used to document trends in resource selection over a period of nearly 4,000 years—from the Early Agricultural period (2100 B.C.-A.D. 50) until the late nineteenth century A.D. The samples recovered from Clearwater, the Mission Gardens, the Tucson Presidio, and Block 181 affirm the trend overall and add much-needed information about certain key intervals, such as the Early Ceramic period (A.D. 50-500) from which more paleobotanical data are needed.

Prior Research

To facilitate the comparison of the Rio Nuevo project assemblages with Tucson baseline data, the information is presented in two parts. Table 14.1 and Table 14.2 describe the Tucson Basin baseline data (excluding new data presented here). A detailed discussion of all 60 taxa in the Tucson Basin macrobotanical database would be both cumbersome and unnecessary. Table 14.1 lists temporal variation in the ubiquities (based on features) of 36 of the 61 taxa in the Tucson Basin database. Unidentified seeds and 13 other taxa whose ubiquities never exceeded 0.02, or that were only used in one time period, were excluded from this table. Table 14.2 tracks temporal variation in the mean total diet breadth and mean within-group diet breadth for Tucson Basin sites at different times. In the discussions that follow, the information in these tables is compared with the data from the Rio Nuevo project assemblages.

The trends described in Tables 14.1 and 14.2 have been extensively discussed elsewhere (Diehl 1997b; Diehl and Waters 2005; Gregory and Diehl 2002) and are only briefly described here. These trends are best understood as a description of the evolving relationship of humans to their environment, driven by the

Table 14.1. Trends in the ubiquities of selected taxa from Tucson Basin sites.

Taxon	Early Agricultural Period			Early Ceramic	Hohokam Periods			
	2100 B.C.- 1200 B.C.	1200 B.C.- 800 B.C.	800 B.C.- A.D. 50		A.D. 50- A.D. 500	A.D. 500- A.D. 750	A.D. 750- A.D. 950	A.D. 950- A.D. 1150
	Pre-San Pedro	San Pedro	Cienega		Pioneer	Colonial	Sedentary	Classic
Number of features (<i>n</i> =)	31	500	304	77	12	16	106	12
<i>Agave</i> sp. spines, etc.	0.00	0.00	0.01	0.00	0.50	0.38	0.44	0.58
<i>Amaranthus</i> sp.	0.00	0.21	0.20	0.17	0.08	0.13	0.10	0.17
Boraginaceae	0.00	0.00	0.00	0.00	0.08	0.00	0.01	0.00
Cactaceae	0.03	0.01	0.04	0.03	0.00	0.00	0.00	0.00
<i>Carnegiea gigantea</i>	0.10	0.12	0.47	0.29	0.25	0.44	0.12	0.25
<i>Echinocereus</i> sp.	0.00	0.05	0.22	0.14	0.25	0.13	0.02	0.08
<i>Opuntia</i> sp.	0.10	0.05	0.08	0.06	0.00	0.00	0.08	0.25
Chenopodiaceae	0.00	0.02	0.12	0.10	0.17	0.19	0.08	0.00
<i>Atriplex</i> sp.	0.00	0.03	0.02	0.03	0.00	0.00	0.01	0.00
<i>Chenopodium</i> sp.	0.81	0.90	0.75	0.65	0.42	0.56	0.64	0.58
<i>Polansia</i> sp.	0.00	0.13	0.06	0.00	0.00	0.00	0.01	0.08
Compositae	0.03	0.03	0.08	0.03	0.17	0.06	0.01	0.17
Cruciferae	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00
<i>Descurainia</i> sp.	0.03	0.46	0.41	0.26	0.08	0.13	0.28	0.08
<i>Cucurbita</i> sp.	0.00	0.00	0.02	0.00	0.08	0.06	0.05	0.08
<i>Juniperus</i> sp.	0.00	0.01	0.01	0.03	0.00	0.00	0.03	0.00
Cyperaceae	0.00	0.03	0.08	0.03	0.00	0.00	0.00	0.00
<i>Euphorbia</i> sp.	0.00	0.00	0.01	0.04	0.08	0.00	0.00	0.00
Gramineae	0.00	0.08	0.30	0.30	0.58	0.44	0.61	0.83
<i>Agrostis</i> or <i>Muhlenbergia</i> sp.	0.00	0.04	0.12	0.04	0.08	0.25	0.14	0.25
<i>Eragrostis</i> sp.	0.00	0.09	0.04	0.08	0.00	0.00	0.01	0.00
<i>Panicum</i> sp.	0.00	0.02	0.03	0.00	0.00	0.00	0.02	0.00
<i>Sporobolus</i> sp.	0.03	0.13	0.17	0.06	0.08	0.00	0.19	0.17
<i>Zea mays</i>	0.19	0.85	0.83	0.52	0.42	0.50	0.62	0.83
Labiatae	0.00	0.13	0.13	0.01	0.33	0.06	0.09	0.08
Leguminosae	0.00	0.01	0.04	0.09	0.17	0.06	0.07	0.00
<i>Phaseolus</i> cf. <i>vulgaris</i>	0.00	0.00	0.01	0.01	0.00	0.00	0.12	0.00
<i>P. acutifolius</i>	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.00
<i>Prosopis</i> cf. <i>juliflora</i>	0.03	0.28	0.41	0.23	0.67	0.38	0.18	0.50
Malvaceae	0.00	0.00	0.01	0.00	0.08	0.06	0.07	0.08
<i>Gossypium</i> sp.	0.00	0.00	0.00	0.00	0.00	0.06	0.05	0.50
<i>Sphaeralcea</i> sp.	0.00	0.01	0.01	0.01	0.17	0.44	0.22	0.33
<i>Boerhaavia</i> sp.	0.00	0.07	0.00	0.00	0.00	0.00	0.04	0.00
<i>Rumex</i> sp.	0.00	0.15	0.04	0.04	0.00	0.00	0.00	0.00
<i>Portulaca</i> sp.	0.06	0.16	0.07	0.01	0.00	0.06	0.01	0.00
<i>Solanum</i> or <i>Physalis</i> sp.	0.00	0.01	0.03	0.00	0.00	0.00	0.01	0.00

Table 14.2. Trends in the mean diet breadths of Tucson Basin sites.

Phase/Period	<i>n</i>	Diet Breadth (mean number of taxa)								
		All Taxa	Crops	Cacti	High-density Weeds	Low-density Weeds	Tree Legumes	Grasses	Local Shrubs	Distant Resources
Pre-San Pedro	1	12.0	1.0	3.0	3.0	3.0	1.0	1.0	0.0	0.0
Early San Pedro	2	21.0	1.0	2.5	5.0	7.0	1.0	5.0	1.0	0.5
Late San Pedro	4	20.5	1.3	3.0	2.8	6.0	0.8	2.0	1.3	1.3
Early Cienega	6	13.8	0.8	2.0	2.3	2.3	1.0	1.2	0.7	0.0
Late Cienega	5	20.6	1.0	2.4	2.6	3.8	1.4	2.2	1.6	0.8
Early Ceramic	4	12.3	1.3	2.3	2.5	3.5	1.3	1.3	0.5	0.3
Pioneer	2	15.0	1.0	3.0	1.5	4.0	1.5	2.5	1.0	0.0
Colonial	4	8.8	1.3	1.8	1.3	1.8	1.0	0.5	0.5	0.0
Sedentary	12	11.2	1.4	1.5	1.8	2.3	1.2	1.3	0.9	0.2
Classic	1	21.0	3.0	4.0	2.0	6.0	1.0	2.0	0.0	0.0

changing productivity (yield) of crops and improving subsistence technologies. Although crops, at least in the form of maize, first appeared in the second millennium B.C., diet breadth remained great despite the very high ubiquities of maize tissues in macrobotanical assemblages. An optimization model predicts that diet breadth should narrow when a very high-yield resource such as maize appears in a subsistence regime. Therefore, an explanation for the sustained, broad diet is desirable. Two explanations are currently favored.

One explanation considers the bottleneck that occurs when maize or any other grain is ground with stone tools. Many of the energetic improvements, in the search and processing costs, that were obtained by the planting of higher-yield crops were lost when maize was ground in the same fashion as small, starchy, wild seeds. The other consideration recognizes that maize farming was a high-risk activity, and wild foods were probably extensively harvested to augment maize in good years and as an insurance strategy for failures in the farming system in bad years. The risk endemic to maize agriculture stems from both unpredictable access to water (mitigated in part by the use of irrigation canals during and after the Early Agricultural period) and to losses incurred in storage. A total of 10-25 percent of the late twentieth century United States grain yield was lost in storage despite the use of very high-technology storage facilities (Bala 1997:1). Prehistoric in-storage loss rates were undoubtedly greater, particularly when the primary means of storage were baskets and underground pits. Dry-matter losses as low as 1 percent from molding will render stored grain inedible to humans

due to mycotoxin contamination (Bala 1997; Nash 1985).

Many of these problems were subsequently partially mitigated in the first millennium A.D. The first obvious change was the introduction of high-quality ceramic containers during the Early Ceramic period. Large, well-fired pots were available, and these would have substantially reduced airflow around stored grains and would have enhanced protection from insects. Both qualities would have immediately reduced in-storage losses of grain as compared with underground storage pits. It is not surprising, therefore, that the frequency of large, underground pits declined substantially in the Early Ceramic period. Two other changes that occurred almost concurrently were the introduction of better metates that continued to improve as maize use intensified (Diehl 1996) and the development or introduction of improved varieties of maize. The "floury" varieties of maize were easier to grind due to the presence of a larger, starchier endosperm, and their intrinsic yields (amount of grain per unit of cultivated land) were much improved (Adams 1994; Upham et al. 1988).

Given this overview of previous studies of changes in prehistoric Tucson Basin subsistence, how does the new information gained from the Rio Nuevo project add detail? The Rio Nuevo data increase confidence in the above-described trend, and they enhance the pre-San Pedro phase and Early Ceramic period data. The ubiquities of the taxa observed at Clearwater, the Mission Gardens, Tucson Presidio, and Block 181 (Hohokam and American Territorial period occupations at the Tucson Presidio site) are provided in Table 14.3. The contents of each flotation sample from the project are listed in Appendix B.

Table 14.3. Ubiquities of identified food, fodder, and ornamental plant taxa in the Rio Nuevo project assemblages.

Taxon	Clearwater Site	Block 181	Mission	Tucson Presidio
Unnamed phase of the Early Agricultural period (2100-1200 B.C.)				
<i>n</i> =	11	0	0	0
<i>Trianthema</i> sp.	0.09	-	-	-
<i>Echinocereus</i> or <i>Mammillaria</i> sp.	0.09	-	-	-
Cheno-am	0.09	-	-	-
<i>Chenopodium</i> sp.	0.45	-	-	-
Gramineae	0.18	-	-	-
<i>Zea mays</i>	0.45	-	-	-
<i>Prosopis</i> cf. <i>juliflora</i>	0.09	-	-	-
<i>Rumex</i> sp.	0.09	-	-	-
Cienega phase (800 B.C.-A.D. 50), predominantly Early Cienega (800-400 B.C.)				
<i>n</i> =	41	0	0	0
<i>Amaranthus</i> sp.	0.15	-	-	-
Cactaceae	0.10	-	-	-
<i>Carnegiea gigantea</i>	0.24	-	-	-
<i>Echinocereus</i> or <i>Mammillaria</i> sp.	0.17	-	-	-
<i>Opuntia</i> sp.	0.02	-	-	-
Cheno-am	0.12	-	-	-
<i>Chenopodium</i> sp.	0.37	-	-	-
Compositae	0.02	-	-	-
Cruciferae	0.02	-	-	-
<i>Descurainia</i> sp.	0.07	-	-	-
Gramineae	0.12	-	-	-
<i>Sporobolus</i> sp.	0.10	-	-	-
<i>Zea mays</i>	0.73	-	-	-
Labiatae	0.02	-	-	-
Leguminosae	0.05	-	-	-
<i>Prosopis</i> cf. <i>juliflora</i>	0.12	-	-	-
<i>Cyperus</i> or <i>Scirpus</i> sp.	0.02	-	-	-
<i>Portulaca</i> sp.	0.02	-	-	-
Early Ceramic period (A.D. 50-500)				
<i>n</i> =	2	0	0	0
<i>Carnegiea gigantea</i>	0.50	-	-	-
Cheno-am	0.50	-	-	-
<i>Chenopodium</i> sp.	0.50	-	-	-
<i>Zea mays</i>	1.00	-	-	-
<i>Prosopis</i> sp.	0.50	-	-	-
Hohokam Pioneer period (A.D. 500-750)				
<i>n</i> =	0	1	0	0
<i>Trianthema</i> sp.	-	1.00	-	-
<i>Amaranthus</i> sp.	-	1.00	-	-
<i>Carnegiea gigantea</i>	-	1.00	-	-
<i>Echinocereus</i> or <i>Mammillaria</i> sp.	-	1.00	-	-
<i>Opuntia</i> sp.	-	1.00	-	-
<i>Chenopodium</i> sp.	-	1.00	-	-
<i>Zea mays</i>	-	1.00	-	-
<i>Prosopis</i> cf. <i>juliflora</i>	-	1.00	-	-

Table 14.3. Continued.

Taxon	Clearwater Site	Block 181	Mission	Tucson Presidio
Hohokam Colonial period (A.D. 750-950)				
<i>n</i> =	1	1.00	-	-
<i>Trianthema</i> sp.	0.00	1.00	-	-
<i>Chenopodium</i> sp.	0.00	1.00	-	-
<i>Zea mays</i>	1.00	1.00	-	-
Hohokam Classic period (A.D. 1150-1450)				
<i>n</i> =	2	0	0	0
<i>Opuntia</i> sp.	0.50	-	-	-
Gramineae	0.50	-	-	-
Spanish period (A.D. 1694-1821)				
<i>n</i> =	0	0	5	8
<i>Trianthema</i> sp.	-	-	0.40	0.38
<i>Rhus</i> sp.	-	-	0.20	0.00
Cactaceae	-	-	0.20	0.25
<i>Carnegiea gigantea</i>	-	-	0.20	0.63
<i>Echinocereus</i> or <i>Mammillaria</i> sp.	-	-	0.00	0.13
<i>Opuntia</i> sp.	-	-	0.20	0.13
Cheno-am	-	-	0.00	0.13
<i>Chenopodium</i> sp.	-	-	0.00	0.50
<i>Cycloloma</i> sp.	-	-	0.00	0.13
<i>Polansia</i> sp.	-	-	0.00	0.13
<i>Cucurbita</i> sp.	-	-	0.20	0.00
Cyperaceae	-	-	0.00	0.13
Gramineae	-	-	0.00	0.38
<i>Panicum</i> sp.	-	-	0.20	0.25
<i>Triticum</i> sp.	-	-	1.00	0.75
<i>Zea mays</i>	-	-	0.40	0.75
<i>Prosopis</i> sp.	-	-	0.40	0.38
<i>Phaseolus</i> cf. <i>vulgaris</i>	-	-	0.00	0.38
<i>Prosopis</i> cf. <i>juliflora</i>	-	-	0.00	0.25
<i>Trifolium</i> sp.	-	-	0.00	0.13
<i>Portulaca</i> sp.	-	-	0.00	0.13
<i>Malus</i> sp.	-	-	0.00	0.13
<i>Capsicum</i> sp.	-	-	0.00	0.50
<i>Solanum</i> or <i>Physalis</i> sp.	-	-	0.00	0.25
American Territorial period (A.D. 1856-1912; in this assemblage, effectively prior to 1900; includes Chinese)				
<i>n</i> =	10	20	0	0
<i>Trianthema</i> sp.	0.00	0.20	-	-
<i>Amaranthus</i> sp.	0.00	0.05	-	-
Cactaceae	0.10	0.05	-	-
<i>Carnegiea gigantea</i>	0.00	0.15	-	-
Cheno-am	0.00	0.05	-	-
<i>Chenopodium</i> sp.	0.10	0.60	-	-
<i>Cycloloma</i> sp.	0.00	0.05	-	-
<i>Polansia</i> sp.	0.00	0.10	-	-

Table 14.3. Continued.

Taxon	Clearwater Site	Block 181	Mission	Tucson Presidio
Compositae	0.00	0.05	-	-
<i>Helianthus</i> sp.	0.00	0.05	-	-
<i>Descurainia</i> sp.	0.00	0.05	-	-
<i>Brassica</i> cf. <i>nigra</i>	0.00	0.05	-	-
<i>Sinapis alba</i>	0.00	0.05	-	-
<i>Cucurbita</i> cf. <i>pepo</i>	0.10	0.05	-	-
Cyperaceae	0.00	0.05	-	-
<i>Citrullus</i> cf. <i>lanatus</i>	0.10	0.00	-	-
Gramineae	0.10	0.30	-	-
<i>Agrostis</i> or <i>Muhlenbergia</i> sp.	0.00	0.05	-	-
<i>Hordeum</i> cf. <i>pusillum</i>	0.00	0.10	-	-
<i>Triticum</i> sp.	0.30	0.35	-	-
<i>Zea mays</i>	0.50	0.30	-	-
cf. <i>Avena sativa</i>	0.10	0.00	-	-
Labiatae	0.00	0.25	-	-
Leguminosae	0.10	0.20	-	-
<i>Phaseolus vulgaris</i>	0.00	0.05	-	-
<i>Prosopis</i> cf. <i>juliflora</i>	0.20	0.25	-	-
<i>Melia azederach</i>	0.00	0.10	-	-
<i>Polygonum</i> sp.	0.00	0.05	-	-
<i>Rumex</i> sp.	0.00	0.05	-	-
<i>Portulaca</i> sp.	0.10	0.15	-	-
<i>Rubus</i> sp.	0.10	0.15	-	-
<i>Capsicum</i> sp.	0.00	0.15	-	-
<i>Solanum</i> or <i>Physalis</i> sp.	0.00	0.20	-	-
<i>Vitis</i> cf. <i>vinifera</i>	0.10	0.00	-	-

Unnamed Phase of the Early Agricultural Period

Eight taxa were observed in the strata 503/504 macrobotanical assemblage from Clearwater. The most important finding is the observation of maize (*Zea mays*) cupules in significant amounts. Radiocarbon dates from maize specimens in the strata 503/504 components indicate occupations near 2100 B.C. and 1500 B.C. The observation is not surprising, because maize was also observed in pre-San Pedro phase contexts in the Sweetwater locality at Los Pozos (Gregory 2001). As shown in Table 14.1, maize was not very ubiquitous at the Sweetwater locality; in contrast, ubiquity at Clearwater ($U_{\text{maize}} = 0.45$) is consistent with later prehistoric maize ubiquities and suggests maize was an important component of the subsistence base of Tucson Basin forager-farmers more than 4,000 years ago.

Differences between the Clearwater site and the Sweetwater locality goosefoot ubiquities are interesting in light of the maize findings. The Clearwater ubiquity ($U_{\text{goosefoot}} = 0.45$) was substantially lower than

the Sweetwater locality ubiquity indicated in Table 14.1—a reversal of the rank of the two sites with respect to maize. This information should be used with caution at this time because the number of sites and the number of features at each site are too small to permit statistical comparison with any confidence. However, the differences may indicate a high degree of experimental variation in the relative emphasis on maize or high-density (floodplain) weeds in nascent local farming strategies. The variation could also be a consequence of a strategy that relied on foods obtained from cleared plots that were alternately farmed for maize and left fallow.

Cienega Phase

New data recovered from Clearwater during the Rio Nuevo project indicated the presence of a suite of plants similar to the assemblages from other Cienega phase sites in the Tucson Basin. Maize ubiquity is relatively high at all Cienega phase sites

($U_{\text{maize-all}} = 0.83$, $U_{\text{maize-Clearwater}} = 0.73$). Cienega phase sites contain moderate-to-high ubiquities of goosefoot, amaranth, or cheno-ams and, to a varying extent, tansy mustard and dropseed. Mesquite and various cacti (principally saguaro) also remained important.

Wild plant taxa from Cienega phase sites include a wide range of species ranging from high-density weeds to long-distance resources. The extreme diet breadth of Cienega phase (as well as the preceding San Pedro phase) – as compared with Early Ceramic period and Hohokam sites – has been suggested to be a consequence of high risks accompanying the initial efforts at agriculture in the Southwest. Eighteen taxa (17 wild taxa plus maize, not including unidentified seeds) were observed in the Clearwater assemblage. This is comparable with the Late Cienega phase mean of 20.6 taxa for other sites and greater than the 13.8 taxa mean derived from Early Cienega phase sites (including the initial Clearwater site excavations reported in Diehl 1997a).

Early Ceramic Period

A very limited sample (two features) of Early Ceramic period data was obtained from the Clearwater site (see Table 14.3). Five taxa, including saguaro cactus, cheno-ams, goosefoot, maize, and mesquite were observed. With respect to ubiquities, maize scored very high ($U_{\text{maize}} = 1.00$), although given the limited sample size, the ubiquity scores do not warrant any test of significance. Early Ceramic period sites generally have fewer taxa (mean = 12.3 taxa) than Early Agricultural period sites (mean = 14–21 taxa), and in prior studies, the difference has been found to be statistically significant (Diehl 1997b; Diehl and Waters 2005; Gregory and Diehl 2002). The samples from Clearwater replicate the general pattern from the Tucson Basin regarding changes in diet breadth, as well as continued emphasis on maize, cactus fruit, high-density weeds, and mesquite pods, and the declining use of low-density weeds, shrubs, low-density grasses, and long-distance resources. The overall decline in diet breadth from the Early Agricultural period into the Early Ceramic period has been attributed to reductions in the risk entailed in floodplain agriculture brought about through the use of higher-quality storage containers (ceramic jars) and the concomitant reduction in losses of grain in storage.

Hohokam Pioneer Period

One feature at Clearwater was identified as a Pioneer period context. The Tucson Basin trend for the Pioneer period indicates a continued reliance on culti-

gens (common beans, squashes, and pumpkins were known to be available by the Pioneer period) and a further decline in the use of local shrubs and long-distance weeds; there was a slight increase in the use of wild grasses. Weeds remained important, with a slight increase in the use of low-density weeds to match a slight decline in the use of high-density weeds. The cause for the shift in low- versus high-density weeds is not obvious. The increasing use of the floodplain for cultivating domestic crops may have adversely affected the availability of key floodplain weeds such as tansy mustard or dropseed. Compensation may have been attempted by substituting some of the low-density weeds for variety or for their vegetative tissues. Alternatively, if floodplain agriculture or wild seeds became less predictable in their yields, the low-density weeds and wild grasses may have seen increased use as famine foods, or as important resources for people who, by virtue of poverty of social distance, did not have access to productive floodplain fields.

Hohokam Colonial Period

Only one Colonial period feature was identified at Clearwater, so present understandings of Colonial period subsistence practices cannot be changed. In the Tucson Basin in general, diet breadth contracted further, with primary emphasis on cultigens, cacti, and high-density (floodplain) weeds. According to Upham et al. (1987), new varieties of higher-yield flourkerneled maize appeared either during the eighth century (the start of the Colonial period) or just prior to the eighth century. The reduction in diet breadth observed in Colonial period samples is attributed to increased reliance on maize and other cultigens, with the concomitant near elimination of wild grasses and most high- and low-density weeds.

No Hohokam Sedentary period features were excavated either at Clearwater or within Block 181. Therefore, the discussion advances to the Classic period, which is the next Hohokam period in the chronological sequence represented in the Rio Nuevo project assemblages.

Hohokam Classic Period

Two Classic period features were excavated at Clearwater. Unfortunately, the Hohokam Classic period is the least well-represented period in the Tucson Basin inventory. In some ways, the anecdotal evidence from Clearwater and Los Morteros, AZ AA:12:57 (ASM), suggest the Classic saw a substantial reorganization of subsistence practices, with a return to the extensive use of wild plants. Six varieties

of low-density weeds and two varieties of wild grasses augmented a subsistence strategy that also used, as much as possible, cultigens, cactus fruit or agave hearts, and mesquite. The changes may be a consequence of a reduction in the need to optimize caloric yields from the entire suite of subsistence practices. Alternatively, the changes may be attributed to some combination of declining floodplain quality, insufficient arable land to feed local populations, or a breakdown in the social organization of food production or food exchange. Any of these latter events would have increased the risk for vulnerable households (lacking either land or social ties to productive farmers) and would have caused the increased use of low-quality foods to avoid starvation.

Historic Era Occupations

The arrival of the Spaniards and later, the Americans, resulted in the introduction of a whole range of new technologies, new crops, and animal husbandry that greatly increased the yield potential and the range of resources that could be grown in the Tucson Basin. The Spaniards introduced primary staples, including wheat, peaches, oats, new varieties of squash, various fodders, and (possibly) apples. Emigrating Americans and Chinese expanded the range of taxa to include, for example, condiments (mustard, black mustard), grains (new varieties of maize, wheat, oats, rye), cover crops (typically clover, hay), new fruits (cantaloupes, dates, figs, olives, plums, raspberries, tomatoes, vine grapes, watermelons), nut masts (pecans, walnuts, pistachios), ornamental plants (China-berry, morning-glory, Osage-orange,

Russian olive), vegetable crops (cabbages, lettuces), root or tuber crops (beets, carrots, potatoes), and pests (Russian thistle, tamarisk) (Diehl et al. 2002, 2003).

Ethnic and class variation evidence in Tucson lifeways remains in a nascent state of research. Studies are ongoing, although there is considerable evidence indicating historically documentable Spanish food preferences are evident in Spanish period and high-status Mexican period or Mexican-American assemblages. In particular, the Spanish and high-status Mexican preference for wheat rather than maize (Pilcher 1998; Super 1988) has been noted in previous studies of Tucson Presidio samples and high-status Mexican households (Diehl et al. 2005), as well as in the new samples recovered from the Mission Gardens and the Tucson Presidio. Chinese preferences for a very diverse diet (Chang 1977) are also evident (Diehl et al. 1998).

The abundance of different categories of foods in the Spanish period and more recent assemblages seems not to require a substantial explanation, because historical records show that Native Americans favored many of the new taxa. These taxa allowed double-cropping (as with winter wheat and maize) and they were flavorful, novel, and desirable (as with most of the new fruit taxa). Watermills for grinding grain and later mechanical, machine-driven mills eliminated the last bottlenecks in the energetic returns from grain consumption and ended the need to optimize food consumption solely based on energy returns. Impoverished people working as wage laborers may have continued to optimize, however, because some of the more desirable new cultivars (such as peaches) may have been beyond the day-to-day reach of their limited means.

REFERENCES CITED

- Adams, Karen R.
1994 A Regional Synthesis of *Zea mays* in the Prehistoric American Southwest. In *Corn and Culture in the Prehistoric New World*, edited by S. Johannessen and C. A. Hastorf, pp. 273-302. Westview Press, Boulder.
- Bala, B. K.
1997 *Drying and Storage of Cereal Grains*. Science Publishers, Inc., Enfield, New Hampshire.
- Cane, Scott
1989 Australian Aboriginal Seed Grinding and Its Archaeological Record: A Case Study from the Western Desert. In *Foraging and Farming: The Evolution of Plant Exploitation*, edited by D. R. Harris and G. C. Hillman, pp. 9-119. Unwin Hyman, London and Boston.
- Chang, Kwang-Chih (editor)
1977 *Food in Chinese Culture: Anthropological and Historical Perspectives*. Yale University Press, New Haven, Connecticut.
- Crosswhite, Frank S.
1980 The Annual Saguaro Harvest and Crop Cycle of the Papagos with Reference to Ecology and Symbolism. *Desert Plants* 2(1):3-62.
- Diehl, Michael W.
1996 The Intensity of Maize Processing and Production in Upland Mogollon Pithouse Villages A.D. 200-1000. *American Antiquity* 61: 102-115.
1997a *Archaeological Investigations of the Early Agricultural Period Settlement at the Base of A-Mountain, Tucson, Arizona*. Technical Report No. 96-21. Center for Desert Archaeology, Tucson.
1997b Rational Behavior, the Adoption of Agriculture, and the Organization of Subsistence during the Late Archaic Period in the Greater Tucson Basin. In *Rediscovering Darwin: Evolutionary Theory and Archaeological Explanation*, edited by C. M. Barton and G. A. Clark, pp. 251-266. Archaeological Papers No. 7. American Anthropological Association, Arlington, Virginia.
- Diehl, Michael W., and Jennifer A. Waters
2005 Aspects of Optimization and Risk during the Early Agricultural Period in Southeastern Arizona. In *Foraging Theory and the Transition to Agriculture*, edited by D. J. Kennett and B. Winterhalder. University of California Press, Berkeley, in press.
- Diehl, Michael W., Jenny L. Adams, J. Homer Thiel, Linda Scott Cummings, and Arthur Vokes
2005 Food, Social Standing, and Ethnic Identity. In *Down by the River: Archaeological and Historical Studies of the León Family Farmstead*, by J. H. Thiel, pp. 179-195. Anthropological Papers No. 38. Center for Desert Archaeology, Tucson.
- Diehl, Michael W., J. Homer Thiel, and Arthur W. Vokes
2002 The Diet of Block 136 Residents. In *Exploring the Barrio Libre: Investigations at Block 136, Tucson, Arizona*, by J. H. Thiel, pp. 66-76. Technical Report No. 2001-08. Desert Archaeology, Inc., Tucson.
2003 The Osborn Family Dinner Table. In *Archaeological Investigations of the Osborn and Hazzard Family Homes, Block 172, Tucson, Arizona*, by J. H. Thiel, pp. 64-77. Technical Report No. 2002-04. Desert Archaeology, Inc., Tucson.
- Diehl, Michael W., Jennifer A. Waters, and J. Homer Thiel
1998 Acculturation and the Composition of the Diet of Tucson's Overseas Chinese Gardeners at the Turn of the Century. *Historical Archaeology* 32(4):19-33.
- Doelle, William H.
1976 *Desert Resources and Hohokam Subsistence: The Conoco-Florence Project*. Archaeological Series No. 103. Arizona State Museum, University of Arizona, Tucson.
1978 Hohokam Use of Nonriverine Resources. In *Discovering Past Behavior*, edited by P. Grebinger, pp. 245-274. Gordon and Breach, New York.

- Ford, Richard I.
1981 Gardening and Farming Before A.D. 1000: Patterns of Prehistoric Cultivation North of Mexico. *Journal of Ethnobiology* 1:6-27.
- Galinat, Walton C.
1988 The Origins of Maiz de Ocho. *American Anthropologist* 90:682-683.
- Gasser, Robert E.
1982 Hohokam Use of Desert Plant Foods. *Desert Plants* 3:216-235.
- Gregory, David A. (editor)
2001 *Excavations in the Santa Cruz River Floodplain: The Early Agricultural Period Component at Los Pozos*. Anthropological Papers No. 21. Center for Desert Archaeology, Tucson.
- Gregory, David A., and Michael W. Diehl
2002 Duration, Continuity, and Intensity of Occupation at a Late Cienega Phase Settlement in the Santa Cruz River Floodplain. In *Traditions, Transitions, and Technologies: Themes in Southwestern Archaeology*, edited by S. H. Schlanger, pp. 200-223. University Press of Colorado, Boulder.
- Kelly, Robert L.
1995 *The Foraging Spectrum: Diversity in Hunter-Gatherer Lifeways*. Smithsonian Institution Press, Washington, D.C. and London.
- Krebs, John R., and Nicholas B. Davies
1991 *Behavioral Ecology: An Evolutionary Approach*. Blackwell Scientific, Oxford, England.
- Mabry, Jonathan B.
2005 Diversity in Early Southwestern Farming and Optimization Models of Transitions to Agriculture. In *Subsistence and Resource Use Strategies of Early Agricultural Communities in Southern Arizona*, edited by M. W. Diehl, pp. 113-152. Anthropological Papers No. 34. Center for Desert Archaeology, Tucson.
- Minnis, Paul E.
1981 Seeds in Archaeological Sites: Sources and Some Interpretive Problems. *American Antiquity* 46:143-152.
- Nash, Michael J.
1985 *Crop Conservation and Storage in Cool Temperate Climates*. 2nd ed. Pergamon Press, New York.
- Pilcher, Jeffrey M.
1998 *¡Que Viva los Tamales! Food and the Making of Mexican Identity*. University of New Mexico Press, Albuquerque.
- Popper, Virginia S.
1988 Selecting Quantitative Measurements in Paleoethnobotany. In *Current Paleoethnobotany: Analytical Methods and Cultural Interpretations of Archaeological Plant Remains*, edited by C. A. Hastorf and V. S. Popper, pp. 53-71. University of Chicago Press, Chicago.
- Schiffer, Michael B.
1996 Some Relationships between Behavioral and Evolutionary Ecologies. *American Antiquity* 61:643-662.
- Simms, Steven R.
1987 *Behavioral Ecology and Hunter-Gatherer Foraging: An Example from the Great Basin*. BAR International Series No. 381. British Archaeological Reports, Oxford, England.
- Super, John C.
1988 *Food, Conquest, and Colonization in Sixteenth-Century Spanish America*. University of New Mexico Press, Albuquerque.
- Upham, Steadman, Richard S. MacNeish, Walton C. Galian, and Christopher M. Stevenson
1987 Evidence Concerning the Origin of Maiz de Ocho. *American Anthropologist* 89:410-419.
- Upham, Steadman, Richard S. MacNeish, and Christopher M. Stevenson
1988 The Age and Evolutionary Significance of Southwestern Maiz de Ocho. *American Anthropologist* 90:683-684.