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Journal
Journal of California and Great Basin Anthropology, 36(2)

ISSN
0191-3557

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Publication Date
2016

Peer reviewed

Journal of California and Great Basin Anthropology | Vol. 36, No. 2 (2016) | pp. 205–219

The Macrofossil and Starch Grain Evidence for the Use of Root Crops in the Owens Valley, California, Including Two Potentially Irrigated Taxa

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The Owens Valley Paiute practice of irrigating wild tuberous plants was reported in early historical accounts and later by ethnographer Julian Steward and others. Despite the ethnographic evidence, archaeological traces of the root crops themselves have proven elusive until relatively recently. Excavations at four sites along the length of the valley have produced carbonized macrofossils of Cyperus esculentus *(nut grass), which is believed to be* taboose*, one of the irrigated crops Steward reported. Many of the contexts with* taboose *macrofossils have been radiometrically dated and range in age from 2,300 years B.P. to statistically modern at a two sigma calibration. This paper examines the archaeological evidence for root crop use, consisting of carbonized* Cyperus esculentus *macrofossils from 17 contexts at four sites and samples of starch residues on groundstone artifacts from one site. These data are then examined in relationship to diachronic trends in plant use in the Owens Valley.*

Historical and ethnographic descriptions of native plant cultivation, using dam and ditch irrigation systems, in the Owens Valley, southeastern California, have enticed anthropologists for decades (Davidson 1859 in Wilke and Lawton 1976; Steward 1929, 1933, 1938; Von Schmidt 1856 in Cavelle 2011). Several scholarly papers have investigated the subject (Lawton et al. 1976; Smith 2011; Steward 1929, 1933, 1938). Despite much academic attention and four decades of archaeological excavation in the Owens Valley, archaeological evidence of irrigation ditches and the purported root crops has not been found until recently. This paper presents archaeobotanical evidence, from macrofossils and starch grains, for the use of root crops in the Owens Valley, including two purportedly irrigated taxa.

New archaeological evidence of *Cyperus esculentus* (*taboose*) tubers and *Dichelostemma* corms (*nahavita*), consisting of carbonized macrofossils and starch residues on groundstone artifacts, are examined in relationship to the backdrop of diachronic trends in plant use in the Owens Valley based on archaeobotanical data. It does not establish a date for the advent of irrigation, but with datasets expanding to include a greater use of starch-grain analysis, this may become possible with the progression of research. Until then, understanding the context in which irrigation arose is essential for inferring when it was likely to have begun. First, the irrigated crops will be described briefly, the archaeobotanical datasets and methods used in starch-grain analysis will be detailed, and the archaeological contexts with *taboose* explored, followed by a synopsis of the last 2,000 years of subsistence intensification in the Owens Valley from an archaeobotanical perspective.

BACKGROUND

To understand why archaeological evidence has been so elusive, both the problematic botanical identification of the plants involved, the nature of the proposed irrigated taxa, and the nature of the archaeological work need to be explained.

Purportedly Irrigated Taxa

Several historical accounts noted that the Owens Valley Pauite practiced crop irrigation. However, the crop plants were only identified in the works of Julian Steward (1929, 1933, 1938). According to Steward, two root crops, called *taboose* and *nahavita* in the native Paiute language, were cultivated by irrigation. However, the botanical identification of these native-named plants has been somewhat challenging. Steward (1933) stated that *nahavita* was a species of the *Eleocharis* (spike rush) genus "having a number of bulbs (1933:245)" collected and prepared in the same way as *taboose*. Steward appeared to be less certain as to what kind of plant *taboose* was, and simply said that it was probably "*Brodiaea capitata* Benth., grassnut or blue dicks (1933:245)."

Figure 1. Photo of *Cyperus esculentus* herberium sheet.
California state University, Chico (courtesy of photographer Lawrence Janeway 2016).

In the most seminal paper to date on the subject, Lawton et al. (1976) proposed that *Cyperus esculentus,* commonly called "nutgrass," is *taboose* and that *Dichelostemma* spp., commonly called "blue dicks," is *nahavita*. Since the 1976 Lawton et al. paper, these species have been accepted as the irrigated crops.

The identification of *Cyperus esculentus* as *taboose* is supported by sources other than Steward (ECMOHP 1991–1995; Fowler 1986) and its importance is reflected in such place names as Taboose Creek. One consultant stated that taboose was "one of the main foods" (ECMOHP 1995:349). Descriptions of *taboose* in ethnographic accounts accurately describe *Cyperus esculentus*. Paiute consultants from the Owens Valley described *taboose* as "growing at the end of roots of a grass that looked like dried up peas" (ECMOHP 1991–1995) (Fig. 1). They also compared its taste to coconut and cashews and said it was added to other foods to "sweeten" them.

The tubers have a white dense meat similar in texture and taste to coconut. It occurs over most of the world, where it is also known as yellow nut sedge, nut grass, tiger nut, and chufa. It has been domesticated and used as a crop plant and is still being cultivated in some places. It is nutritionally and calorically comparable to pinyon nuts (*Pinus monophylla*), another important staple food in the Owens Valley (Table 1).

Steward (1933, 1938) stated that the tubers could be eaten raw, but most were dried, roasted for storage, and then ground into flour upon use. In an unpublished oral history archived at the Eastern California Museum, the preparation of the raw tubers was described. They were simply cleaned and ground into paste for immediate consumption; they could also be eaten dry (ECMOHP 1991–1995). When prepared this way, they would not become carbonized macrofossils because no heat was used in this process, but a starch residue would be left on the stones used for grinding the tubers. This is why we believe carbonized *taboose* is evidence of storage.

The other important irrigated crop was *nahavita*. Lawton et al. (1976) assumed *nahavita* was incorrectly identified because "*Eleocharis* spp. do not produce a number of tubers or bulbs." This assumption is erroneous as a few species do produce tubers or bulbs, the best known being the commercially produced Chinese water chestnut (*E. dulcis*). Another bulb-producing species of this genus, *Eleocharis quinqueflora*, is native to the Owens Valley area. *E. quinqueflora* produces bulbs at the tips of its rhizomes (Fig. 2), and it has been recently identified in several archaeobotanical samples from the White Mountains (Rhode 2015). The identification by Lawton et al. of *nahavita* is called into question by Rhode's findings. It is also

Table 1

PROXIMATE COMPOSITION OF *CYPERUS ESCULENTUS*[a] AND *PINUS MONOPHYLLA*[b] (PINYON)

Tiger Nut	Protein (%)	Fats (%)	CHO (%)	Fiber (%)	KCalories per 100g. (mean)
Dry	3.94 ± 0.05	27.54 ± 0.34	41.59 ± 0.12	15.60 ± 0.42	429.18
Dry	5.00 ± 0.08	30.00±2.00	47.00±1.50	6.50±0.90	
Pinyon	**7.80**	**24.00**	**58.00**		**481.00**

[a]Arafat et al. 2009; Monago and Uwakwe 2009. [b]Gilliland 1985.

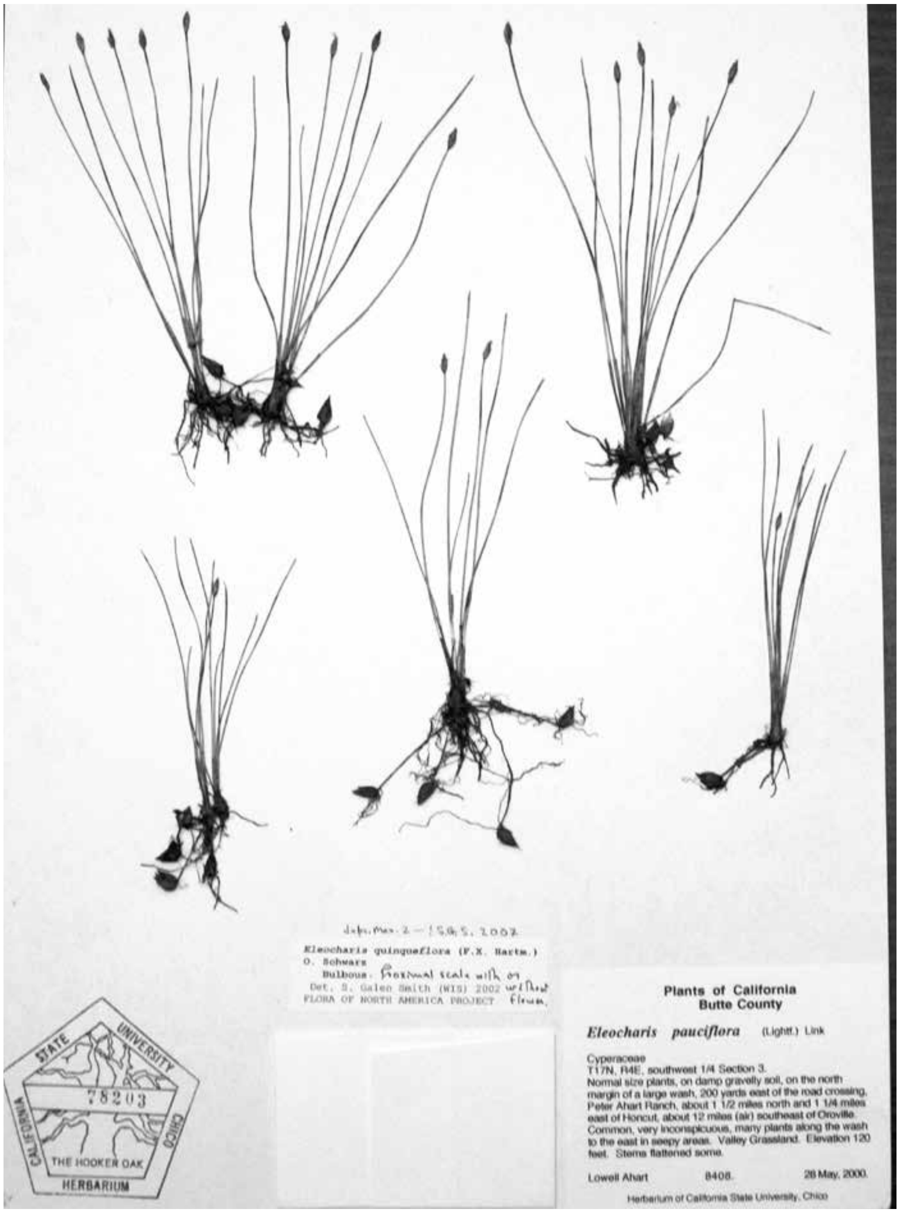

Figure 2. Photo of *Eleocharis quinqueflora* herberium sheet. California state University, Chico (courtesy of photographer Lawrence Janeway 2016).

Figure 3. *Dichelostemma* spp.

interesting to note that in Steward's 1938 volume, blue dicks are called *si'go* by the Owens Valley Paiute and *see ko* or *see go* by the Shoshoni (Irwin 1980), not *nahavita*.

Regardless, Lawton et al. (1976) presented a reasonable case for *Dichelostemma* spp. being *nahavita* (Fig. 3). They produce edible corms and were widely used for food by indigenous peoples throughout the California floristic province, but there is scant ethnographic mention of blue dicks or their use in the Owens Valley. In ethnographic descriptions from other areas, blue dicks are collected in the late spring or early summer, and were eaten either raw or roasted. Macrofossils of corms are found archaeologically in the Central Valley and on the Channel Islands (Gill 2015; Reddy and Erlandson 2012; Wohlgemuth, this issue).

Preservation of Botanical Remains

Plant food remains in California and the Great Basin are most commonly preserved through carbonization, which changes the food chemically but retains the morphology of the plant, allowing for subsequent identification. These remains are called carbonized macrofossils. Foods that were eaten raw are rarely preserved as macrofossils in the archaeological record. It is only hard, dry seeds and nutshells that are usually preserved by carbonization. Foods with a high moisture content, such as greens and roots, tend to burn to ash or fall apart into unidentifiable fragments. Thus roots, greens, and pulpy fruits are routinely underrepresented, if represented at all, in archaeological contexts. This is why it is very important to use complimentary archaeobotanical methods (such as starch-grain analysis) that capture food residues from raw foods or from foods that are not processed or preserved by cooking.

Cyperus esculentus tubers are hard, with a low moisture content, and therefore preserve fairly well when carbonized. The growth of the tubers must be arrested by parching so that they will not sprout or spoil during long-term storage. Archaeological macrofossil specimens most likely became carbonized as a result of loss during the parching or heating process. When either parched or raw tubers or corms are later ground into flour, they leave starch-grain evidence on the milling tools.

When plants are not processed in a manner requiring the application of heat, they have little chance of becoming preserved through carbonization. However, uncooked plants may leave microscopic traces such as starch or other residues on stone tools if they are used to process those plants. Because carbonized *Dichelostemma* spp. have not been found to date, it must be assumed that cooking was not a method used in the Owens Valley to process these plants.

Archaeological Research in the Owens Valley

Since *taboose* was important and it preserves by carbonization, one might expect it to have been recovered sooner. Beginning in the 1970s, a sizeable number of archaeological excavations and archaeobotanical analyses have taken place at sites in the Owens Valley. However, the majority of work has taken place along Highway 395, a mostly arid corridor in the sagebrush shrubland, which runs along the west side of the valley between the alluvial fans of the Sierra Nevada Mountains and the Owens River (Fig. 4). Only a handful of sites have been excavated in other environmental contexts by academics (Basgall and Giambastiani 1995; Bettinger 1989; Riddell 1951). Therefore, the archaeological sample of plant remains is heavily biased by the number of sites that lie mostly in the shrubland environment. This has undoubtedly biased the archaeobotanical record for the region, though not entirely, because it is common to find plant remains from both the pinyon-juniper upland and the riparian environments in these valley sites.

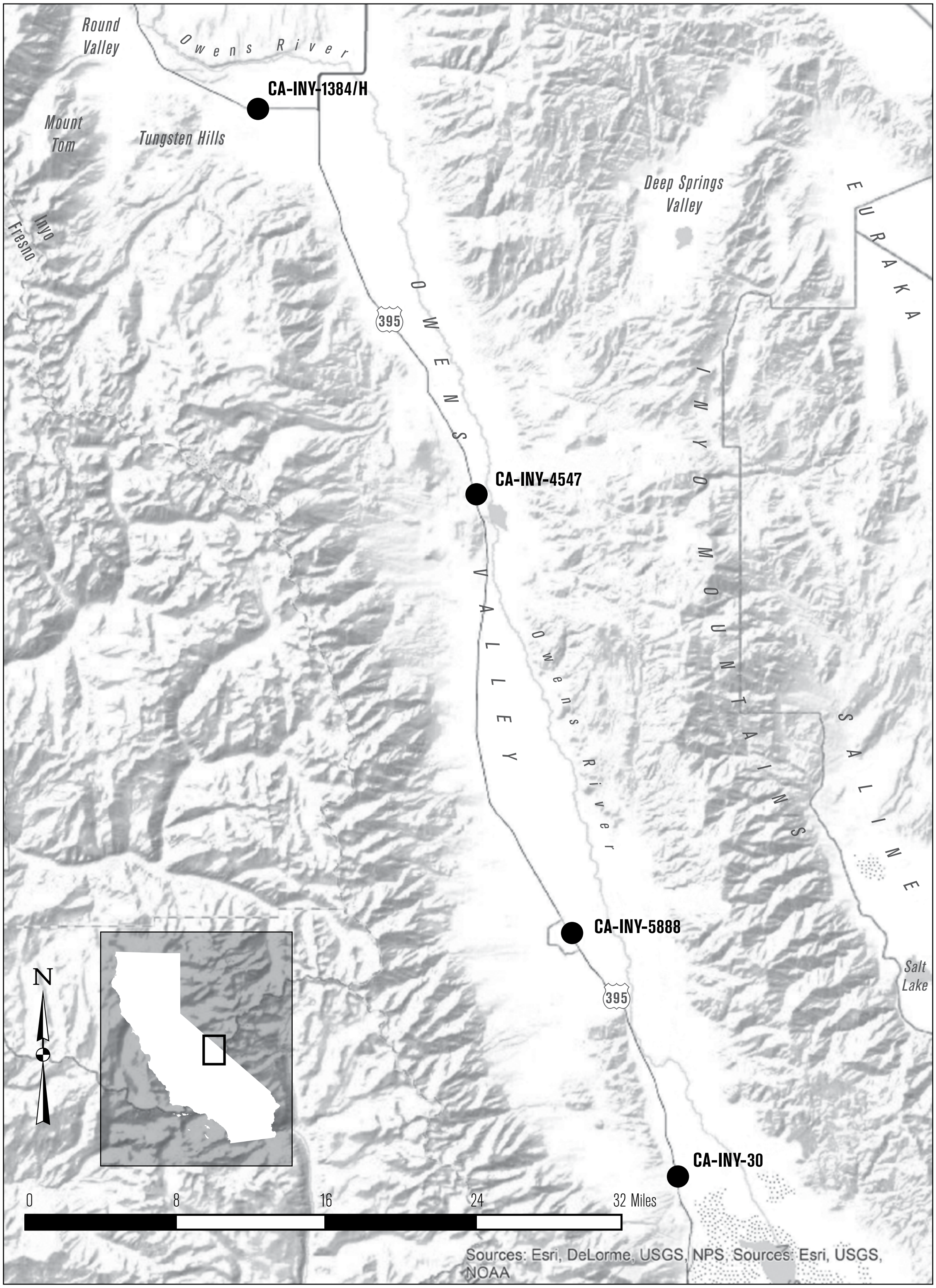

Figure 4. Map of Owens Valley and vicinity. Locations of archaeological *Cyperus esculentus*.

In the particular case of *taboose* macrofossils, they have only been found in the sites along Highway 395 that crossed or came close to what were once wetlands before historical water diversion. One *Cyperus esculentus* tuber is a potential exception, as it was reported from a site near Fish Springs (Wickstrom et al. 1993).

ARCHAEOBOTANICAL DATA

Pertinent chronological periods defined for the region are as follows—the Newberry (3,150–1,350 B.P.), Haiwee (1,350–650 B.P.), and the Marana Period (650 B.P.–0 B.P.) (Bettinger and Taylor 1974) (Table 2). These temporal periods are based on projectile point types with paired ^{14}C dates; however, there were significant changes in subsistence and settlement that are not reflected in the point typology. One of these subsistence/settlement changes occurred around 2,000 B.P., separating the early Newberry from the late Newberry Period (Basgall and Delacorte 2012; Basgall and McGuire 1988). The Newberry settlement shift is most notable at two sites which both had ample archaeobotanical analyses, CA-INY-30 near Owens Lake and Lubkin Creek, and CA-INY-1384/H near Birch Creek and the Owens River west of Bishop (Basgall and Delacorte 2012; Basgall et al. 2003; Basgall and McGuire 1988). It should be mentioned that these are not the only sites with assemblages from this period, but the others do not have archaeobotanical datasets for comparison (Basgall and Giambastiani 1995; Delacorte 1990).

Starch Grain Dataset

The starch grain dataset used for this study comes from nine artifacts from INY-1384/H. All nine starch residue samples are from two Late Newberry-age structures from two separate loci at INY-1384/H; they are derived from handstones (n=2), milling slabs (n=3), and cobble tools (n=4). The methods used for the chemical starch extraction from artifacts, microscope analysis, starch description, and taxonomic identification were adapted from Fullagar et al. (1998), Horrocks et al. (2004), Lentfer et al. (2002), Rumold (2010), Therin (1994), and Scholze (2011). Comparative starch samples from *Pinus monophylla* nuts, *Cyperus esculentus* tubers, *Dichelostemma capitatum* corms, *Typha* sp. rhizomes, *Lomatium* sp. tap root, *Eleocharis quinqueflora* bulbs,

Table 2

OWENS VALLEY CHRONOLOGICAL PERIODS

Period Names	Dates
Newberry	3,150–1,350 B.P.
(Early Newberry)	(3,150–~2,000 B.P.)
(Late Newberry)	(~2,000–1,350 B.P.)
Haiwee	1,350–650 B.P.
Marana	650–Historic Era
(Early Marana)	(650–200 B.P.)
(Late Marana)	(200 B.P.–Historic Era)

Table 3

CARBONIZED MACROFOSSIL DATA SET FROM OWENS VALLEY: TOTAL NUMBER OF CONTEXTS DATED TO PERIOD

Period	Sites	Structures	Hearths[a]	Midden/ Matrix	Other	Total
Newberry	12	19	17	7	–	43
Haiwee	17	5	7	7	–	19
Marana	38	21	40	18	7	86
Total	**67[b]**	**45**	**48**	**32**	**7**	**148**

[a]Not in structures, [b]Some sites have more than one temporal context.

and plants belonging to several other genera were used for comparison.

Macrofossil Dataset

The carbonized macrofossil dataset from the Owens Valley compiled for this study comes from 66 sites from Sherwin Grade in the north to Olancha in the south. These sites provided 164 contexts with macrobotanical remains. When the sites with mixed temporal or no temporal information are removed, the dataset consists of 52 sites with 148 contexts dated to chronological periods from Newberry to Marana (Table 3). These contexts are dated structures, hearths, middens, and other features with radiocarbon dates that range from 3,340+/–40 B.P. to statistically modern. When those three chronological periods are broken down into finer components—primarily on the basis of radiometric assays—into Early Newberry (3,150–2,300 B.P.), Late Newberry (2,300–1,350 B.P.), Haiwee (1,350–650 B.P.), Early Marana (650–200 B.P.), and Late Marana (200 B.P.-historic-era) respectively, feature distributions become more differentiated, particularly houses within the Newberry Period (Table 4). Contexts which cannot be securely dated within the components were eliminated, leaving a sample of 119 contexts with component-level data.

Diachronic Trends in the Macrofossil Data

Plant remains from pre-early Newberry contexts are very limited, but several contexts with Late Newberry floral remains have been analyzed and reported. These macrobotanical data involve a wide variety of plants from many environments, including the riparian, aquatic, meadow, scrub, and pinyon/juniper woodland. Fauna found in these house contexts indicate the alpine zone was also used. The plant remains at INY-30, INY-1384/H, and other Late Newberry sites indicate a broad-spectrum subsistence strategy was followed at these camps. While the houses have many plant remains collected in different seasons, it is inferred that these houses were associated with winter camps because many contain winter-ripening *Artemisia tridentata* seeds, almost all contain pinyon nutshell (although in sparse quantities), and they are located in productive and reliable riparian/wetland areas which have starchy roots available year round as long as the ground is not too frozen for them to be dug up. The presence of pinyon nuts indicates that the nuts were obtained in the uplands and brought down to the base camp, but they do not appear to have been collected in sufficient quantities to have lasted through the winter.

Subsistence practices changed from a broad-spectrum adaptation in the Late Newberry to a Haiwee Period strategy that is difficult to characterize. A shift is clearly evident in the archaeobotanical data in the ubiquity of pinyon and the percentage of structures (Table 5). According to Bettinger (1976), the exploitation of pinyon nuts in quantities for storage over winter became important at this time. Winter camps appear to have moved to areas closer to stored pine nut caches, up the alluvial fans at the margins of the valley, as the percentage of house structures found in the valley bottom plummets after the Late Newberry (Fowler and Liljeblad 1986; Steward 1933). The change in percentages of structures appears to reflect an increase in temporary camps and resource procurement locations in the valley from this period on. Densities of pinyon do not increase significantly in the valley, and other seed resources vary appreciably in both ubiquity and frequency. Average seed densities increase only slightly after the Late Newberry Period.

The Marana Period is significantly different from the preceding Haiwee Period and is similar to the Late Newberry in taxa diversity and context percentages. However, the Marana Period had on average much higher quantities of seeds and nutshells (Table 5). Pinyon was undeniably the chief winter staple, and quantities increased appreciably at valley sites in this period.

Table 4

CARBONIZED MACROFOSSIL DATA SET FROM OWENS VALLEY: TOTAL NUMBER OF CONTEXTS DATED TO PERIOD

Period	Structures	Hearths	Midden/ Matrix	Other	Total
Early Newberry	–	9	1	–	10
Late Newberry	19	2	1		22
Haiwee	5	8	6	–	19
Early Marana	7	15	2	2	26
Late Marana	11	17	9	5	42
Total	**42**	**51**	**19**	**7**	**119**

Table 5

MACROFOSSIL DATA FOR PINYON NUTSHELL AND SMALL SEEDS IN THE OWENS VALLEY OVER TIME

	Late Newberry (2,300–1,350 B.P.)	Haiwee (1,350–650 B.P.)	Early Marana (650–200 B.P.)	Late Marana (200–0 B.P.)
Pinyon Ubiquity (%)	90.0	37.0	38.0	40.0
Ave. Pinyon Density (#/l.)	0.9	1.1	14.8	17.1
Ave. Seed Density (#/l.)	2.5	6.5	26.1	56.8
No. of Contexts	20.0	17.0	17.0	35.0
% of contexts = structures	85.0	26.0	28.0	27.0

Table 6

STARCH GRAINS FROM LATE NEWBERRY ARTIFACTS AT CA-INY-1384/H

Cat #	Description	Structure	*Cyperus*	*Typha*	*Dichelostemma*	*Lomatium*	*Pinus Monophylla*	Unknown	Unidentifiable	Total #
791	Cobble tool	8	2	1[a]	2			1	5	11
975	Cobble tool	8	1					1	1	3
834	Cobble tool	8	3				2/1[a]	3	5	14
1063	Cobble tool	8					46[a]			46
1031	Milling slab	8	1/3[a]	2/2[a]	1			3	9	21
731	Milling slab	8	10/1[a]	2/2[a]				1	1	16
1115	Handstone	8	1					2	0	3
1019	Handstone	8	6	1[a]				2	10	19
2840	Milling slab	2		1		2		2	3	8
Total			**24/4[a]**	**5/6[a]**	**3**	**2**	**2/47[a]**	**15**	**34**	**142**

[a]Provisional classification

Nuts must have been cached closer to the valley or more frequent trips were made to retrieve cached nuts. Plant collection and processing methods continued to intensify during this period with the numbers of seeds and the amount of labor increasing. In the Late Marana Period (~200 B.P.-historic-era), features associated with the mass collection and processing of various seed plants are found in association with soaring seed densities. While mass seed processing may have started earlier, during the Haiwee pattern of focused harvesting (Delacorte 1995), the evidence from well-dated single component features occurs at roughly 200 B.P. and later. The mass collection, threshing, and winnowing of seeds is highly labor-intensive and is well-documented as such in the ethnographic record of the Shoshoni (Irwin 1980; Zigmond 1981). At the latter end of the Marana Period, with the maximization of pinyon and small seed harvesting, one of the only ways left to expand the quantity of food available was through the manipulation of the existing resource tracts or niches themselves to increase plant density, homogeneity, and yield. This is consistent with the historical accounts describing dam and ditch irrigation systems in the valley.

Results of Starch Grain Analysis

All nine of the sampled tools had starch grains present (Table 6). Altogether, 142 starch grains were counted, but only 36 were positively identified, with an additional 57 tentatively identified. The taxa identified were *Cyperus esculentus* (nutgrass), *Dichelostemma capitatum* (blue dicks), *Lomatium* (biscuit root), *Pinus monophylla* (pinyon nut), and *Typha* (cattail). *Eleocharis quinqueflora* bulb starch was acquired after the original identifications were finished, and the slides were reexamined for the presence of this taxon. *Eleocharis* starch was not found on the mounted slides.

Taboose is the most ubiquitous starch found on seven of the nine artifacts (78%); five artifacts (56%) had cattail rhizome starch, blue dick and pinyon starch were found on two artifacts (22%), and biscuit root starch was found on one artifact (11%). *Taboose* is also the most abundant starch, comprising half (50%) of securely identified starch grains (not including those provisionally identified). However, when the provisionally identified starches are included in the totals, pinyon is the most abundant at 53%, followed by *taboose* (30%), and then cattail (12%).

The *Dichelostemma* sp. starch represents the first and only archaeological evidence for this plant being processed and used in the Owens Valley, and like *taboose*, its use dates back to the Late Newberry Period. Fifteen unidentified starches were also present. The unidentified starches could potentially be identified if a larger and more diverse comparative collection was available.

All nine starch residue samples are from two Late Newberry-age structures and come from handstones,

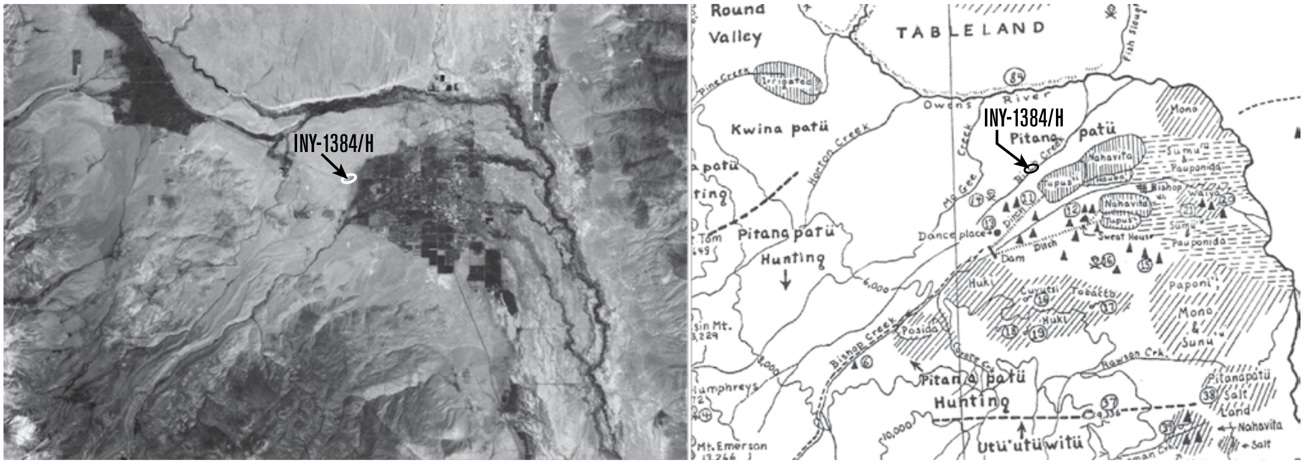

Figure 5. Comparison of modern aerial image and Steward's Ethnographic Map 2 (Steward 1933) showing irrigated locations in the vicinity of CA-INY-1384/H on Birch Creek.

milling slabs, and cobble tools. The different tool types were sampled to look for patterns of tool usage with certain plant taxa, but the results did not show any patterning and most taxa were present on different kinds of tools. One would expect handstones and milling slabs to share taxa since they are used together, but the function of the cobble tools is enigmatic. Pine nut starch was found only on the cobble tools, but was only present on half. The sample is too small for results to be significant; however, patterns may emerge with a much larger sample of tools.

Though this sample is small, it underscores the importance of starch analysis to provide evidence of plant use that is largely invisible in the macrofossil record. It provides us with a much more well-rounded understanding of the plant-based portion of the diet and has the potential to shed light on the function of some tool classes.

Archaeological Contexts with Taboose *Macrofossils*

The archaeological contexts with *taboose* macrofossils, to date, are from 30 flotation samples and two screened lots from 17 different contexts in four sites distributed along the valley from west of Bishop to the north end of Owens Lake (Fig. 4).

The Archaeological Research Center, CSUS excavated a site complex west of Bishop (CA-INY-1384/H) (Fig. 5) where definitive archaeological evidence of *taboose* was first documented in quantity from dated contexts (Basgall et al. 2003). Site INY-1384/H returned 138 tubers from five loci and eleven contexts. Excavations at a site near Manzanar (CA-INY-5888) also produced ten tubers from two house structures in two different loci and an area near one of the houses (Basgall and Delacorte 2011). The "tubers" from CA-INY-30 (Basgall and McGuire 1988) were re-examined for this paper and seven of them from two structures were positively identified as *Cyperus esculentus*. Lastly, one *taboose* tuber was reported from a mixed midden context from CA-INY-4547 near Fish Springs (Wickstrom et al. 1993). That identification was not verified for this paper.

Taboose macrofossils are present in four sites (6%) and 17 contexts (10%) (Table 7) out of the macrofossil dataset involving 65 sites with 164 contexts from the Owens Valley. The results cluster in two time periods, the Late Newberry and the Marana. There are eight Newberry contexts that range from 2,300–1,290 B.P. at a two sigma calibration range. All are from within what appear to be winter houses at two sites, INY-1384/H and INY-30 (Table 8). The nine Marana contexts come from

Table 7

NUMBERS OF DATED SITES AND CONTEXTS WITH *TABOOSE* TUBER MACROFOSSILS

	No. Sites with macrofosill data	% of Sites with *Taboose*	No. Contexts with macrofossil data	% of Contexts with *Taboose*
Newberry	12	17	43	20
Haiwee	17	0	19	0
Marana	38	11	86	11

Table 8

LATE NEWBERRY CONTEXTS WITH *TABOOSE*

COMPONENT	SITE	LOCUS	CONTEXT	C14 2Σ Cal	SEED/L.[a]	REFERENCE
Late Newberry	CA-INY-1384/H	2	STR 8[b]	1,530–1,330 B.P.	0.7	Basgall and Delacorte 2012
Late Newberry	CA-INY-1384/H	2	STR 9	1,410–1,290 B.P.	0.1	Basgall and Delacorte 2012
Late Newberry	CA-INY-1384/H	2	STR 10	2,010-1,550 B.P.	0.1	Basgall and Delacorte 2012
Late Newberry	CA-INY-1384/H	2	STR 11	2,300–1,900 B.P.	0.2	Basgall and Delacorte 2012
Late Newberry	CA-INY-1384/H	3	STR 2[b]	1,990–1,820 B.P.	0.1	Basgall and Delacorte 2012
Late Newberry	CA-INY-1384/H	3	STR 5	2,010–1,870 B.P.	0.1	Basgall and Delacorte 2012
Late Newberry	CA-INY-1384/H	3	STR 7	2,270–1,920 B.P.	0.1	Basgall and Delacorte 2012
Late Newberry	CA-INY-30	–	STR 15	1,460+/–60 B.P.	0.2	Basgall and McGuire 1988

[a]The density of the macrofossils is calculated as number of tubers divided by liter of sampled soil.
[b]Starch analyzed from these contexts.
STR = structure.

Table 9

MARANA PERIOD TO HISTORIC-ERA CONTEXTS WITH *TABOOSE*

COMPONENT	SITE	LOCUS	CONTEXT	C14 2Σ Cal	RAW NO.	SEED/L .	REFERENCE
Marana	CA-INY-5888	1	STR-2	690+/–40 B.P.	6	0.7	Basgall and Delacorte 2011
Marana	CA-INY-5888	2	STR-1	680–490 B.P.	3	0.2	Basgall and Delacorte 2011
Marana	CA-INY-5888	2	BLK F near STR	–	1	0.3	Basgall and Delacorte 2011
Marana	CA-INY-1384/H	6	STR 13	360+/–40 B.P.	1	0.1	Basgall and Delacorte 2012
Marana	CA-INY-30	–	STR 9	180+/–60 B.P.	6	0.4	Basgall and McGuire 1988
Marana	CA-INY-1384/H	10	Probable STR	Statistically modern	66	4.3	Basgall et al. 2003
Marana	CA-INY-1384/H	10	Midden	–	1	0.5	Basgall et al. 2003
Historic	CA-INY-1384/H	9	Fandango	–	1	1/8" screen	Basgall et al. 2003
Mixed	CA-INY-4547	–	Midden	–	1	0.1	Wickstrom et al. 1993

STR = Structure

three sites, INY-30, INY-1384/H, and INY-5888, and the single occurrence from INY-4547 comes from a mixed late midden, so this sample cannot be securely assigned to a time period (Table 9).

Late Newberry Taboose. The earliest time band with *taboose* macrofossils and starch on artifacts occurs at a 2 sigma calibration between 2,300 and 1,300 B.P. during the last half of the Newberry Period (Table 8). The data in the table reflect the combined sample volume for each house. Almost half (41%) of all the Newberry structures at these two sites contain *taboose* and are located near very productive wetlands, with most (90%) also containing very low densities of pinyon nutshell. All of the *taboose* in the Late Newberry is found inside houses, where it was presumably stored for winter. Pinyon nuts were another important storable winter staple food, but they do not appear to have been collected in large quantities and stored, because the density of nutshell is very low in all samples (except in one feature from CA-INY-30).

Haiwee Period (1,350–650 B.P.). To date, there is no evidence of *taboose* macrofossils in the Hawiee Period. This period lies between the two time bands with *taboose* (Table 7).

Marana Period Taboose *Patterns*. There are nine Marana Period contexts with *taboose* macrofossils. Of these, two thirds are from within houses, one was adjacent to a structure that also had *taboose*, one was in a midden, and one is from a historic-era feature (Table 9). While *taboose* is still strongly associated with houses in this period, it is found in a broader range of contexts than in the Late Newberry. Densities of *taboose* macrofossils are also more variable in the later period. No starch samples from this period were examined.

DISCUSSION AND INTERPRETATIONS

Certain classes of foods like pinyon nuts and small seeds show strong patterns through time in the macrofossil data (Table 5). These patterns have been used to help interpret subsistence-settlement shifts (Basgall and Delacorte 2012; Pierce 2002, 2003). The progression from broad based, but not intensive, to targeted mass-capture strategies involving pinyon and other resources in the Haiwee, followed by a shift back to broad spectrum collecting with the addition of small seed intensification, is the archaeobotanical backdrop for interpreting the role of the potential irrigated taxa.

Before archaeological evidence of *taboose* was discovered, the lack of data combined with the historic-era accounts of irrigation made it appear that both the irrigation and the use of these particular root crops occurred at a very late point in time and were not well established or prevalent enough to produce an archaeological pattern (Pierce in Basgall et al. 2003). The first contexts with *taboose* were dated to the late prehistoric period (Marana, 650 B.P. to 0 B.P.) and appeared to be consistent with that interpretation. However, as increasing numbers of *taboose* tubers were found during subsequent work, the temporal and contextual distribution of the tubers patterned in a distinctive way (Table 7).

Cyperus esculentus and *Dichelostemma* sp. were both used in the late Newberry Period, and *Cyperus* tubers also appear to have been used as a stored food source at that time. The data also show that *Cyperus esculentus* tubers were used and stored in the Marana Period as well. While there are 19 contexts with flotation samples from 17 sites dating to the Haiwee Period in the dataset, there are no carbonized *Cyperus* macrofossils. The absence of *taboose* macrofossils could be due to sampling error since structures and clean Haiwee deposits are the least numerous contexts in the archaeobotanical dataset. However, there is clearly a change in the subsistence-settlement pattern at this time away from winter camps on the valley floor that appears to account for this absence.

Our interpretation of this lack of macrofossils is that the tubers were not being stored for most of the Haiwee Period, and if they were, they were not stored at valley sites. If they were collected and eaten raw during this time band, there should be starch residues present on groundstone artifacts, but no carbonized macrofossils. Perhaps future starch residue analysis will reveal Haiwee Period *taboose* data. For now, there are two sites, INY-1384/H and INY-30, where *taboose* is present in the Newberry and Marana periods, and the four Haiwee contexts with macrofossil data from those two sites lack *taboose*, and it is lacking from other Haiwee deposits with archaeobotanical data.

The question of why it was apparently not stored during this temporal period when it was evidently stored before and after appears to be related to shifts in settlement location and subsistence strategies. Around 1,350 B.P. there was a significant change in subsistence-settlement patterns; the most notable was the change to a fall pinyon collection strategy that led to a change in winter camp locations, which presumably were nearer pinyon caches and further up the sides of the valley away from the Owens River (Fowler and Liljeblad 1986; Steward 1933, 1938).

It is hypothesized here that the concentration on pinyon collection created a scheduling conflict with *taboose* collection in the valley, in that relocation off the valley bottom for the fall pinyon harvest effectively cut people off from collecting *taboose* in the lowlands. Because Haiwee foragers targeted pinyon at the expense of *taboose*, macrofossil evidence of *taboose* is not seen again in valley sites until the Marana Period. It is possible that *taboose* was still collected and stored if it was found in the vicinity of the pinyon harvest, but the existing macrofossil dataset is too spatially constrained to test that.

If *taboose* was not stored in the Haiwee Period, why—if the Newberry broad-spectrum strategy was successful and *taboose* was energetically equivalent to pinyon—did the subsistence strategy change to favor pinyon? The answer may be that as population grew, the wetland resource tract was simply not large enough to handle the population increase. The simplest way to resolve the problem was to move to an area with higher storable crop yields.

In the Marana Period, subsistence and settlement patterns changed again, and continued to change within the period, as shown most notably by the dramatic increase in seed and nutshell frequencies in the valley. Some scholars assert that a time-saving and yield-maximizing process called green-cone procurement was incorporated at this time (Eerkens et al. 2004). Green-cone procurement involved harvesting the cones before the scales opened naturally and distributed the nuts. This method allowed closed cones to be stored in large caches or dried and heated to open the scales for immediate use. Once this strategy was established, scheduling the harvest was much more predictable, freeing time up for other pursuits. This change would have eliminated the scheduling conflict with the *taboose* harvest, and allowed an earlier return to the valley floor.

This is especially evident during the last 200 years of the Marana Period, when mass processing methods, another higher labor- and higher yield-per-area system, became increasingly common. The practice was similar in concept to green-cone, in that mass collection and processing involved removing a substantial part of a plant's biomass by cutting, hand-stripping, or up-rooting the whole plant. This method captures considerably greater quantities of seeds, but large amounts of inedible vegetal material then have to be processed to obtain the seeds. This makes large-scale drying, threshing, winnowing, and sometimes flash-burning necessary.

The Evolution of Resource Tract Use Leading to Niche Modification

Late Newberry sites near productive wetlands appear to mark the beginning of a cycle of successful strategies that involved storage of key resources over winter and repeated seasonal occupation of the same productive resource tract. This success resulted in population growth, necessitating subsequent changes in foraging practices in response. Some would argue that the environment was driving the change in subsistence practices, but several studies in this region have specifically examined this issue and concluded that population growth was the main driver of change in the Owens Valley (Bettinger 1978, 2015; Bouey 1979; Delacorte 1991; Polson 2009). Smith, in his Cultural Niche Construction Theory (2012, 2015), argues that no environmental or population pressure was necessary to induce intensive wild plant management practices. We would agree that wild plant management is practiced at present without pressure from environmental or population factors and may have been in the past, but the archaeological evidence in the Owens Valley demonstrates that subsistence practices were moving along a trajectory of intensification and that population was rising. It appears that these were the main factors behind the innovation of dam and ditch irrigation in the Owens Valley case.

At Euroamerican contact, the native Paiute were using mass collection and processing techniques in both the pinyon and valley seed tracts. It makes sense that they would also have modified and enhanced the wetland resource tract through irrigation. Irrigation fits into this backdrop perfectly. Irrigation purposefully modified the environment to maximize yields of wetland root crops by creating larger, more homogeneous patches. It also encouraged the spread of *taboose* and *nahavita*, increasing plant density, and encouraged the expansion of other economically important wetland crops. While according to Steward these root crops were the focus of irrigation, they were not individually selected at the expense of other plants; it was the whole niche that was enlarged and enhanced.

Conclusions and Further Questions

Given the backdrop of a gradual maximization of all resources and of expanding population sizes, modification by irrigation in order to maximize returns by enlarging the resource niche for important root crops and wetland plants probably began sometime during the Marana Period. Since *Cyperus esculentus* had been a storable and highly ranked resource like pinyon since the Late Newberry, niche modification through irrigation was a logical next step.

This research opens new lines of inquiry. While we did positively identify *Dichelostemma* sp. (blue dicks) starch archaeologically for the first time, it still has not been demonstrated unequivocally to be the irrigated crop plant *nahavita* described by Steward. *Eleocharis quinqueflora*, another root crop similar in habit to *Cyperus esculentus*, should garner more study, whether it is *nahavita* or not. *Eleocharis* was collected and identified as such during Steward's research, and it is a starch-producing plant. It should be identifiable on artifacts through starch grain analysis.

The social evolution of irrigation is another avenue of research. By the time of Euroamerican contact, irrigation was a community endeavor, like rabbit drives. However, plant resources were generally privately owned, as illustrated by the fact that mass seed collection and processing was done by individuals or family groups. It is conceivable that irrigation also began with small privately-held irrigated plots, and then grew to become a community endeavor. Since water is a valuable commodity in arid locations, privatization of the water supply by independent "farmers" may have been viewed negatively and a communal solution may have arisen. The process by which irrigation arose would also potentially have affected the amount of labor involved with the inception of irrigation. If it arose gradually from small plots and small diversions to larger, more extensive areas with much longer ditches, the labor expenditure may not have seemed great. On the other hand, if it began as a large-scale community endeavor, it would have been very labor intensive to build a large and extensive system from scratch.

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