Extracting Salt from *Distichlis spicata*: Continued Investigations into Methods of Salt Extraction and Salt Utilization in Prehistoric California

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*This article expands on previous actualistic studies conducted on the extraction of salt from salt grass (*Distichlis spicata*), the results of which were presented at the 2015 Society for California Archaeology annual meeting in Redding. The goal of this article is to summarize previous research on prehistoric salt extraction techniques, add new findings from continued actualistic experimentation, and put these findings into a contextual discussion about the prehistoric use of salt in California.*

This article expands on actualistic studies conducted on the extraction of salt from salt grass (*Distichlis spicata*), the results of which were presented at the 2015 SCA meeting. I discuss first the importance of salt among hunter-gatherers globally, then turn to the Americas, and finally settle on the role of salt in California. I then discuss ongoing research on salt extraction from salt grass. Finally, the results of the actualistic studies are incorporated into an analysis of ethnographic accounts of salt extraction from plants in California and the potential to detect, in the archaeological record, signs of salt extraction from salt grass.

BACKGROUND

The Global Importance of Salt

Salt is an essential mineral which has been utilized by many populations worldwide, both medicinally and ritually, and its importance is emphasized by its appearance globally in taboos and rituals (Hathaway 2008; Kurlansky 2002). Salt has been offered as part of sacrifices by the ancient Greeks and Romans, is associated with truth and wisdom in the Catholic Church, and is used in traditional Japanese theater to ward off evil spirits (Kurlansky 2002). In Jewish and Muslim culture, salt protects against the evil eye. Salt springs were considered by the ancient Maya (and modern Maya) to be sacred places (Andrews 1983). Salt was used in witchcraft rituals by both the Lowland and Highland Maya. Among the Zinacantecos of highland Chiapas, saltwater is sprinkled around the inside of a house shortly after a birth or death (Andrews 1983). Salt was also used by the Maya for healing, and in California, salt was used medicinally by the Sierra Miwok to relieve stomachaches and by the Patwin to cure colds. Salt taboos also existed among several Californian Native tribes (Heizer 1958; Kroeber 1941).

Non-Plant-Based Salt Extraction Techniques

Salt has prehistorically and historically been extracted from a variety of sources, including rocks, saline waters (such as salt springs), saline or nonsaline plants, and saline soils. During the Iron age, in Sielle, France, salty brine was procured and boiled in *briquetage*, or ceramic pots, to obtain salt (Riddiford et al. 2012). Evidence indicates that salt extraction was likely occurring in Europe on a large scale by the Neolithic era (Riddiford et al. 2012; Weller 2015; Weller and Dumitroaia 2005). As early as 2500 B.C. in Japan, salt was being extracted in the same way (Kawashima 2015).

In eastern North America, the Mississippian culture (A.D. 700-contact) procured salt from salt springs, mineral salt deposits in caves, and boiling brine in pots. As Brown (1981) describes, salt pans were placed within depressions in the ground, then brine was carried from a spring and poured into the pans, followed by heated stones from nearby fires. After the water evaporated, crystallized salt would then be scraped from the bottom of the containers.

Salt extraction methods in Mesoamerica echo methodologies seen elsewhere globally. Since there were no natural salt mines or mounds within the Maya Lowlands, the Maya produced salt by the *sal solar* and *sal cocida* methods. The method for obtaining salt by boiling brine is known as *sal cocida*, while the method for obtaining salt by evaporating seawater is known as *sal solar*. The *sal cocida* method, like the method previously described as utilized in Iron-age Europe, consists of using ceramic pots to boil brine, which leaves a salty cake. The brine was often pretreated by using *sal solar* methods or by passing the brine through salty earth to soak up additional sodium prior to using the *sal cocida* method. The *sal solar* method seems to have predominated in the Yucatan region. In the Maya lowlands along the Belizean coast, evidence for the *sal cocida* method abounds at sites like Stingray Lagoon, Killer Bee, Orlando's Jewfish, and David Westby, and at Paynes Creek National Park in Belize (McKillop 1995, 2002, 2005; Watson et al. 2013).

Plant-based Salt Production and Extraction Techniques

In addition to other means of extraction, obtaining salt from plants is and has been a global practice. The inland Maya burned palms (*Sabal mayarum* and *Cryosophila argentea*) to obtain salt (Andrews 1983, 1984; Marcus 1983; McKillop 1996). Palms have also been exploited for salt in North and South America and in West Africa (Andrews 1983). Grasses and other plants were also burned, the resultant ashes were soaked in brine, and then salt was obtained following evaporation. Likewise, in North America, burning various plants for salt was not unknown. Driver and Massey (1957) note that salt was obtained from plants or salty ash from the burning of plants in the Southeast and Southwest regions of North America.

In modern New Guinea, salt is extracted from plants which have been steeped in brine from salt springs (Gouletquer and Weller 2015; Petrequin et al. 1999). The first of many steps includes taking the young shoots of long plants with porous structures (such as *Elatostema macrophylla* Brogn. of the Urticaceae family) and soaking them in the salt spring brine. While the plants soak, leaves and bark are gathered in which to wrap the salt. After soaking for three or four days, firewood is used to build a square pyre and is set alight. The rolls of Urticaceae are untied and stacked on the pyre, where the fire will be kept going from the afternoon until the morning of the next day. The result is a large pile of charcoal, ashes, and salt concretions. The salt is picked out and placed on a large wooden platter, then pressed into a rectangular mold, kneaded with brine, compressed, and wrapped. The salt is further dried over a hearth for a week, which forms a "salt stone" or compact block of salt. The Witoto Indians of northwest Amazonia also produce ash salts from burning palms (Echeverri and Roman-Jitjutjano 2011). The process is similar to other methods of obtaining salt from palms. Various plant material sources are burned, the resulting ashes are filtered out or removed, and the brine is dehydrated to obtain salt.

Ethnographic Overview of Salt Extracted from Plants in California

Ethnographic and linguistic evidence indicates that salt was important to prehistoric groups in California, as in other parts of the world. Native groups in California extracted salt as others have done globally: from salt springs, saline soil, rock salt, and saline and nonsaline plants. Salt was valued by Native Californians, a point emphasized by its importance as a trade item. Davis's (1961) essential paper on trade in California lists salt as the number one trade item. Of the 35 native groups listed by Davis, all either supplied or received salt from other groups, and 11 of the groups both supplied and received salt from different sources (see Figure 1). For example, the Western Mono supplied rock salt and the Tule-Kaweah Yokuts supplied salt from salt grass to the Eastern Mono.

Many California tribes extracted salt from plants. (See Table 1 below for a summary of some Central Valley/Sierra Nevada salt sources from the ethnographic literature.) As indicated by Davis and others, salt was rarely acquired from a single source. Various plants were burned to create salty ashes, but

Figure 1. Map adapted from Davis (1961) depicting salt exchange trade routes (produced by Aislynn Davids, 2015).

in some cases, the salty plants were either threshed to remove any salty residue or were eaten raw or with clover.

Barrett and Gifford's (1933) account of the Miwok discusses how salt was obtained from the saline ashes of a species of Umbelliferae, which was obtained from the marshes of the San Joaquin River. The grass was piled and burned, and the saline constituents accumulated in a hard, glassy cake at the bottom of the fire. The wind soon blew the ashes away and the cake was broken for use. Another Miwok account notes that a type of nonsaline grass was soaked in brackish water and then burned. According to Chesnut (1902), Round Valley groups utilized the leaves of *Mimulus guttatus*, of the figwort family, as a source of salt. The Yuki used the ashes of *Petasites palmatus* (thistle family) by rolling the stem and leaves into balls while still green, drying them out, and then burning them on top of a small fire on a rock.

Kroeber's 1929 account of the Nisenan notes that "salt was either dug from the ground or cooked from a plant with cabbage-like leaves in the summer" (Kroeber 1929:262) The leaves were piled on a fire in a pot, in which the salt collected in a cake so hard that it had to be broken with a stone. The Yokuts collected salt from a "salty grass" and extracted the salt by beating it on stones (Kroeber 1925:530). The Southern Miwok were noted as owning a salt spring called "the Salts" (Aginsky 1943). Salt was said to accumulate on top of the salty spring, and it was then gathered in baskets. Once a fire had been built over

Table 1. Summary of Central Valley and Sierra Nevada region ethnographic salt sources (non-exhaustive).

TRIBE	LOCATION	SALT SOURCES	REFERENCES
(Valley) Nisenan	Sacramento Valley	Obtained from the ground and cooked from a plant with cabbage	Kroeber 1929
Miwok	Sierra Nevada	Springs (*ko'yo*), rarer than from plants; saline lakes; certain plants (*wi'skoyo*); saline ashes obtained from Umbelliferae (*he'mpa* and *toko'pu*), grass piled and burned	Barrett and Gifford 1933; Kroeber 1929
Western (Northfork) Mono	San Joaquin River drainage	Salt springs	Gifford 1932
(River) Patwin	Sacramento Valley	From salt grass (*wel*) found on the plains	Kroeber 1925, 1932; McKern 1922
(Hill) Patwin	Sacramento Valley	From stones in certain creeks in the Cortina region; for northern Hill Patwin, from great deposit in Salt Pomo territory	Kroeber (1932)
Nomlaki	Sacramento Valley	From beds near Newville and Elder Creek (*wel*); collected from banks of running streams in midsummer, then scraped and dried on hot stones	Goldschmidt 1951
Groups north of Tehachapi / Western Mono	Southern Central Valley; Fresno	Roasting and burning salt grass; grasses which collect salt are cut, laid on flat surface and beaten with a stick to dislodge salt; rock salt deposits	Gayton 1948a; Heizer 1958
Yokuts, Western Mono	Southern Sierra Nevada	Rock salt; salt grass	Driver 1937
Yana	Northern Sacramento Valley	Rock salt; brackish mud	Sapir and Spier 1943
Owens Valley Paiute	Owens Valley	Saline soils; salty brush	Steward 1933
Washo	Northern Sierra Nevada; Lake Tahoe	Traveled south to Antelope Valley for salt	Price 1980

a pit, grass was put on the fire, and the salt was poured on the grass. The salt melted and accumulated in the pit. It was said to be as hard as a rock and was regarded as "special salt." Aginsky also noted specifically that the Central Miwok gathered salt and cooked it in one day. Grass was placed around it, and it was burned in a large fire which was allowed to die out. Salt was taken out in the form of a large mass.

Distichlis spicata and Salt Extraction Techniques in the California Ethnographic Record

Salt grass, or *Distichlis spicata*, was used by numerous Central Valley groups for the procurement of salt. The modern distribution of *Distichlis spicata* is pervasive throughout the Central Valley, although it can also be found in coastal areas, such as estuaries and along dunes, and is found in 43 states (U.S. Department of Agriculture 2014). It is a native perennial whose height ranges from 15 to 35 in. It can survive in both freshwater and saltwater areas where the water table ranges from between 6 and 2 in. below the surface. Salt grass is of the Poaceae, or grass family, and is propagated by seeds which are then distributed via wind or rain, or by underground rhizomes. It can form dense mats and tends to dominate areas in which it grows. Salt grass flowers from June through October and is one of the most drought-tolerant plants in the West. It also can survive complete inundation (Calflora 2014).

Kroeber's 1941 study "Culture Element Distributions: XV Salt, Dogs, Tobacco" indicates that salt grass burning prevailed throughout the Central Valley: out of 12 Yokuts tribes, 11 burned salt grass. It was the same case with five out of seven Western Mono tribes, five out of eight Miwok tribes, and three out of six Maidu-Nisenan groups (cf. Kroeber 1925). Kroeber also notes that some cases exist outside of the Central Valley, including two groups in the Russian River drainage, three in the Eel, and one on the lower Klamath. Most accounts list roasting, while some note threshing, or beating and scraping salt off of vegetation, as a means of extracting salt. Kroeber believed that burning salt grass to extract salt was a

Figure 2. Yokuts salt sifting basket (drawing by Aislynn Davids, 2015).

supplementary method used in addition to other sources of salt, and was largely a method chosen as a direct result of the environment.

Ethnographic accounts give varying reports as to how the grass was gathered and the salt extracted. The Tūbatulabal (Voegelin 1938) obtained salt from salt grass by cutting the grass in dry weather and laying it out on mats to dry out in the sun. The grass was then flayed vigorously with hardwood stick beaters. The salt grains would stick to the mats or skins. The collected crystals were then formed into balls.

> Chunks of dry salt would then be broken off from the balls or flat cakes and dissolved in a cup of water. The salty water was then used for refreshment or for rinsing out the stomach. Fresh salt grass was also soaked in water and this water sprinkled over raw chopped clover, or sprigs of salt grass and clover were rolled and eaten. The salt from salt grass was never used to season meat or mushes [Voegelin 1938:19].

Other central Sierra Native Californian tribes noted as utilizing salt obtained from burning salt grass include the Yokuts, Mono of the North Fork of the San Joaquin River, Central Miwok, Northern Miwok, and Plains Miwok (Aginsky 1943). Driver also listed the Mono, Yokuts, and Tūbatulabal as burning salt grass for salt (Driver 1937).

Gayton's 1948 ethnography of the Yokuts and Western Mono describes the Yokuts as gathering a marsh grass and placing it over coals. Once reduced to ashes, the process would be repeated, taking two nights and a day. The Chukchansi were said to procure a salt called *alit* from salt grass. The salt grass was gathered, then dried on flat rocks and pounded in a mortar hole. Following this step, it was winnowed using a circular tray which separated the salt from the grass (Figure 2). The resulting salt was then "dampened and pressed into balls … the balls were broken as needed for use. The salt was consumed with clover and sour berries. Rock salt was used if this was not obtainable" (Gayton 1948:181). Within the Eshom Valley region (Michahai and Waksachi*)*, salt grass was burned in a pit which measured 2 ft. long by 1 ft. wide by 1 ft. deep (Figure 3). A fire was built in the pit which was burned down to coals. A grating of hardwood sticks was laid across the earth surface, and the plants were laid on the grating. The fire was fanned with a fire fan. The material oozed out of the plants and dropped on the coals, forming lumps. It was then covered and left overnight. In the morning, the pit was opened and the salt, which was now a hard large mass, was cleaned of dirt. The lumps were trimmed and sold. Although never put

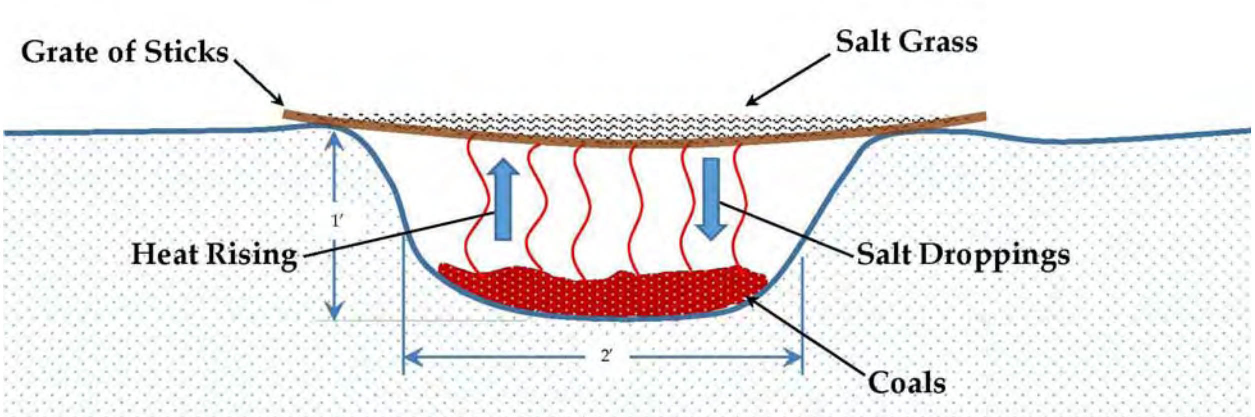

Figure 2. Salt grass roasting pit, as conceptualized from ethnographic accounts (drawing by R. Heath Browning, 2014).

directly on food, it was used with meat and to cure nausea (Gayton 1948). The Western Mono (Wobonuch and Entimbich) were said to obtain salt from rock salt and from salt grass which was black and burned in lumps (Gayton 1948).

Kroeber's ethnography of the Patwin notes that salt grass (*wel*) was also roasted:

> A fire was built in a hole a foot and a half deep. Heavy sticks were laid on it, then a pile of grass. Soon the salt "melted" and could be heard dripping. The one who looked in said "Stop" – by this time the wood had burned through. After several hours of cooling, a large, hard, blackish cake was taken out and broken to divide. It was kept to be ground as needed. Its taste was said not be like "modern" salt [Kroeber 1932:280].

McKern (1922) notes that the Patwin had special trade families whose function was to burn salt grass. A pit was dug, and dried salt grass, mixed with salmon vertebrae, was piled above it. Fire was applied, and as the mixture burned, the natural tar from the plant and the salt with which it was crusted accumulated in the pit. The result was a hard gray-black material, soluble in hot water and very salty to the taste. It was used sparingly for seasoning food (McKern 1922:249). Ethnographic accounts describe the Nomlaki as obtaining salt from salt springs and mineral deposits. These accounts describe the Colusa obtaining salt by burning salt grass over a straw fire until the salt dripped down and formed hard lumps like glass; obtaining salt using this method was a special technique that no one else knew (Goldschmidt 1951).

A modern informant has noted one other technique for extracting salt from salt grass: soaking the salt grass in water and using the resulting salty water for cooking (Beverly Ogle, personal communication 2015).

SALT AND THE ARCHAEOLOGICAL RECORD

As noted by many others, salt is incredibly hard to trace archaeologically, due to its intangible nature. Adshead stated, "As an object of archaeology, salt leaves evidence fairly abundant for its production, and scarce for its consumption" (Adshead 1992:4). This statement is even truer in prehistoric California. As noted earlier, the evidence of salt production globally is often ceramic pots or fragments of *briquetage* used to boil brine and manufacture salt. As salt does not preserve, the archaeologist must use other methods to discern its use and place of procurement/extraction. Others have attempted assessing possible soil signatures of salt production, such as stratigraphy, paleoenvironmental evidence which may have helped conditions for salt production, and analysis of the physical characteristics of ceramic

Table 2. Results of experiments gathering and roasting salt grass.

EXPERIMENT	TIME SPENT GATHERING (HOURS)	AMOUNT GATHERED, CONDITION	AMOUNT ROASTED	TIME ROASTING (HOURS)	TEMPER-ATURE	RESULT
1	0.50	1,000 g partially dry	950 g	1.5	--	533 g (not caked)
2	--	1,973 g fresh; 1,677 g partially dried; 1,155 g dried	294 g fresh; 259 g partially dried; 152 g dried	5.0	--	No salt cakes; some black flecking noted on fresh grass grate
3	0.50	6,128 g	2,000 g	9.0	340- 380°F	Grass smoked but did not combust; no salt cakes; some black flecking on one grate; halted early due to fire

fragments (McKillop 2002; Murata 2011; Petrequin et al. 1999; Riddiford et al. 2012; Schrimpff 2015; Weller 2015; etc.).

A series of experiments were carried out in order to discern salt in the archaeological record through other methods, by attempting to replicate salt grass roasting and determining if this act leaves a material signature.

EXPERIMENT 1

The goal of the first experiment was to discern the ease with which salt could be extracted from salt grass using the roasting method and to assess the concentration of any resulting salt. In order to complete our initial study, we first had to identify likely spots where salt grass could be harvested. The plant grows throughout Solano and Sacramento Counties. Salt grass is extremely easy to harvest, and a relatively large amount was procured quickly. This appeared to be true regardless of season. On average, it took one person one-half hour to harvest salt grass from a 7-x-6-m area. A half hour's labor consistently yielded approximately 900-1,000 g of salt grass (Table 2).

Once collected, the salt grass was stored in gallon-size plastic freezer bags. The initial roasting experiment was conducted within seven days of harvesting. The grass was partially dry at this point, having been harvested in a 50 percent desiccated state. Approximately 950 g of salt grass was burned in a commercial metal fire pit using an entire standard-sized bag of Kingsford charcoal briquettes. Once placed on the grate, the salt grass immediately gave off thick and pungent smoke and then almost instantly charred and calcined. About 250 g was placed on the grating at once, and as soon as this burned down, another 250-300 g was added. The fire reached at least 400°F. After 1.5 hours, all 950 g of the grass had been reduced to a fine ash, interspersed with blackened organic particulates. The salt grass did not appear to have exuded a tar. Likewise, the resulting ash mixture in the bottom of the fire pit lacked any black "cakes" or lumps. The ash had a faint salty taste. After 12 hours, the ash was still too hot to collect. The resulting ashy mixture from this first initial experiment weighed approximately 533 g.

In the next stage of this experiment, the salt content of the ashy mixture was assessed. The method chosen involved adding water to the ashy mixture, screening out particulates and solids, and boiling until only the salt remained. First, the mixture was rinsed with distilled water through a fine-grained sieve to remove particulates. The sample was then placed in a steel 8-qt. stockpot, and additional distilled water was added. The pot was placed on a burner that was turned on high. The water was boiled until evaporation had been achieved—approximately 1.5 hours. The result was a thick black sludge 1 cm thick, caked on the bottom of the pot. When sampled, the sludge was definitely salty. This wet mixture weighed 58 g. After several days, the sample had dried out and decreased to a weight of 39 g.

A second experiment was initiated using another 50 g of the ashy mixture. The same process as before was followed, with the addition of deionized water and cheesecloth. The result was a very thin, light gray caking on the bottom of the pot, which was estimated to weigh 12 g. Due to the consistency of this mixture, only 6 g could be scraped off the bottom of the pot. The mixture tasted faintly of salt but was nowhere near as strong as the first attempt. Future experiments will use less water and a less fine-grained mesh for screening out particulates.

EXPERIMENT 2

The next experiment focused on the condition of the grass, and whether this had any bearing on the result. To this end, the salt grass was harvested in three different conditions: 1,973 g of fresh green salt grass, 1,677 g of partially dried salt grass, and 1,155 g of dried salt grass were collected (Table 2).

To more closely mirror the ethnographic accounts, three pits which were approximately 2 x 1 x 1 ft. in size were excavated using shovels and a railroad pick. Instead of Kingsford charcoal briquettes, lump charcoal was placed in the bottom of each pit (one-half bag per pit) and started using a chimney starter. The resulting coals were placed in the pit. After about 10 minutes, a latticework was laid on each pit. Between 250 and 300 g of grass was placed on the latticework of each pit: 294 g of fresh grass was placed on the first pit, 259 g of partially dried grass on the second pit, and 152 g of dried grass on the third. The fresh grass did make a sizzling sound when first laid on the grate, but afterwards was silent. Although all three pits seemed to burn fairly hot, they cooled off quickly. Several handfuls of Kingsford charcoal briquettes were added to the bottom of each pit to maintain a consistent temperature.

After five hours, very little had changed, aside from the fresh grass drying out. No black tar or residue had exuded from the salt grass and dripped onto the coals in any of the pits. Ethnographic accounts are unclear as to whether the hardwood latticework was supposed to burn and fall into the pit or if it was manually placed into the pit (Kroeber 1932; McKern 1922). Two accounts also noted that the pit was covered with earth at a certain point (Gayton 1948; Heizer 1958). As no change had been noted, the decision was made to place the latticework in the pits and cover with soil. The fresh grass remained unchanged, although flecks of black residue were noted on several pieces of the wood lattice. The residue was salty to taste. After the resized latticework had been placed into the pit, the partially dried salt grass smoked and caught flame and was soon incinerated, and the dried grass caught on fire almost immediately. Finally, each pit was covered with soil, with the intent of leaving it overnight and investigating it the next morning.

The next morning, the pits were still too hot to examine, and the following evening brought rain. In the end, covering the pits had no effect. The soil had effectively insulated the fire and smothered it. No blackened cakes or lumps were noted within the ashes. Although we were not able to extract salt from the salt grass in the form of a cake, a minimal amount of salty black reside had accumulated on the wood lattice. Results from this experiment indicated that the next experiment should entail gathering a larger amount of grass, keeping a consistent fire going, and weaving a tightly woven latticework on which to place the grass. If a large volume of grass was continuously placed on the latticework and left to smoke, over time a greater accumulation of salty residue would result.

EXPERIMENT 3

In this experiment, the goal was to further explore gathering, seasonality, and temperature regulation during the roasting process. Partially dry salt grass was gathered in Solano and Sacramento Counties. The grass was harvested by plucking near the base of each grass stem and placing it in either a plastic zip lock bag or in a paper bag. In total, 6,128 g was gathered on a total of seven different gathering trips (Table 2).

Utilizing the common measurements given in the ethnographic accounts, two earthen pits were dug using a shovel and rail pick. They measured 2 ft. long by 1 ft. wide by 1 ft. deep. A latticework of hardwood sticks was created. A burn pile was constantly fed with oak and pine branches and logs. The burn pile was used to generate coals for both pits throughout the process.

In total, the salt grass was roasted for nine hours. A digital thermometer was used to check the temperature of the fire every 15-20 minutes. After observing the salt grass and fire interaction, it became evident that the salt grass would combust if the temperature of the fire was increased to 400°F. If the temperature stayed between 340° and 380°F, the grass made a noticeable sizzling sound but did not combust. To maintain this temperature, fresh coals had to be added every 20 to 30 minutes. After the grate on one of the pits caught fire, it was modified to ensure that only half the pit was covered. This made it much easier to continue to add coals to the pit by not having to lift the entire grate off the pit every time. It was not until the temperature fluctuation was somewhat controlled, or between 340° and 380°F, that the salt grass dried out at a significant rate. If the fire dropped lower than 340°F, the grass would take hours to dry out. Throughout the process, dried grass was removed and fresh grass was added, making sure to leave gaps for oxygen flow. Removing half of the grate presumably also led to better oxygen flow. In order to reduce the chances of the grass igniting, an experiment was also conducted on one pit, wherein the salt grass was evenly soaked in collected rainwater and then put on the grate. The grass then more effectively smoked and did not ignite as easily.

Ultimately, salt was not extracted from the salt grass, although a possible salty residue (black flecking) was noticed on one of the grates. The experiment was halted on both grates when the temperature fluctuated too much and the salt grass and grate caught on fire. Despite the lack of salt extracted from the salt grass, knowledge was gained regarding fire pit temperature, maintenance, and labor. In order to keep the salt grass from completely combusting, the temperature needed to be maintained between 340° and 380°F. Importantly, the act of generating coals, keeping the fire going in the pits, and adding additional grass was easier with two people.

DISCUSSION

The purpose of the series of experiments conducted is to successfully replicate salt grass roasting as described in the ethnographic literature in order to extract salt. Once this has been accomplished, the associated archaeological signature (depositional context) will be identified.

The salt grass roasting techniques utilized for Experiments 2 and 3 have utilized information from several ethnographic accounts (Gayton 1948; Goldschmidt 1951; Kroeber 1932; McKern 1922). Experiments so far have focused on several components: 1) time and effort to gather the salt grass; 2) salt concentration of the resulting ash; 3) quantity, condition, and seasonality of the salt grass; 4) temperature of the fire during the roasting process; and 5) level of effort to roast the salt grass. As a result of the experiments, we have determined that the act of gathering salt grass would not have been labor-intensive, excluding any travel cost to get to a good patch. We have also learned that seasonality likely has a bearing on possible salt yield from the roasting process. Additional observations have been made on maintaining a consistent temperature without completely incinerating the salt grass, and on the overall labor necessary to roast salt grass and maintain a consistent temperature.

FUTURE STUDY

Continued work on this study will need to include additional research and continued correspondence with members of the Native American community who are willing to share their knowledge of salt grass and salt grass roasting. Experimentation will continue in order to replicate processing techniques found in the ethnographic literature, including additional investigations into seasonality, salt gathering methodology, salt roasting techniques, and quantitative methods to measure the resulting salt concentration.

After a definite archaeological signature is identified, future analysis will include phytolith studies, soil and charcoal analysis, and paleoenvironmental studies.

ACKNOWEDGEMENTS

I have received a lot of help throughout this process, both from my colleagues at Cardno and others. I appreciate all of the help that I have received. I would especially like to thank the following individuals: Joshua Peabody, for all of his help, advice and guidance throughout this process (and for the use of his yard for several salt grass roasting experiments); Beverly Ogle, for her insight and knowledge; Mark Hicks, for his help with Experiment 3, including the use of his yard for salt grass roasting; Aislynn Davids and R. Heath Browning, for their advice and assistance with figures; Erik Allen, for his help throughout this project; Bonnie Peterson, for helping out in all things *Distichlis spicata*, including conducting recon in order to find the best salt grass spots; Mark Castro for sharing information from his treasure trove on salt in prehistoric California; and Darren Andolina, Garret Root, and Carly Whelan, for their advice and helpful criticism.

REFERENCES CITED

Adshead, Samuel Adrian M.
1992 *Salt and Civilization*. St. Martin's Press, New York.

Aginsky, Bernard Willard
1943 Culture Element Distribution: XXIV Central Sierra. *Anthropological Records* 8:392-468. University of California Press, Berkeley.

Andrews, Anthony P.
1983 *Maya Salt Production and Trade*. University of Arizona Press, Tucson.
1984 Long-Distance Exchange among the Maya: A Comment on Marcus. *American Antiquity* 49:826-28.

Barrett, Samuel Alfred, and Edward Winslow Gifford
1933 *Miwok Material Culture*. Bulletin of Milwaukee Public Museum No. 2(4). Milwaukee, Wisconsin.

Brown, Ian W.
1981 *The Role of Salt in Eastern North American Prehistory*. Louisiana Archaeological Survey and Antiquities Commission, Anthropological Study No. 3. Baton Rouge.

Calflora
2014 Taxon Report 2743: *Distichlis spicata* (L.) E. Greene, Electronic document, http://www.calflora.org/cgi-bin/species_query.cgi?where-calrecnum=2743, accessed August 25, 2014.

Chesnut, V. K.
1902 *Plants Used by the Indians of Mendocino County, California*. Contributions from the U.S. National Herbarium, Vol. 8, No. 3. U.S. Department of Agriculture, Washington, D.C.

Davis, James T.
1961 *Trade Routes and Economic Exchange among the Indians of California*. University of California Archaeological Survey No. 54. Berkeley.

Driver, Harold E.
1937 Culture Element Distributions: VI Southern Sierra Nevada. *Anthropological Records* 1:55-154. University of California Press, Berkeley.

Driver, Harold E., and William C. Massey
1957 Food Preparation and Preservation. *Transactions of the American Philosophical Society, Philadelphia, Comparative Studies of North American Indians* 47(2):245-251.

Echeverri, Juan Alvaro, and Oscar Enokakuiodo Roman-Jitjutjano
2011 Witoto Ash Salts from the Amazon. *Journal of Ethnopharmacology* 138(2):492-502.

Gayton, Anna H.
1948 Yokuts and Western Mono Ethnography. *Anthropological Records* 10:1-302. University of California Press, Berkeley.

Gifford, E. W.
1932 The Northfork Mono. *University of California Publications in American Archaeology and Ethnology* 31:15-65. Berkeley.

Goldschmidt, Walter
1951 Nomlaki Ethnography. *University of California Publications in American Archaeology and Ethnology* 42:303-443. Berkeley.

Gouletquer, Pierre, and Olivier Weller
2015 Techniques of Salt Making: From China (Yangtze River) to their World Context. In *Archaeology of Salt*, edited by Robin Brigand and Olivier Weller, pp. 13-28. Sidestone Press, Leiden, Netherlands.

Hathaway, Sarah-Jane
2008 Take it with a Pinch of Salt? Thinking about the Cultural Significance of Producing and Consuming Salt. In *Food and Drink in Archaeology I: University of Nottingham Postgraduate Conference 2007,* edited by Sera Baker, pp. 47-56. Prospect Books, Totne, England.

Heizer, Robert F.
1958 Salt in California Indian Culture. In *Salt in California*, by William Everett Ver Planck and Robert F. Heizer, pp. 103-104. California Division of Mines Bulletin No. 175. San Francisco.

Kawashima, Takamune
2015 Prehistoric Salt Production in Japan. In *Archaeology of Salt*, edited by Robin Brigand and Olivier Weller, pp. 125-138. Sidestone Press, Leiden, Netherlands.

Kroeber, A. L.
1925 *Handbook of the Indians of California*. Bureau of American Ethnology Bulletin No. 78. Washington, D.C.
1929 The Valley Nisenan. *University of California Publications in American Archaeology and Ethnology* 24:253-290. Berkeley.
1932 The Patwin and their Neighbors. *University of California Publications in American Archaeology and Ethnology* 29:253-423. Berkeley.
1941 Culture Element Distributions: XV: Salt, Dogs, Tobacco. *Anthropological Records* 6:1-20. University of California Press, Berkeley.

Kurlanksy, Mark
2002 *Salt: A World History*. Penguin Books, New York.

Marcus, Joyce
1983 Lowland Maya Archaeology at the Crossroads. *American Antiquity* 48:454-88.

McKern, W. C.
1922 Functional Families of the Patwin. *University of California Publications in American Archaeology and Ethnology* 13:235-258. Berkeley.

McKillop, Heather
1995 Underwater Archaeology, Salt Production, and Coastal Maya Trade at Singray Lagoon, Belize. *Latin American Antiquity* 6:214-228.
1996 *Prehistoric Maya Use of Native Palms: Archaeobotanical and Ethnobotanical Evidence*. In The Managed Mosaic: Ancient Maya Agriculture and Resource Use, edited by Scott L. Fedick, pp. 278-294 University of Utah Press, Salt Lake City.
2002 *Salt: White Gold of the Ancient Maya*. University Press of Florida, Gainesville.

2005 Classic Maya Workshops: Ancient Maya Salt Works in Paynes Creek National Park, Belize. *Research Reports in Belizean Archaeology* 2: 279-289.

Murata, Satoru
2011 Maya Salters, Maya Potters: The Archaeology of Multicrafting on Non-residential Mounds at Wits Cah Ak'Al, Belize. Unpublished Ph.D. dissertation, Department of Anthropology, Boston University.

Petrequin, Pierre, Olivier Weller, Emilie Gauthier, Alexa Dufraisse, and Jean-Francois Piningre
1999 Salt Springs Exploitation without Pottery during Prehistory: From New Guinea to the French Jura. In *Ethnoarchaeology and Its Transfers*, edited by Sylvie Beyries and Pierre Petrequin, pg. 37-65. BAR International Series Vol. 983. Oxford.

Price, John A.
1980 *The Washo Indians: History, Life Cycle, Religion, Technology, Economy and Modern Life*. Nevada State Museum Occasional Papers No. 4. Carson City.

Riddiford, Naomi G., Nicholas P. Branch, Christopher P. Green, Simon J. Armitage, and Laurent Olivier
2012 Holocene Paloenvironmental History and the Impact of Prehistoric Salt Production in the Seille Valley, Eastern France. *The Holocene* 22:831-845.

Sapir, Edward, and Leslie Spier
1943 Notes on the Culture of the Yana. *Anthropological Records* 3:239-297. Berkeley.

Schrimpff, Marianne Cardale
2015 Pre-Columbian Salt Production in Colombia: Searching for the Evidence. In *Archaeology of Salt*, edited by Robin Brigand and Olivier Weller, pp. 29-46. Sidestone Press, Leiden, Netherlands.

Steward, Julian
1933 Ethnography of the Owens Valley Paiute. *University of California Publications in American Archaeology and Ethnology* 33:233-350. Berkeley.

U.S. Department of Agriculture
2014 Plant (L.) Greene saltgrass, Electronic document, http://plants.usda.gov/core/profile?symbol=DISP, accessed September 1, 2014.

Voegelin, Erminie W.
1938 Tubatulabal Ethnography. *Anthropological Records* 2:1-90. University of California Press, Berkeley.

Watson, Rachel, Heather McKillop, and Elizabeth C. Sills
2013 Brine Enriching Slag Heaps or Mounded Remains of Salt Makers Homes? Earthen Mounds in the Mangroves at the Paynes Creek Salt Works. *Research Reports in Belizean Archaeology* 10:297-304.

Weller, Olivier
2015 First Salt Making in Europe: A Global Overview from Neolithic Times. In *Archaeology of Salt*, edited by Robin Brigand and Olivier Weller, pp. 67-82. Sidestone Press, Leiden, Netherlands.

Weller, Olivier, and Gheorghe Dumitroaia
2005 The Earliest Salt Production in the World: An Early Neolithic Exploitation in Poiana Slatinei-Lunca, Romania. *Antiquity* 79:1-4.