The Holocene

Plant dependency and risk management in the Andean Puna during the Mid to Late Holocene.

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Editor-in-Chief,
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Please find enclosed our manuscript entitled "Plant dependency and risk management in the Andean Puna during the Mid to Late Holocene" which is an invited contribution to the upcoming Special Issue titled "Risky Business: Comparative Approaches to Risk and Resilience in Arid Landscapes of the Holocene," for which the Guest Editors are Alison Damick, Camille Weinberg, and Emily Dawson.

Thank you for your consideration.
Sincerely,

Elizabeth L. Pintar, Ph.D.

Plant dependency and risk management in the Andean Puna during the Mid to Late Holocene

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Abstract

The archaeology of the Puna, a high elevation desert in South America, gives us a long-term perspective on the role of wild plants in people's diets during the last 10,000 years. We explore the impact of aridification on the use of edible wild plants among desert people through the study of macrobotanical remains. Our goal is to examine the variation in plant dependency and risk management strategies used over time, in particular during the drought of the Middle Holocene (7500 - 4500 BP). The macrobotanical record suggests the use of risk-averse strategies in order to cope with unpredictable resource productivity. Hunter-gatherers relied on carbohydrate rich resources from the *vega* wetlands and *tolar* shrublands, such as roots and tubers, as well as low-ranked seeds, stems, leaves and fruits. They also obtained non-local edible plants by strengthening ties and forming safety nets with groups living in different ecozones that were not subject to the same resource fluctuation. Social interaction with areas lying beyond the ecological boundaries of the Puna has a longstanding tradition in this area beginning in the Early Holocene, and was likely a means of providing food security to populations whose subsistence depended mainly on camelid hunting, and eventually camelid pastoralism. A notable increase in that interaction began during the Late Holocene, which was a period of lesser aridity, with the introduction of corn and quinoa.

KEY WORDS: Edible wild plants, Holocene, risk, drought, South Puna, hunter-gatherer subsistence strategies.

1. INTRODUCTION

Hunter-gatherer lifeways predominated in the South Puna of Northwest Argentina for at least 5000 years before domesticated animals and plants first appeared in the archaeological record after ca. 5000 BP. The ruggedness of the landscape (with a baseline elevation of 3300 masl), the low ET and the distribution of resources dependent on a decreasing E-W and N-S rainfall gradient surely had an impact on the prehistoric landscape use, subsistence and mobility of ancient hunter-gatherer groups. In this paper we follow Binford (2001) among others in arguing

there is a link between environmental variables and hunter-gatherer organization, especially risk management and decision-making strategies used by hunter-gatherers aimed at dealing with the unpredictable variability and fluctuation in the amount of food available for consumption.

Risk means the chance of not having enough food (Kelly 2013), and montane hunter-gatherers living in marginal and desert areas with patchy resources such as the South Puna should have practiced risk-averse strategies in order to cope with unpredictable resource productivity stemming from the lack of perfect information about their environment, that is not knowing exactly what the outcome of a strategy would be. Rather, they generally had complete information, which allowed them to have a high probability of success in their activities (Kelly 2013). As a result, decisions would have been based on predicting the outcome of events with a certain degree of probability, or best guesses, instead of foraging optimally. Many hunter-gatherers would have chosen to reduce the risk of failure (and returning empty-handed) by focusing on food security and ensuring minimum subsistence targets were met instead of maximizing net returns relative to labor input which involves a much higher level of risk. Hunter-gatherers would have aimed at satisfying the range of intra-group needs, and "satisficed" instead of "optimized" their goals of obtaining a secure and reliable resource base (Aldenderfer, 2006; Binford, 2001; Kelly, 1995, 2013; Morgan, 2008; Ramsey et al., 2016; Zeder, 2012).

Current hunter-gatherer subsistence models for the Puna are biased toward hunting, favoring the importance of meat in hunter-gatherer diet (Mondini and Elkin, 2006; Mondini et al., 2013; Yacobaccio, 2013; Yacobaccio et al., 2013, 2017; among others). These models are derived from the high camelid biomass in the environment, the historical and ethnohistorical record of camelid pastoralism in the area, the abundance of camelid bones in the archaeological record and the apparent lack of diversity of edible wild plants in this high elevation desert. Although this kind of hunting bias appears to be more prevalent in environments where soft evidence like plants and basketry, is not well preserved or entirely absent, such as in tropical and temperate areas with high humidity, the botanical assemblages in archaeological sites in the Puna are extremely abundant due to the exceptionally dry desert conditions that have enabled the preservation of macrobotanical plant parts like woody stems and roots, tubers, flowers, fruits, seeds, long grasses, etc.

However, despite the abundant archaeobotanical record and ethnobotanical surveys and studies showing that some fruits, resins and tubers are edible and have medicinal uses, the role of plants within risk management strategies in early hunter-gatherer subsistence has been difficult to assess given:
a) that edible parts of plants (seeds, fruits, roots) were consumed, resulting in little to no hard evidence —other than coprolites (which are rarely found), and
b) technology such as formal grinding equipment (though *ad hoc*, single-use rocks might have been preferred over formal grinding stones left at sites as site furniture) and basketry that could provide a context for processing and/or storing edible plant parts (seeds, roots) are not commonly found in hunter-gatherer sites.
For these reasons, the focus of archaeobotanical research was placed on the more obvious use of plants as fuel and for constructing well preserved features (such as bedding, carpeting or seating in habitation sites) (Rodríguez 1999, 2000).

In this paper we will first explore the archaeobotanical record for plant macrofossils in the region of Antofagasta de la Sierra, in the South Puna of Argentina (Figure 1) throughout the Early and Middle Holocene, and focus on the archaeobotanical record of plants that produce edible wild roots and tubers, stems, resins and small fruits. Then, we will discuss plant resource risk management strategies, at the local and regional scale, used to mitigate the environmental stress of the hyper arid trend of the Middle Holocene (7500 – 4500 BP).

2. ENVIRONMENT:
   a. Modern environment

The South Puna of NW Argentina is a high elevation desert where vegetation is sparse, climate is cold and average temperature is < 10 ^{o} annually. Solar radiation is high. Rainfall is estival (November to March) and averages less than 100 mm annually and potential evapotranspiration is 570 mm, resulting in a pronounced hydric deficit year-round and arid environment (Morlans 1995). Precipitation decreases in an east-west gradient, and a complete lack of rainfall over several consecutive years is common (Cabrera, 1976). Soils are immature, sandy and gravelly. The landscape is dominated by *pampas*, or undulated plateaus, that are interrupted by quebradas, or narrow gorges, rivers, and volcanoes and mountains which top 5500 masl. The basin of Lake Antofagasta (2500 km^2), where this study is centered, is endorheic and has a base level of about 3400 masl. The watershed of the Punilla river flows into this lake and comprises several permanent tributaries. These rivers transect the landscape and are bordered by high altitude wetlands (*vegas*) —vegetation carpets characterized by a dense plant cover of Poaceae and Juncaceae species, which are patches of high primary productivity with a dense groundcover. *Vegas* provide pastures for livestock, plants and wildlife, and high-quality drinking water, and are associated with human dwellings, settlements and corrals. They have a marked seasonality, with their vegetation growing in spring and summer and wilting in winter when plants allocate energy into their roots and underground storage systems. These wetlands have been highly valued for centuries by Andean cultures who have managed their moisture and promoted their expansion and productivity (Amaya et al., 2019).

From a phytogeographical standpoint, the vegetation of the Puna belongs to the Andean Dominion, which includes the Altoandean and Puneño provinces (Cabrera, 1957), better known as the *pajonal* and *tolar* respectively. The *tolar* plant community is characterized by shrub steppes dominated by *Fabiana densa, Aloysia deserticola, Adesmia horrida, Parastrephia* sp. and *Baccharis* sp. that occupy the lower elevations of the Puna in the basin floors between 3400 and 3900 masl. Ground cover is 20-30%. Tolar shrubs form heterogeneous associations dominated by one species. Shorter herbaceous plants grow in the shade of these shrubs. As elevation increases, shrubs become lower and are scattered.

The *pajonal* plant community, which covers mountain slopes at elevations between 3900 masl and 5600 masl, consists of grasslands where species of Poaceae (*Stipa* and *Festuca* genera) are predominant, although sub-shrub species of *Adesmia horrida, Sysimbrium philippianum, Baccharis tola and Fabiana bryoides* are also present. Pajonal grasses grow in sandy soils, lack

continuity given the topography, and form small islands. Ground cover ranges between 5 and 10%.

The local fauna includes vicuñas (*Vicugna vicugna*), which mainly graze in the pajonal grasslands, and llamas (*Lama glama*), which mostly feed off wetland grasses. Large rodents (Chinchillidae family) are found in quebrada rockeries, whereas birds (*Rhea pennata*, Phoenicopteridae family) are common around water sources. Foxes (*Pseudalopex culpaeus* and *P. griseus*) and pumas (*Puma concolor*) are the main predators (Olivera and Elkin, 1994).

In sum, in this environment where relief and altitude gradient have a pronounced effect on plant and animal communities, as well as on transportation and mobility costs to hunter-gatherers, overall primary productivity is low, although with some variation (Morales, 2011), and pockets of resources result in a mosaic or patchy and fragmented environment (Yacobaccio, 2013).

b. Paleoenvironment of Antofagasta de la Sierra (10,000 – 4500 BP)
Paleoenvironmental studies show that climate in the Puna of NW Argentina fluctuated throughout the Holocene. During the Early Holocene moist conditions prevailed (Alcalde and Kulemeyer, 1999; Fernández et al., 1991; Markgraf, 1985; Morales, 2011; Olivera et al., 2004; Tchilinguirian et al., 2012; Yacobaccio and Morales, 2005). In our study area (Figure 1), sediment analyses in Laguna Colorada reveal a cold and wet climate that resulted in lake transgression, ca. 10,000-8700 BP, when the first human settlements in the study area occurred at Peñas de las Trampas 1.1 site ca. 10,200 BP, Quebrada Seca 3 site ca. 9400 BP and Punta de la Peña 4 ca. 8900 BP (Martínez, 2012; Urquiza and Aschero, 2014) (Figure 2). In general, an arid trend is observed in the Middle Holocene, ca. 8700-4500 BP. In our study region, this period coincided with the occupation of several rock shelters, such as Cueva Salamanca 1, Quebrada Seca 3 and Peñas de la Cruz 1 with brief humid events in the late Middle Holocene, ca. 6300-5800 BP, as shown by diatoms, organic materials and paleosols in Laguna Colorada, Mirihuaca River and Las Pitas River (Tchilinguirian and Morales, 2013; Tchilinguirian and Olivera, 2014). This trend toward arid conditions is also observed in other regions of the South-Central Andes. Many Altiplano lakes, such as Lake Titicaca (Bolivia), Laguna Miscanti, Laguna del Negro Francisco (Chile), and Laguna El Peinado (Argentina) show low lake levels between 8500 and 4000 BP. An increase in grass pollen in Laguna Seca (Chile) and El Aguilar (northern Argentina) not only shows an increase in aridity, but also in temperature after 8000 BP (Baied and Wheeler, 1993; Grosjean et al., 2001, 2007; Markgraf, 1985; Valero Garcés et al., 1996, 2000). However, there is some disagreement regarding the extent of this aridity, given the presence of moist phases lasting several hundred years (Betancourt et al., 2000; Grosjean, 2001; Latorre et al., 2003, 2006, among others). It appears, therefore, that this climatic change did not have the same severity throughout the Puna, and that some locations retained moisture, such as rivers and lakes with large catchments as well as rivers that descend from the Puna into the Mesothermal valleys, which were fed by glaciers (Tchilinguirian and Morales, 2013).

3. MATERIALS AND METHODS
   a. Archaeological sites in Antofagasta de la Sierra (NW Argentina)

The basin of the Laguna de Antofagasta, located in the region of Antofagasta de la Sierra, is an endorheic basin that covers approximately 2500 km^2 (Figure 1). The landscape is dominated by undulated plains, or pampas, that are interrupted by narrow gorges, or quebradas, rivers, volcanic cones and mountain ranges such as the Sierra de Calalaste (to the west), the Sierra de Laguna Blanca and Cerro Galán (to the east), and the Cordillera de Buenaventura (to the south). Wetlands border the narrow rivers and occupy the lower elevation zones, such as Laguna de Antofagasta and the Laguna Colorada.

The site that provides a chronological backbone of the region is Quebrada Seca 3 site, where the excavation of an area about 30 m^2 revealed over 25 successive occupation levels ranging ca. 9500–2500 BP (Aschero, 1988; Martínez, 2003; Pintar, 2014). Over 20 sites in the drainage basin of the Laguna de Antofagasta have yielded shorter occupation ranges and most are located in the drainage of the Las Pitas River in the localities of Peñas Chicas, Punta de la Peña, Peña de las Trampas, Peñas de la Cruz and Cueva Salamanca.

b. Methodology

Twelve pedestrian surveys in different micro-environments surrounding these archaeological sites were carried out, and associated vegetation was registered according to their location. Plants collected were deposited in the herbarium at the Instituto de Botánica Darwinion (SI) in Buenos Aires (Argentina) where they were taxonomically identified and anatomically analysed in order to build a reference collection and comparative sample. Ethnobotanical information obtained from inhabitants of the area who participated in the surveys was also used to determine the probable use that human groups that occupied the sites made of the plant resources (Rodríguez 1999, 2000).

To carry out the anatomical analysis of the roots, stems and leaves of the modern reference collection, the following procedure was used: pieces of these structures were separated from the collected specimens, boiled according to their hardness with drops of detergent of commercial use and placed in alcohol 70°. Then, histological cross and longitudinal sections of the plants were carried out with a sliding microtome. The best sections were selected under a magnifying glass, emptied with sodium hypochlorite (bleach) and colored with safranine fast-green. Finally, they were set up in artificial Canada balsam (D'Ambrogio de Argüeso, 1986).

These histological sections were observed and photographed with a light microscope. This observation allowed the analysis of the anatomy of present-day plants, taking into account the following features:

- Vessels: shape, size, quantity and disposition (porosity).
- Parenchyma: type and disposition.
- Radios: length and quantity; type of cells which formed them.
- Fibers: quantity and characteristics.
- Growth rings: marked or not.

For the culm cross sections of woody bamboos, the following characters were considered: epidermis, hypodermis, cortical parenchyma, sclerenchyma, vascular bundles (peripheral,

transitional and central) and interfascicular parenchyma. The number of vascular bundle cycles, their position and the size and form of central vascular bundles were also considered. To determine the position of vascular bundles, the phloem location in relation to the stem cortex was taken into consideration (Rúgolo de Agrasar and Rodríguez, 2002). The form of the central vascular bundles was recorded based on Stearn's (1983) terminology and the whole descriptions were made based on Metcalfe (1960).

In relation to the herbaceous species, cross sections of leaves, stems and culms of grasses and rushes were made manually. The histological sections were stained with dilute safranine and mounted in glycerin - gelatin. They were observed and photographed with light a microscope. The anatomical analyses were carried out taking into account the foliar characters (leaf contour, ribs and furrows, margins, hairs, papillae and papillae cells, prickle hairs or hooks, epidermal cells, adaxial and abaxial sclerenchyma, vascular bundles) and culinary ones (culm contour, sclerenchyma, subepidermal chlorenchyma, vascular bundles and parenchyma).

When considering grasses, the following superficial characters were observed by SEM: ribs and furrows, costal long cells, intercostal long cells, silica short cells (silica bodies), stomatal apparatus, prickle hairs or hooks, macro-hairs and micro-hairs. Individual silica or cork short cells that in some cases could not be identified with a Scanning Electronic Microscope (SEM) were seen with light microscopy (Rúgolo de Agrasar and Rodríguez, 2002). Plant nomenclature was based on Judziewicz et al. (1999).

c. Archaeological material

Histological sections were carried out in order to analyze the woody species (including bamboos), following the steps indicated for the present-day material. Histological sections were observed and photographed with a light microscope. However, the process required more care because of the difficulties presented due to the varying conservation of the material. Cross sections of the charcoal fragments were carried out with razor blades under a magnifying glass. Likewise, a similar procedure was carried out for woody bamboos, from which pieces of epidemis were taken to analyze with SEM, as well as cross sections observed with a light microscope. These were observed and photographed with SEM. Finally, histological sections of the herbaceous species (family Poaceae and others) were made as indicated for modern material. In all cases, samples from each level or layer were analyzed. Scientific identification was made by anatomical and morphological comparison with present-day material of the reference collection.

4. RESULTS AND DISCUSSION

a. The role of plants in risk management strategies during the Holocene

Plant dependency among early hunter-gatherers (who lived prior to horticultural practices) is critical to the discussion surrounding forager subsistence, despite the overwhelming attention that hunting practices have received in archaeology. While ethnographic and ethnoarchaeological studies examine the extent to which modern foragers depended on plant foods and which species

were taken over others at different times of year and in different habitats (Binford 2001; Kelly 2013; Hawkes et al. 1997; Hurtado et al. 1985; Kaplan and Hill 1992; O'Connell and Hawkes 1981, among others), archaeological research of plant dependency during pre-agricultural times has lagged behind for several reasons, including the abundant and well preserved faunal remains and lithic projectile points at archaeological sites, the prevailing theoretical models of terrestrial hunting, and the unfounded notion that the more visible remains were associated with highly important tasks, such as male hunting. By contrast, perishable plant remains, baskets, ropes and cordage which are not always preserved in the archaeological record, have been commonly perceived as the result of less important gathering activities performed by women (Adovasio et al. 2009). Hominin diets cannot exclusively rely on animal protein because it can prove to be lethal, while plants contain carbohydrates which are essential for human nutrition (Butterworth et al. 2016; Copeland 2016). Consequently, plant dependency should be recognized as an important component of prehistoric diets, and further, beyond the fact that many plant foods can be stored, roots and tubers have carbohydrates which are important to the survival of young children, and plant dependency can also counteract animal protein shortage during times of hunting scarcity or failure (Elston and Zeanah, 2002; O'Connell and Hawkes, 1981; Pintar, 2008; Sellen, 2006).

The study of hunter-gatherer subsistence in the Puna has mostly focused on the identification of animal species being hunted, and the NISP and MNI of each species as means to identify specialized hunting, age groups being targeted and the origins of camelid domestication (Mondini and Elkin, 2014; Mondini *et al.*, 2013; Reigadas, 2014). These studies have also relied on typological sequences of projectile points to infer weaponry and hunting strategies utilized to suggest an economic specialization in camelid hunting which was concomitant with reduced residential mobility during the arid mid-Holocene which had caused landscape fragmentation (Aschero and Martínez, 2001; Martínez, 2005; Yacobaccio, 2013). In this paper we would like to highlight the importance of gathering activities and plant dependency as complementary to hunting, as well as discuss mechanisms that were used to avert or mitigate subsistence risk due to hunting shortcomings.

Hunter-gatherer success was dependent on their knowledge of the environment and its resources, as well as their specific location, behavior and timing. In the South Puna foragers gained an increased knowledge of their environment from the Early to mid-Holocene, as shown by the repertoire of edible plants present in the archaeobotanical record, particularly roots and tubers. However, while the location of plants can be predicted with a high degree of probability and allows gathering strategies to provide a certain degree of economic security to the members of their group, risk reduction strategies used to deal with the variance in the abundance of resources would have been used as the mid-Holocene drought increased patchiness in the Puna. Whereas some hunter-gatherers opted to abandon some parts of the Puna, as the occupational hiatus or "*silencio arqueológico*" shows in the Atacama Puna in the Chilean Andes (Grosjean et al. 1997, 2007; Núñez et al. 1999, 2001, 2013) in the South Puna a combination of risk management strategies were implemented that allowed a greater occupation continuity.

These strategies involved relocating residential bases to areas close to gathered resources, increasing foraging radii, and making changes to what they ate by relying on carbohydrate rich resources from the *vega* wetlands and *tolar* shrublands, such as roots and tubers, as well as low-ranked seeds, stems, leaves, fruits; introducing non-local plants (and eventually cultigens) into

their subsistence by strengthening ties and forming safety nets with groups living in different ecozones that were not subject to the same resource fluctuation; risk pooling by sharing in cooperative activities (like cooperative hunting) (Aschero and Martínez 2001), as well as relying on protected herds of camelids (Yacobaccio et al., 2013). In essence, hunter-gatherers placed their bets on multiple resources and developed a series of independent strategies that were unlikely to fail together, and thus avoid the failure of eating. Next, we will discuss those strategies related to plant dependency.

b. Ethnobotanical evidence

Ethnobotanical surveys of the region of Antofagasta de la Sierra which have resulted in the identification of 55 species of native plants distributed in several plant communities: namely *pajonal*, *tolar* and wetlands (*vegas*) (Cuello, 2006; Rodríguez, 1998, 2013a, 2013b) The most common uses for plants, as identified by local inhabitants, are: forage for animals, fuel and for thatching roofs. Only a very small number of wild plants are considered as having any subsistence value today. While some are used in infusions because of their medicinal properties, 10 species of plants with edible roots or rhizomes, leaves and small fruits (*Hoffmannseggia eremophila*, *H. glauca*, *Juncus balticus, Schoenoplectus americanus, Festuca orthophylla, Atriplex imbricata* and *Ephedra multiflora, Maihuenopsis glomerata, Neuontobotrys tarapacanus*) (Table 1) are occasionally gathered and consumed by local people whose sustenance largely depends on llama, sheep and goat by-products, plants grown in small family gardens (quinoa, maize, fava beans and potatoes) as well as products obtained in the market (Apóstolo et al., 2019; Babot et al., 2018; Cabrera, 1957; Lund, 2016; Margarita Morales, 2011, *pers. comm.*).

Additionally, in neighboring Puna areas to the north and northwest., there are five species of wild plants known to be parasitized by the *Ombrophytum subterraneum* (Balanophoraceae) which produce edible tubers. We have included them in Table 1 because there is the possibility that ethnobotanical surveys in our study area were conducted outside of the season in which they mature. These (parasitic) tubers, known as the "*alcañorca*" in the Jujuy province of northern Argentina or "*sichas*" in northern Chile, grow on the roots of the *Parastrephia* genera (*P. lucida, P. quadrangularis*), *Artemisia copa*, *Aloysia deserticola* and *Baccharis tola* species (Cabrera, 1957; Villagrán and Castro, 2004), all of which form part of the plant communities in our area. Additionally, in northern Chile the roots of the *Adesmia rahmeri*, a relative of the *Adesmia horrida* that also grows in our study area, are consumed (Romo et al., 1999; Villagrán and Castro, 2004).

Therefore, by considering all this ethnobotanical evidence *in toto*, it follows that about one third of the plant species (n=15/55; 27%) that grow in our study area produce edible roots, tubers, rhizomes, stems, fruits, resins and honey which are available during the summer and early fall months.

c. Archaeobotanical approaches: macro and microbotanical remains

Archaeobotanical analyses of extremely abundant and well-preserved assemblages of macrobotanical remains both in hunter-gatherer contexts ca. (9500-4500 BP) and in the mixed

hunting-herding and horticultural contexts (ca. 4500-1000 BP) have resulted in the identification of plant species used for different purposes, such as: a) to make artifacts (cordage, ropes), b) to make features presumably used as bedding and seating, c) to burn as fuel, and d) to consume reproductive organs (seeds, fruits, roots and tubers). The identification of these macro-remains has allowed to make inferences about the provenience of these plants (either from Puna plant communities or beyond the ecological boundaries of the Puna), the woody species selected for heating and cooking, the selection of grass species used for making cordage and ropes, the extent of hunter-gatherer foraging and annual radii. In this paper we focus only on edible/potentially edible plant taxa. For a list of all macrobotanical taxa identified in archaeological contexts in the South Puna, see Rodríguez 1999a, 1999b, 2004, 2008, 2013a, 2013b, 2014.

Microbotanical analyses, on the contrary, have focused on microfossils of starch and phytoliths adhered to artifacts (stone tools and ceramics), and in hunter-gatherer contexts have mostly focused on micro-residues found on grinding stones found in Middle and Late Holocene contexts, beginning *ca.* 7500 BP (Babot, 2006, 2009, 2011; Babot and Hocsman, 2016; Hocsman and Babot, 2018, among others) (Table 2). The early use of some edible plants (*ca*. 7500 BP) is evidenced by microfossils of roots and tubers, Fabaceae and Poaceae on two grinding stones, although the particular taxa were not identified. The scant groundstone assemblage in hunter-gatherer contexts probably relates to a dependency on plants that did not require processing, although the adhered residues suggest that tubers were crushed prior to their consumption. In the transition from the Middle to Late Holocene contexts (*ca*. 5400BP), microfossils of Fabaceae and Oxalidaceae have been identified. And in Late Holocene contexts, post 4500 BP, microfossils of the Fabaceae, Poaceae, Cyperaceae and Juncaceae families, as well as several domesticate microfossils have been identified: *Chenopodium quinoa*, *Zea mays*, *Solanum tuberosum*, *Canna edulis*, *Prosopis* sp., *Juglans australis*, and *Amaranthus caudatus*, *Phaseolus* sp., as well as non-local wild species of *Opuntia* sp*., Prosopis* sp*., Amaranthus caudatus* and *Juglans australis* (Table 2). These finds suggest a more diverse gathering and food producing economy than what characterized the Middle Holocene. While some processed and consumed plants were locally grown, others (both wild and domesticated) were obtained though trade/barter with groups living in the eastern lowlands (Babot 2011, 2016; Hocsman and Babot, 2018, among others).

d. Macrobotanical evidence of hunter-gatherer dependence on plant foods

The excellent preservation conditions in this high desert have resulted in especially abundant assemblages of macrobotanical remains that generally yield wood, roots, stems, grass, leaves, flowers, fruits, seeds and pods, and thorns. While most of these remains are in their natural state, others are burned and recovered in large hearths.

While there are very few specific remains of the edible parts of wild plants in the macrobotanical record of hunter-gatherer contexts, the remains of wood, thorns, seeds and flowers of plant taxa that produce edible parts (such as tubers, rhizomes, stems, fruits, leaves and nuts) that are consumed today suggest a high probability that they would have also been eaten in the past (principle of uniformity). We have recorded 18 species —thirteen (13) local taxa and 5 non-local taxa—in the Early to Late Holocene record, though this list is probably not exhaustive given that

some plants could have been consumed beyond the confines of the archaeological sites we have excavated (Table 3).

The identification of these taxa gives us a good picture of risk management strategies used during the first few millennia of human occupation in the Salt Puna. Although the record for the Early Holocene is sparse (n=4), it highlights the role of tubers in the diet of early hunter-gatherers. Stems and roots belonging to three families (Arecaceae/palm, Asteraceae/sunflower and Fabaceae/legume), specifically *Adesmia horrida*, which produce edible tubers (Babot 2009, 2011; Romo et al. 1999), and the remains of three taxa which are parasitized by *Ombrophytum subterraneum* that also produce edible roots (*Baccharis tola* which also produces edible resin, *Parastrephia lucida* and *P. quadrangularis*) have been identified. We should note that all four taxa are also recorded in Middle and Late Holocene contexts. Additionally, seeds of the non-local legume *Prosopis* sp. were identified.

During the early Middle Holocene (*ca*. 8300 – 7000 BP), there is an increase in the number of taxa recorded (n=13), adding nine new macrobotanical taxa with edible parts to those gathered in the Early Holocene. The list includes seven local wild plants belonging to seven families (Chenopodiaceae, Fabaceae, Cactaceae, Brassicaceae, Juncaceae, Poaceae, Asteraceae), specifically *Atriplex imbricata, Hoffmannseggia eremophila* (that produces edible tubers known as "papa cuchi"), *Maihuenopsis glomerata* (producing edible fruits or "pencas"), *Neuontobotrys tarapacanus* (edible seeds and fruits), *Juncus balticus* (with an edible stem base), *Festuca* sp. (producing edible roots) and *Parastrephia* sp. The record also shows the remains of two non-local wild plants —*Trichocereus pasacana* (Cactaceae) and *Amaranthus hybridus* (Chenopodiaceae), both of which produce edible parts and which we will discuss separately.

During the period of extreme aridity of the late Middle Holocene (*ca*. 7000 – 6000 BP), the record shows a reduced number of taxa utilized (n=9). In addition to the remains of the same four tuber/root taxa identified in the Early and early Middle Holocene, three new taxa that can be parasitized by *Ombrophytum subterraneum* —including *Aloysia deserticola* (Verbenaceae), *Ephedra multiflora* (Ephedraceae) which also produces edible fruits, and *Artemisia copa* (Asteraceae) were identified, as well as leaves of *Atriplex imbricata* (Chenopodiaceae) and fruits of *Maihuenopsis glomerata* (Cactaceae). In these contexts there is a striking absence of *Hoffmannseggia eremophila* that produces tubers, and of taxa that produce edible seeds and stems.

Further, the record for the transition from the Middle to Late Holocene, ca. 5500 BP, yielded a lower number of local taxa (n=6) including remains of three parasitized species that continued to be present since the Early Holocene (*Baccharis tola*, *Parastrephia lucida* and *Adesmia horrida*), *H. eremophila* (Fabaceae), *Neuontobotrys tarapacanus* (Brassicaceae) and *Festuca* sp. (Poaceae) and one non-local species —*Arachis* sp. (Fabaceae).

Finally, the macrobotanical record for the Late Holocene *ca*. 4500 BP reveals a greater use of edible plant taxa: 12 local and 7 non-local. While taxa used in the Middle Holocene continued to be gathered, such as those with parasitic tubers, *Hoffmannseggia eremophila*, *Atriplex imbricata*, *Maihuenopsis glomerata*, the rhizomes of a sedge (Cyperaceae), possibly *Schoenoplectus americanus* —a wild plant that grows in *vega* wetlands —currently managed by local inhabitants

(Lund, 2016; Babot et al., 2018; Gonnet, 2018), was incorporated into the diet. Cultigens like *Chenopodium quinoa* and *Zea mays* were introduced from other ecological areas and grown locally, signaling the beginnings of horticultural practices by hunter-gatherer groups who were also beginning to herd camelids (Aschero et al., 2010; Reigadas, 2014; Yacobaccio et al., 2013). Other non-local wild taxa were likely obtained through trade and consumed, such as *Lagenaria siceraria, Prosopis* sp*., Geoffrea decorticans* and *Phaseolus vulgaris* (Babot and Hocsman, 2016; Hocsman and Babot, 2018; Winkel et al., 201⬭ Table 3).

These results suggest that tubers were targeted plant taxa, followed by lower-ranked foods like fruits and seeds. While some tubers grow in dry, sandy and rocky soils (Slanis and Grau, 2001) and others favor more humid areas (Hawkes and Hjerting, 1969), they provide sufficient amounts of carbohydrates and require low processing costs. Specifically, edible roots and tubers made up all 4 taxa during the Early Holocene (100%), 7 of 13 taxa (54%) during the early Middle Holocene, 7 of 9 taxa (78%) in the late Middle Holocene, and 5 of 7 (71%) taxa during the transitional period leading up to the Late Holocene (Table 3; Figure 2). This record proposes the importance of edible terrestrial tubers in the diet of hunter-gatherers as a reliable food source— that can also be stored, thus providing economic security to the group— found within the reconstructed foraging radii of the Early and mid-Holocene groups, 3km and 7 km respectively (Morgan, 2008; Pintar and Rodríguez, 2015; Ramsey et al., 2016). These results also underscore the importance of different plant communities over time: *vega* wetlands in the Early Holocene, and *vega* wetlands plus *tolar* shrublands in the Middle Holocene, with the *tolar* having provided terrestrial tubers like *Hoffmannseggia eremophila* ("papa cuchi") and a wider variety of lower-ranked plant taxa such as edible stems, leaves, fruits and seeds that require higher search and processing costs (Figure 3). This risk-averting strategy was enabled by relocating residential bases from the *pajonal* grasslands where high elevation *vegas* would have been exploited, to the lower elevation *tolar* shrublands with lower elevation *vegas* being targeted during the arid phase of the Middle Holocene, and by expanding foraging radii which would have reduced transportation and mobility costs for gatherers (Pintar and Rodríguez, 2015).

It appears that a threshold was reached during the late mid-Holocene (ca. 7000-6000 BP) and the transitional period towards food production *ca*. 5500 BP (Hocsman and Babot, 2018), when hunter-gatherers faced a high variance in resource returns resulting from the increased aridity and ensuing unpredictable variability in the outcome of subsistence efforts. While 15 plant taxa that produce edible parts were used prior to this transitional period, the record shows a decrease in the variety of wild plants gathered to six taxa, as subsistence strategies relied on significantly fewer resources from the *vega* wetlands (Figures 2 and 3). It is possible that the aridity reduced the abundance of resources and that the pressure on certain plants as a result of gathering activities caused their depletion, as has been observed ethnographically (O'Connell and Hawkes, 1981). Further, the majority of macrobotanical taxa identified during this period were *tolar* plants that produce terrestrial roots and tubers, which again highlights the role of tubers in hunter-gatherer subsistence as a reliable resource that also has an ease for storage. Additionally, given their high carbohydrate and lipid content, tubers would also have helped offset the shortage of camelid protein during this time and positively affected child survivorship (Sellen 2006). However, as the mid-Holocene drought increased patchiness in the environment, residential mobility became limited to the few areas in the landscape with water sources and potential animal and plant resources.

During the Late Holocene, *ca.* 4500 BP, the management of aquatic roots of *Schoenoplectus americanus* (Cyperaceae) that grew in the wetlands along the margins of rivers is suggested by their microfossil residues on grinding stones (Babot et al., 2018), however, macrobotanical evidence is lacking. Ethnobotanical studies show this taxa is currently under management in the *vega* wetlands and consumed by local families at certain times of the year, suggesting its use in the past as well (Lund, 2016). The non-local cultigen *Chenopodium quinoa* was introduced during this period and was cultivated in the *vega* wetlands. During this time the process of camelid domestication was also well underway (Aschero et al., 2010; Reigadas, 2014; Yacobaccio et al., 2013).

e. Safety nets and social networks

While the mid-Holocene drought was widespread in Salt Puna, it was harsher in the Chilean Atacama basin, where a 3000-year occupational hiatus (or "*silencio arqueológico*" *sensu* Núñez et al., 2013) was documented. However, in the basin of the Laguna de Antofagasta, on the eastern slopes of the Andes, less significant occupational hiatuses have been identified during the late mid-Holocene to Late Holocene: *ca.* 7000–6200 BP, *ca.* 6200–5400 BP and *ca.* 5400–4800 BP. However, the sporadic occupations from this period reflect an impoverished environment as suggested by the macrobotanical records. (Table 3; Figure 2) Beyond including middle to low return resources such as roots and tubers to avoid avoid maladaptations and local group extinctions (*sensu* Muscio, 1999), other risk-averse strategies aimed at mitigating the effects of a dry environment and unpredictable resources to buffer the effects of hunting and gathering failure would have included the formation of alliances and safety nets with neighbors from other ecozones which would have enabled groups to obtain comestible resources. In fact, evidence for the interaction with other ecozones is already present during the Early Holocene, *ca.* 9000 BP, with the presence of edible seeds of *Prosopis* sp. and of non-edible macrobotanical remains in archaeological contexts such as palm cordage made with *Acrocomia aculeata*, wooden shafts of *Salix humboldtiana, Rhipidocladum neumannii*, *Chusquea lorentziana* as well as *Trichocereus pasacana ca.* 8000 BP (Rodríguez, 1998, 1999a; Pintar and Rodríguez, 2015) which suggest a firmly established relationship between the South Puna and neighboring regions at the eastern foothills of the Puna from where these resources came from, as well as the *yunga* forests 450 km to the east. Shell beads from the Pacific coast about 300 km to the west also suggest participation in networks on the western side of the Andes.

We have suggested elsewhere that as resources in the South Puna became increasingly unpredictable from the early to late Middle Holocene, inter-regional relations with groups inhabiting other ecozones would have offered insurance against resource failure (Aschero, 2014; Kelly, 2013; Pintar and Rodríguez, 2015; Whallon, 2006, 2011). Given that mobility was not an option to offset declining yields given that hunter-gatherer groups were tethered to limited spots surrounding wetlands on the landscape, by investing intensively in broad social networks, hunter-gatherers would have obtained edible products like nuts of *Arachis* sp., seeds of *Amaranthus hybridus* and fruits of *Trichocereus pasacana* from neighboring ecological zones. Eventually, during the transition between the Mid and Late Holocene these safety nets must have become consolidated with family alliances and relationships that created a system of exchange and reciprocity that provided fruits and seeds of wild species such as *Lagenaria siceraria, Prosopis* sp.*, Geoffrea decorticans*, *Juglans australis*, as well as seeds of cultivated species of

Zea mays, Chenopodium quinoa and *Phaseolus vulgaris*. Finally, as climatic conditions ameliorated during the Late Holocene (post 4500 BP) in the Salt Puna, other cultigens were introduced, such as *Amaranthus caudatus*, *Canna edulis*, *Oxalis tuberosa* and *Solanum tuberosum* which were grown in family gardens on the margins of wetlands (Babot, 2014, 2016; Hocsman and Babot, 2018).

5. CONCLUSIONS

In sum, hunter-gatherer groups living in the Puna would have used a variety of risk management strategies in order to deal with the unpredictable variability in the outcome of their subsistence efforts. Rather than focus on a few resources and practice intensified behaviors, they chose to spread the risk among many resources. Thus, interaction and trade replaced residential mobility and enabled Puna hunter-gatherers to avert environmental risk, broaden their diet albeit with resources that required high handling and processing costs. The emergence of a mixed subsistence comprised of hunting, gathering, small garden horticulture, herding camelids and interacting with other ecological regions became a strategy that offset seasonal shortages and shortfalls, and became the foundation of an economy that is still practiced today.

6. REFERENCES

Aldenderfer M (2006) Modelling plateau peoples. The early human use of the world's highest plateau. *World Archaeology* 38:357-370.

Alcalde JA and Kulemeyer JJ (1999) The Holocene in the South-Eastern region of the province Jujuy, North-West Argentina. *Quaternary International* (57-58): 113-116.

Amaya NE, Blanco DE, Chamorro Cuestas AF, Gonnet JM, Hegoburu C and Sosa HJ (2019) *Conservación y manejo de vegas altoandinas en Argentina y Perú. Dos estudios de caso.* Buenos Aires: Fundación Humedales/Wetlands International.

Aschero CA (1988) De punta a punta: producción, mantenimiento y diseño de puntas de proyectil precerámicas de la Puna Argentina. In: *Actas del IX Congreso Nacional de Arqueología* (No eds), October 31-November 5 1988, pp. 219-229. Buenos Aires: Facultad de Filosofía y Letras, Instituto de Ciencias Antropológicas.

Aschero CA (2014) Hunter-gatherers of the Puna in a temporal perspective (10,500-3500 BP): the case of Antofagasta de la Sierra (Catamarca, Argentina). In: Pintar E (ed) *Hunter-Gatherers from a High-elevation Desert: People of the Salt Puna (Northwest Argentina)*. Oxford Archaeopress, BAR International Series 2641, pp. 27-44.

Aschero CA and Martínez JG (2001) Técnicas de caza en Antofagasta de la Sierra, Puna Meridional Argentina. *Relaciones de la Sociedad Argentina de Antropología* 26: 215-241.

Aschero CA, Urquiza S and Isasmendi V (2010) Las Representaciones de "Cartuchos" en Peñas de las Tumbas, Antofagasta de la Sierra, Catamarca, Argentina. In: VIII Simposio Internacional de Arte Rupestre. Tucumán, Argentina, 8-12 November 2010, Format CD.

Apóstolo N, Rodríguez MF, Pintar E (2019) Macrorrestos vegetales en el sitio arqueológico Cueva Salamanca 1, Antofagasta de la Sierra (Catamarca, Argentina). Paleoambiente y uso de la vegetación durante el Holoceno. *Boletín de la Sociedad Argentina de Botánica* 54(1): 43-65.

Babot MP (2006) El papel de la molienda en la transición hacia la producción agropastoril: Un análisis desde la Puna Meridional argentina. *Estudios Atacameños* 32: 75-92.

Babot MP (2009) Procesamiento de tubérculos y raíces por grupos agropastoriles del noroeste argentino prehispánico: análisis de indicadores en residuos de molienda. In: Capparelli A, Chevalier A and Piqué R (eds) *La alimentación en la América precolombina y colonial: una aproximación interdisciplinaria*. Madrid: Estilo Estugraf Impresores, pp. 67-82.

Babot MP (2011) Cazadores-recolectores de los Andes Centro-Sur y procesamiento vegetal. Una discusion desde la Puna Meridional Argentina (ca. 7.000-3.200 años A.P. *Chungara* 43 (1): 413-432.

Babot MP (2014) Grinding, processing, settlement and mobility in hunter-gatherers of the Argentine South Puna (*ca.* 7400-3200 BP). In: Pintar E (ed) *Hunter-Gatherers from a High-Elevation Desert: People of the Salt Puna (Northwest Argentina)*. Oxford Archaeopress: BAR International Series 2641, pp. 169-200.

Babot MP (2016) Notas sobre la arqueología de las plantas en un desierto de altura. *Cadernos do Lepaarq. Textos de Antropologia, Arqueologia e Patrimônio* 13(25):333-365.

Babot MP and Hocsman S (2016) Quinoa. A millenary grain in Northern Argentina. In: *Encyclopaedia of The History of Science, Technology, and Medicine in Non-Western Cultures*, Selin H (ed). DOI 10.1007/978-94-007-3934-5_10319-2. Heidelberg: Springer.

Babot MP, Lund J and Hocsman S (2018) El antiguo papel de las vegas en la Puna catamarqueña. In: Grau HR, Babot MJ, Izquierdo AE and Grau A (eds) *La Puna Argentina. Naturaleza y Cultura*. Tucumán: Fundación Miguel Lillo, pp. 73-74.

Baied C and Wheeler J (1993) Evolution of high Andean Puna ecosystems: environment, climate, and culture change over the last 12,000 years in the Central Andes. *Mountain Research and Development* (13)2: 145-156.

Betancourt JL, Latorre C, Rech JA, Quade J and Rylander K (2000) A 22,000 year record of monsoonal precipitation from northern Chile's Atacama desert. *Science* 289:1542-1546.

Binford LR (2001) *Constructing Frames of Reference. An Analytical Method for Archaeological Theory Building Using Ethnographic and Environmental Data Set*. Berkeley and Los Angeles: University of California Press.

Butterworth PJ, Ellis PR and Wollstonecroft M (2016) Why protein is not enough: the roles of plants and plant processing in delivering the dietary requirements of modern and early *Homo*. In: *Wild Harvest: Plants in the Hominin and Pre-Agrarian Human worlds*. Oxford and Philadelphia: Oxbow Books, pp. 31-54.

Cabrera AL (1957) La vegetación de la Puna Argentina. *Revista de Investigaciones Agrícolas* (11): 317-413.

Cabrera AL (1976) Regiones fitogeográficas argentinas. In: *Enciclopedia Argentina de Agricultura y Jardinería,* (2)1. ACME, Buenos Aires.

Copeland L (2016) Food carbohydrates from plants. In: *Wild Harvest: Plants in the Hominin and Pre-Agrarian Human worlds*. Oxford and Philadelphia: Oxbow Books, pp. 19-30.

Cuello AS (2006) *Guía ilustrada de la flora de Antofagasta de la Sierra - Catamarca (Puna Meridional Argentina).* Licenciate Thesis. Universidad Nacional de Tucumán, Argentina.

D´Ambrogio A (1986) *Manual de Técnicas en Histología Vegetal*. Buenos Aires: Editorial Hemisferio Sur.

Elston RG and Zeanah D (2002) Thinking outside the box: a new perspective on diet breadth and sexual division of labor in the Prearchaic Great Basin. *World Archaeology* 34 (1): 103-130.

Fernández J, Markgraf V, Panarello H, Albero M, Angiolini F, Valencia S and Arriaga M (1991) Late Pleistocene-early Holocene environment and climates, fauna, and human occupation in the Argentine Altiplano. *Geoarchaeology* 6: 251-272.

Gonnet J (2018) El manejo de las vegas como estrategia adaptativa de las poblaciones puneñas. In: Grau HR, Babot MJ, Izquierdo AE and Grau A (eds) *La Puna Argentina. Naturaleza y Cultura*. Tucumán: Fundación Miguel Lillo, pp.112-113.

Grosjean M (2001) Mid-Holocene climate in the south-central Andes: humid or dry? *Science* 292: 2391-2392.

Grosjean M, Núñez L, Cartajena I and Messerli B (1997) Mid- Holocene climate and culture change in the Atacama Desert, Northern Chile. *Quaternary Research* 48:239-246.

Grosjean M, Van Leeuwen JN, Van Der Knaap WO, Geyh MA, Ammann B, Tanner W, Messerli B, Núñez LA, Valero-Garcés BL and Veit H (2001) A 22,000- year sediment and pollen record of climate change from Laguna Miscanti (23S), northern Chile. *Glob*al *Planet Change* 28: 35-51.

Grosjean M, Santoro C, Thompson L, Núñez L, Standen V (2007) Mid-Holocene climate and culture change in the South-Central Andes. In: Anderson D, Maasch K, Sandweiss D (eds) *Climate Change and Cultural Dynamics: A Global Perspective on Mid-Holocene Transitions*. San Diego: Elsevier, pp.51-115.

Hawkes JG and Hjerting JP (1969) *The Potatoes of Argentina, Brazil, Paraguay, and Uruguay. A Biosystematic Study*. Oxford, Clarendon Press.

Hawkes K, O'Connell JF and Blurton Jones NG (1997) Hadza Women's Time Allocation, Offspring Provisioning, and the Evolution of Long Postmenopausal Life Spans. *Current Anthropology* 38(4): 551-565.

Hocsman S and Babot MP (2018) La transición de cazadores-recolectores a sociedades agropastorlies en Antofagasta de la Sierra (Puna de Catamarca, Argentina): perspectivas desde la agencia y las prácticas. *Chungara* 50(1):51-70.

Hurtado AM, Hawkes K, Hill K and Kaplan H (1985) Female subsistence strategies among Ache hunter-gatherers of eastern Paraguay. Human Ecoloby 13(1): 1-28

Judziewicz EJ, Soreng RJ, Davidse G, Peterson PM, Filgueiras TS, Zuloaga FO (2000) Catalogue of New World Grasses (Poaceae): I. Subfamilies Anomo- chlooideae, Bambusoideae, Ehrhartoideae, and Pharoideae. *Contributions from the United States National Herb*arium 39: 1-128.

Kaplan H and Hill K (1992) The Evolutionary Ecology of Food Acquisition. In: Smith EA and Winterhalder B (eds), *Evolutionary Ecology and Human Behavior*. New York: Aldine de Gruyter, pp. 167-201.

Kelly RL (1995) *The Foraging Spectrum. Diversity in Hunter-Gatherer Lifeways*. Washington DC: Smithsonian Institution Press.

Kelly R (2013) *The Lifeways of Hunter-Gatherers. The Foraging Spectrum.* New York: Cambridge University Press.

Latorre C, Betancourt JL, Rylander KA, Quade J, Mathei O (2003) A vegetation history from the arid prepuna of northern Chile (22-23S) over the last 13,500 years. *Palaeogeography, Palaeoclimatology, Palaeoecology* 194: 223-246.

Latorre C, Betancourt JL, Arroyo MTK (2006) Late Quaternary vegetation and climate history of a perennial river canyon in the Rio Salado basin (22 S) of Northern Chile. *Quaternary Research* 65: 450-466.

Lund J (2016) *Tubérculos y raíces útiles de la Puna Meridional Argentina. Un abordaje desde la arqueobotánica y la etnobotánica en Antofagasta de la Sierra (Provincia de Catamarca).* Licentiate Thesis. Universidad Nacional de Tucumán, Argentina.

Markgraf V (1985) Paleoenvironmental history of the last 10,000 years in north- western Argentina. *Zentralblatt fur Geologie und Palaontologie* 11/12: 1739-1749. Stuttgart.

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Martínez JG (2003) Ocupaciones humanas y tecnología de caza en la microrregión de Antofagasta de la Sierra (10000-7000 AP). PhD Thesis, Universidad Nacional de Tucumán, Argentina.

Martínez JG (2005) Tecnología de cazadores en la puna meridional argentina: el caso de Peñas de la Cruz 1. *Mundo de Antes* 4: 25-49.

Martínez JG (2012) Evidence of early human burials in the Southern Argentinian Puna. In: Miotti L, Salemme M, Flegenheimer N, Goebel T (eds) *Southbound: Late Pleistocene Peopling of Latin America*, Special Edition Current Research in the Pleistocene. College Station: Centre for the Study of First Americans, Texas A&M University, pp. 75-78.

Metcalfe CR (1960) *Anatomy of Monocotyledons*. 1. Gramineae. Oxford: Clarendon Press.

Mondini M and Elkin D (2006) Cazadores-recolectores de la cuenca de Antofagasta de la Sierra (Puna Meridional Argentina). Una perspectiva arqueozoológica y tafonómica. Cazadores y recolectores del Cono Sur. *Revista de Arqueología* 1: 69-81.

Mondini M and Elkin D (2014) Holocene hunter-gatherers in the Puna. Integrating bones and other zooarchaeological evidence in Antofagasta de la Sierra (Argentina). In: Pintar E (ed) *Hunter-Gatherers from a High-elevation Desert: People of the Salt Puna (Northwest Argentina)* BAR International Series 2641. Oxford: Archaeopress, pp. 117-124.

Mondini M, Martínez J, Pintar E, Reigadas M.R (2013) Middle Holocene foraging, mobility and landscape use in the southern Argentinean Puna: hunter- gatherers from Antofagasta de la Sierra, Catamarca, Argentina. *Quaternary Int*ernational 307: 66-73.

Morales M (2011) *Arqueología Ambiental del Holoceno Temprano y Medio en la Puna Seca Argentina. Modelos Paleoambientales Multi-Escalas y sus Implicancias para la Arqueología de Cazadores-Recolectores*. Oxford: Archaeopress BAR Reports S2295, South American Archaeology. Series 15.

Morgan C (2008) Reconstructing prehistoric hunter-gatherer foraging radii: a case study from California's southern Sierra Nevada. *Journal of Archaeological Science* 35: 247-258.

Morlans MC (1995) Regiones naturales de *Catamarca. Provincias geológicas y provincias fitogeográficas.* Catamarca: Editorial Científica Universitaria. Universidad Nacional de Catamarca.

Muscio H (1999) Colonización humana del NOA y variación en el consumo de los recursos: la ecología de los cazadores de la puna durante la transición Pleistoceno-Holoceno. In: *Noticias de Antropologia y Arqueologia*. Available at: https://www.equiponaya.com.ar/articulos/arqueo03.htm (accessed 10 October 2021).

Núñez LA and Santoro C (1988) Cazadores de la puna seca y salada del área centro-sur andina (Norte de Chile). *Estudios Atacameños* 9:11-60.

Núñez L, Grosjean M and Cartajena I (2001) Human Dimensions of Late Pleistocene/Holocene Arid Events in Southern South America. In: Markgraf V (ed) *Interhemispheric Climate Linkages*. New York: Academic Press, pp.105–117.

Núñez L, Grosjean M and Cartajena I (1999) Un ecorefugio oportunístico en la puna de Atacama durante eventos áridos del Holoceno Medio. *Estudios Atacameños* 17:125-174.

Núnez L, Grosjean M and Cartajena I (2013) Archaeological silence and ecorefuges: arid events in the Puna of Atacama during the Middle Holocene. *Quaternary International* 307: 5-13.

O'Connell J and Hawkes K (1981) Alyawara plant use and optimal foraging theory. In: Winterhalder B and Smith EA (eds) *Hunter-gatherer foraging strategies: ethnographic and archaeological analysis.* Chicago: University of Chicago Press, pp. 99-125.

Olivera, D and Elkin D (1994) De cazadores y pastores: el proceso de domesticación de camélidos en la Puna Meridional Argentina. In: Elkin D, Madero, C, Mengoni Goñalons G, Reigadas MC, and Yacobaccio H (eds) *Zooarqueología de Camélidos 1, Perspectivas teóricas y metodológicas* (1ª parte). Buenos Aires: Grupo de Zooarqueología de Camélidos, pp. 95-124.

Olivera D, Tchilinguirian P and De Aguirre MJ (2004) Paleoambiente y arqueología en la puna meridional argentina. *Relaciones de la Sociedad Argentina de Antropología* 29: 229-247.

Pintar, EL (2008) Estrategias de caza y recolección: una aproximación a la división sexual del trabajo en la Puna salada. *Relaciones de la Sociedad Argentina de Antropología* 33: 133-154.

Pintar EL (2014) Desert hunter-gatherers: mobility and aridity thresholds. A view from the Argentine Puna. In: Pintar E (ed) *Hunter-Gatherers from a High- elevation Desert: People of the Salt Puna (Northwest Argentina)*, Oxford: Archaeopress, BAR International Series 2641, pp. 97-118.

Pintar EL and Rodríguez MF (2015) Understanding foraging radius and mobility in a high desert. *Journal of Archaeological Science* 59: 142 – 158.

Ramsey MN, Maher LA, Macdonald DA and Rosen A (2016) Risk, reliability and resilience: phytolith evidence for alternative 'Neolithization' pathways at kharaneh IV in the Azraq Basin, Jordan. *PLoSONE* 11(10): 1-26.

Reigadas MC (2014) The exploitation and use of faunal resources.The role of Quebrada Seca 3 and Cueva Cacao 1A (Antofagasta de la Sierra, Catamarca, Argentina). In: Pintar E (ed) *Hunter-Gatherers from a High-elevation Desert: People of the Salt Puna (Northwest Argentina)*. Oxford: Archaeopress, BAR International Series 2641, pp.125-144.

Rodríguez MF (1998) *Arqueobotánica de Quebrada Seca 3: Recursos vegetales utilizados por cazadores-recolectores durante el período Arcaico en la Puna Meridional Argentina.* PhD Thesis, Universidad de Buenos Aires, Argentina.

Rodríguez MF (1999a) Arqueobotánica de Quebrada Seca 3 (Puna Meridional Argentina): Especies vegetales utilizadas en la confección de artefactos durante el Arcaico. *Relaciones de la Sociedad Argentina de Antropología* 24: 159-184.

Rodríguez MF (1999b) Plant species at an archaeological site of the Southern Argentina Puna (Families: Poaceae, Asteraceae, Fabaceae and Solanaceae). *Journal of Ethnobiology* 19(2): 228-247.

Rodríguez MF (2000) Woody plant species used during the Archaic period in the Southern Argentine Puna. Archaeobotany of Quebrada Seca 3. *Journal of Archaeological Sciences* 27(4): 341-361.

Rodríguez MF (2004) Cambios en el uso de los recursos vegetales durante el Holoceno en la Puna meridional argentina. *Chungara Revista de Antropología Chilena* volumen especial: 403-413.

Rodríguez MF (2005) Human evidence during Middle Holocene in the Salty Argentine Puna. Archaeobotanical record analyzes. *Quaternary International* 132(1): 15-22.

Rodríguez MF (2008) Recursos vegetales y tecnofacturas en un sitio arqueológico de la Puna meridional argentina, Área centro-surandina. *Darwiniana* 46(2): 240 - 257.

Rodríguez MF (2013a) Los grupos humanos y las plantas en la Puna meridional argentina: Arqueobotánica de Antofagasta de la Sierra. *Intersecciones en Antropología* 14: 315-339.

Rodríguez MF (2013b) Acerca de la flora de Antofagasta de la Sierra, Catamarca, Argentina. Ambiente y Paleoambiente. *Darwiniana* nueva serie 1(2): 295-323. DOI: 10.14522/darwiniana.2013.12.529

Rodriguez MF (2014) Archaeobotany and vegetal resources. Settlement systems and mobility in the Argentine South Puna. In: Pintar E (ed) *Hunter-Gatherers from a High-elevation Desert: People of the Salt Puna (Northwest Argentina)*. Oxford: Archaeopress, BAR International Series 2641, pp. 145-168.

Romo M, Castro V, Villagrán C and Latorre C (1999) La transición entre las tradiciones de los oasis del desierto y de las quebradas altas del Loa superior: etnobotánica del valle del Río Grande, 2ª Región, Chile. *Chungara Revista de Antropología Chilena* 31(2): 319-360.

Rúgolo de Agrasar ZE, Rodríguez MF (2002) Caulinar anatomy of native woody Bamboos in Argentina and neibhbouring areas: Cross section. *Bamboo Science and Culture. The Journal of the American Bamboo Society* 17 (1): 28 - 43.

Sellen, Daniel
2006. Lactation, Complementary Feeding, and Human Life History. In: Hawkes K and Paine R (eds) *The Evolution of Human Life History*. New Mexico: School of American Research Press, pp. 155-198.

Slanis AC and Grau A (2001) The genus Hypseocharis (Oxalidaceae) in Argentina. *Darwiniana* 39(3-4): 343-352.

Stearn WT (1983) *Botanical Latin. Third Edition*. London: David & Charles.

Tchilinguirian P and Olivera DE (2012) Degradación y formación de vegas puneñas (900-150 años AP), Puna Austral (26 S)¿ Respuesta del paisaje al clima o al hombre? *Acta geológica lilloana* 24(1-2): 41-61.

Tchilinguirian P and Morales M (2013) Mid-Holocene paleoenvironments in Northwestern Argentina: main patterns and discrepancies. *Quaternary International* 307: 14-23.

Tchilinguirian P and Olivera D (2014) Late Quaternary paleoenvironments, South Andean Puna (25º-27ºS), Argentina. In: Pintar E (ed) *Hunter-gatherers from a high-elevation desert.People of the Salt Puna (northwest Argentina),* BAR International Series. S2641. Oxford: Archaeopress, pp. 45-72.

Urquiza S and Aschero C (2014) Economía animal a lo largo del Holoceno en la Puna austral argentina: Alero Punta de la Peña 4. *Cuadernos del Instituto Nacional de Antropología y Pensamiento Latinoamericano – Series Especiales* 2(1): 86-112.

Valero Garcés B, Grosjean M, Schwalb A, Geyh, M, Messerli B and Kelts K (1996) Limnogeology of Laguna Miscanti: evidence for mid to late Holocene moisture changes in the Atacama Altiplano (Northern Chile). *Journal of Paleolimnology* 16: 1-21.

Valero Garcés B, Delgado-Huertas A, Ratto N, Navas A and Edwards L (2000) Paleohydrology of Andean saline lakes from sedimentological and isotopic records, Northwestern Argentina. *Journal of Paleolimnology* 24: 343-359.

Villagrán C and Castro V (2004) *Ciencia indígena de los Andes del norte de Chile*. Santiago de Chile: Editorial Universitaria.

Whallon R (2006) Social networks and information: non-"utilitarian" mobility among hunter-gatherers. *Journal of Anthropological Archa*eology 25, 259-270.

Whallon R (2011) An introduction to information and its role in hunter-gatherer bands. In: Whallon R, Lovis WA, Hitchcock RK (eds.) *Information and its Role in Hunter-Gatherer Bands*. California: The Cotsen Institute of Archaeology Press, pp. 1-28.

Winkel T, Aguirre MG, Arizio CM, Aschero C, Babot M, Benoit L, Burgarella C, Costa-Tártara S, Bubois M, Gay L, Hocsman S, Jullien M, López Campeny S, Manifesto M, Navascués M, Oliszewski N, Pintar E, Zenboudji S, Bertero H, Joffre R (2018) Discontinuities in quinoa biodiversity in the dry Andes: an 18-century perspective based on allelic genotyping. *PLoS One* 13 (12): 1-13.

Yacobaccio, H (2013) Towards a human ecology for the Middle Holocene in the Southern Puna. *Quaternary International* 307: 24-30.

Yacobaccio H and Morales M (2005) Mid-Holocene environment and human occupation of the Puna (Susques, Argentina). *Quaternary International* 132: 5–14.

Yacobaccio H, Morales M, Solá P, Samec C, Hoguin R and Oxman B (2013) Mid-Holocene occupation of the Dry Puna in NW Argentina: Evidence from the Hornillos 2 rockshelter. *Quaternary International* 307: 38-49.

Yacobaccio H, Morales M and Hoguin R (2017) Habitats of ancient hunter-gatherers in the Puna: resilience and discontinuities during the Holocene. *Journal of Anthropological Archaeology* 46: 92-100.

Zeder M (2012) The Broad Spectrum Revolution at 40: Resource diversity, intensification, and an alternative to optimal foraging explanations. *Journal of Anthropological Archaeology* 31: 241-264.

TABLE 1 **Species of wild plants in the South Puna that produce edible parts**

Edible part	Species	Family	Source	Additional Current Use
Fruit	*Ephedra multiflora*	Ephedraceae	Cabrera, 1957	Fuel
	Maihuenopsis glomerata	Cactaceae	Cuello, 2006	-
	Neuontobotrys tarapacanus	Brassicaceae	Apóstolo et al. 2019; Cuello, 2006	Animal fodder
Leaves	*Atriplex imbricata*	Chenopodiaceae	Villagrán and Castro, 2004	Animal fodder
Parasitic roots (*)	*Aloysia deserticola*	Verbenaceae	Villagrán and Castro, 2004	Fuel, medicinal leaves
	Artemisia copa	Asteraceae	Villagrán and Castro, 2004	Medicinal leaves
	Baccharis tola	Asteraceae	Villagrán and Castro, 2004	Fuel
	Parastrephia lucida, P. quadrangularis	Asteraceae	Cabrera, 1957; Villagrán and Castro, 2004	Fuel
Resin	*Baccharis tola*	Asteraceae	Lund, 2016; Villagrán and Castro, 2004	Fuel
Root, rhizome	*Adesmia horrida*	Fabaceae	Babot, 2009; Romo et al.,1999	Fuel; edible root
	Festuca orthophylla	Poaceae	Lund, 2016:83	Animal fodder; edible root
	Hoffmannseggia eremophila; H. glauca	Fabaceae	Cabrera ,1957; Ulibarri, 1979; Lund, 2016	Edible root
	Schoenoplectus americanus	Cyperaceae	Babot et al., 2018; Lund, 2016:84	Edible roots
Stem	*Juncus balticus* ssp. *mexicanus*	Juncaceae	Babot et al., 2018; Lund, 2016:85	Animal fodder; edible stem

(*) Parasitic roots associated with these plant species in North Chile and Northwest Argentina though currently have not been identified in the study area.

TABLE 2: A summary of microbotanical remains of wild and domesticated plant species with edible parts identified on grinding stones in the South Puna (7000 – 1000 BP), by taxa. Sources: Babot, 2004, 2010, 2018; Hocsman and Babot, 2018 and Lund, 2016.

Origin	Family	Species	Period, Site[1]				
			Middle Holocene (8000-4500BP)		Late Holocene (4500 – 1000 BP)		
			Middle Holocene: early and late (8000 – 6000 BP)	Transition (5500 BP)	4500-3000 BP	3000-2000 BP	2000-1000 BP
Local	-	Non-identifiable roots	QS3, CS1	QS3-2b5	QS3, PCh1.1, PP4		PP9.I, CChM1
	Fabaceae (Legume)	-	CS1		PCh1.3		PP9.I
		aff. *Hoffmannseggia glauca*	-	-	PP4, PCh1.1-1.6	-	-
		aff. *Adesmia nanolignea/A. minor.*	-		PCh1.1-1.6		-
	Poaceae (Grass)	-	QS3, CS1		QS3, PCh1.1, 1.3, PP4		PP9.I, II
Local	Cyperaceae (Sedge)	-	-		QS3, PCh1.3	-	-
		aff. *Schoenoplectus americanus*			PP4, PCh1.1-1.6		
Local	Juncaceae (Rush)	-	-		QS3	-	-
		aff. *Juncus balticus* ssp. *mexicanus*		-	PCh1.1-1.6		

Local	Chenopodiaceae (Chenopod)	*Chenopodium quinoa (*)*	-	-	QS3, PCh1.1	-	PP9.I, CChM1
Non-local	Cactaceae (Cacti)	*Opuntia* sp.	-	-	QS3, PP4	-	PP9.I
Non-local, possibly cultivated locally	Poaceae (Grass)	*Zea mays*	-	-	QS3, PP4	-	PP9.I, III
Non-local, possibly cultivated locally	Oxalidaceae (Wood sorrel)	*Oxalis tuberosa*	-	QS3-2b5	PP4, PCh1.3	-	PP9.I
Non-local, possibly cultivated locally	Solanaceae (Potato)	*Solanum tuberosum*	-	-	PP4	-	PP9.I
Non-local, possibly cultivated locally	Cannaceae (Canna)	*Canna edulis*	-	-	PCh1.1, 1.3	-	PP9.I
Non-local	Fabaceae (Legume)	*Prosopis* sp.	-	-	PCh1.3, PP4	-	PP9.I,II,III
Non-local	Juglandaceae (Walnut)	*Juglans australis*	-	-	PP4, PCh1.3	-	
Non-local	Amaranthaceae (Amaranth)	*Amaranthus caudatus*	-	-	PCh1.1	-	PP9.I
Non-local	Fabaceae (Legume)	*Phaseolus* sp.	-	-		-	PP9.I,III
Non-local	Geranaceae (Geranium)	*Hypseocharis pimpinellifolia*	-	-	-	-	PP9.I

(*) Non-local origin, possibly grown in the South Puna/ANS.

(+) Non-local origin, probably obtained through trade.

[1] QS3: Quebrada Seca 3 site; CS1: Cueva Salamanca 1 site; PCZ: Peñas de la Cruz 1 site; PP3: Punta de la Peña 3 site; PP4: Punta de la Peña 4 site; PP9: Punta de la Peña 9 site; PP11A: Punta de la Peña 11A site; ; PP11B: Punta de la Peña 11B site; PCh1.1: Peñas Chicas 1.1 site PCh1.3: Peñas Chicas 1.3 site; PCh1.6: Peñas Chicas 1.6 site CChM1: Casa Chávez Montículos 1 site.

Source: Aguirre 2005; Apóstolo et al 2019; Babot 2011; Pintar and Rodríguez 2015; Rodríguez 1999, 2004, 2008, 2013.

TABLE 3: Macrobotanical remains of wild plant species with edible parts in the South Puna (9500 – 1800 bp), by taxa discussed in this study.

Family	Macro remains	Species	Edible part	Plant community	Early Holocene	Middle Holocene			Late Holocene
						early	late	transition	
					(10,000-8000 BP)	(8000 – 7000 BP)	(7000 – 6000 BP)	(5500 BP)	(4500-1000 BP)
					Site/level[1]	Site/level[1]	Site/level[1]	Site/level[1]	Site/level[1]
Arecaceae (Palm)	wood	*Baccharis tola*	Resin *Parasitic root	Gorge slopes (>4000 masl)	QS3-2b24/2b15	QS3-2b14-2b10 CS1-2(3)	QS3-2b8	QS3-2b5	QS3-2b2-1 CS1-2(1)
Asteraceae (Sunflower)	wood	*Parastrephia lucida*	*Parasitic roots	*Vega* wetlands (3400-4600 masl)	QS3-2b25/2b15	QS3-2b14/2b11 PCz	QS3-2b8 CS1-2(2)	QS3-2b5	QS3-2b1
		Parastrephia quadrangularis			QS3-2b25/2b15	QS3-2b14/2b9	QS3-2b8		QS3-2b4/2b1 PP9, PP11B PCh1.3, PP3, PP4
		Parastrephia sp.	*Parasitic roots			CS1-2(6),(4)			CS1-2(1),1(2),1(1)
Fabaceae (Legume)	wood	*Adesmia horrida*	Tuber	Upper *tolar* and lower *pajonal* (3700-4000 masl)	QS3-2b24-2b15	QS3-2b12-2b10 PCz CS1-2(6)	CS1-2(2) QS3-2b8	QS3-2b5	QS3-2b3-2b1 CS1-2(1) PCH

									PP3, PP4, PP11A
Chenopodiaceae (Chenopod)	Leaves	*Atriplex imbricata*	Leaves	*Tolar* shrublands (3400-3900 masl)		QS3-2b11 CS1-2(6)	CS1-2(2)		PP3 CS1-1(1),(2)
Fabaceae (Legume)	pods	*Hoffmannseggia eremophila*	Tuber	*Tolar* shrublands (3400-3900 masl)		PCz1.1 CS1-2(6),(4),(3) QS3-2b11		QS3-2b5	QS3-2b2-2b4 CS1-1(1) PP3
Cactaceae (Cacti)	fruit	*Maihuenopsis glomerata*	Fruit	*Tolar* shrublands (3400-3900 masl)		CS1-2(6),(3)	CS1- 2(2)		CS1-1(1)
Brassicaceae (Mustard)	fruit	*Neuontobotrys tarapacanus*	Seeds / Roots	*Tolar* shrublands (3400-3900 masl)		CS1-2(6)		QS3-2b5	CS1-1(1), 2(1)
Juncaceae (Rush)	stems	*Juncus balticus* ssp. *mexicanus*	Stem	*Vega* wetlands (3400-4600 masl)		PCz1.1 CS1-2(3)			
Poaceae (Grass)	stems	*Festuca* sp.	Root	*Pajonal* grasslands (3900-4700 masl)		CS1 -2(3)		QS3-2b5	
Cactaceae (Cacti)	thorns	*Trichocereus pasacana*	Fruit	Non-local		QS3 PCz1			PP4

						CS1			
Amaranthaceae (Amaranth)	Seeds	*Amaranthus hybridus*	Seeds	Non-local		PCz1.1			
Verbenaceae (Verbena)	Wood	*Aloysia deserticola*	*Parasitic root	*Tolar* shrublands (3400-3900 masl)			CS1-2(2)		PP11B PP3, PP4
Ephedraceae (Ephedra)	Wood	*Ephedra multiflora*	Fruit, *Parasitic root	*Tolar* shrublands (3400-3900 masl)			CS1-2(2)		
Asteraceae (Sunflower)	Flower	*Artemisia copa*	*Parasitic root	*Pajonal-tolar* ecotone (3700-4000 masl)			CS1-2(2)		
Cyperaceae (Sedge)	stems	*Schoenoplectus americanus*	Rhizome	*Vega* wetlands (3400-4600 masl)					PP4
Poaceae (Grass)	grains	*Zea mays*	Grain	Non-local					PP9, PP4
Fabaceae (Legume)	shells	*Arachis* sp.	Nut	Non-local				QS3-2b5	PP9
Chenopodiaceae (Chenopod)	grains	*Chenopodium quinoa*	Seeds	*Vega* wetlands (3400-3900 masl)					PCh1.3 PP4

									CS1- 1(2)
Cucurbitaceae (Cucurbit)	seeds	*Lagenaria siceraria*	Fruit	Non-local					PP4, PP3, PP9
Fabaceae (Legume)	Wood, seeds	*Prosopis* sp.	Seeds	Non-local	QS3-2b17				PP4, PP3, PP9
	seeds	*Geoffrea decorticans*	Seeds	Non-local					PP9
	beans	*Phaseolus vulgaris*	Seeds	Non-local					PP4
Total plant taxa		**23 species**		**15 local**	**4 local**	**11 local**	**9 local**	**6 local**	**12 local**
				8 non-local	**1 non-local**	**2 non-local**		**1 non-local**	**7 non-local**

Notes:

* *Balanophoraceae* associated with edible parasitic roots in Northwest Argentina and North Chile (Villagrán and Castro 2004:89-91; Cabrera 1957:369).

(1) QS3: Quebrada Seca 3 site; CS1: Cueva Salamanca 1 site; PCz: Peñas de la Cruz 1 site; PP3: Punta de la Peña 3 site; PP4: Punta de la Peña 4 site; PP9: Punta de la Peña 9 site; PP11A: Punta de la Peña 11A site; ; PP11B: Punta de la Peña 11B site; PCh1.3: Peñas Chicas 1.3 site..

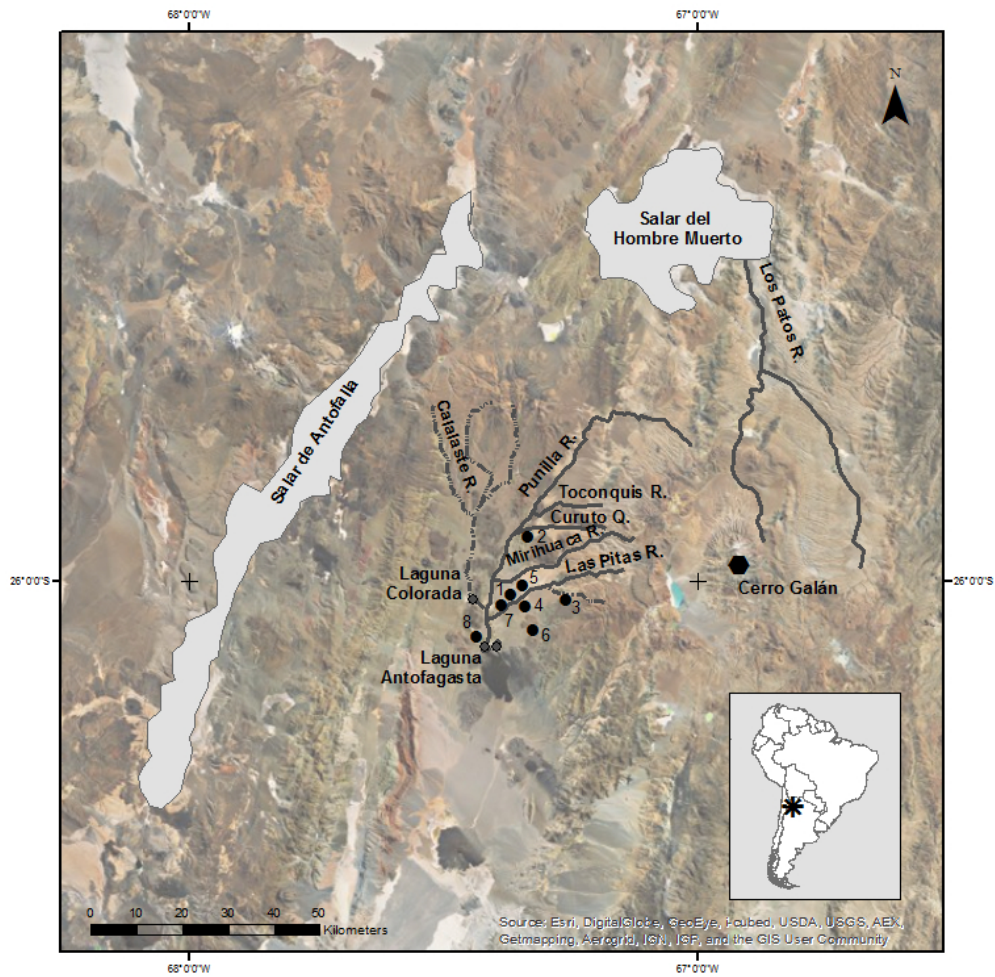Source: Aguirre 2005; Apóstolo et al 2019; Babot 2011; Pintar and Rodríguez 2015; Rodríguez 1999, 2004, 2008, 2013.
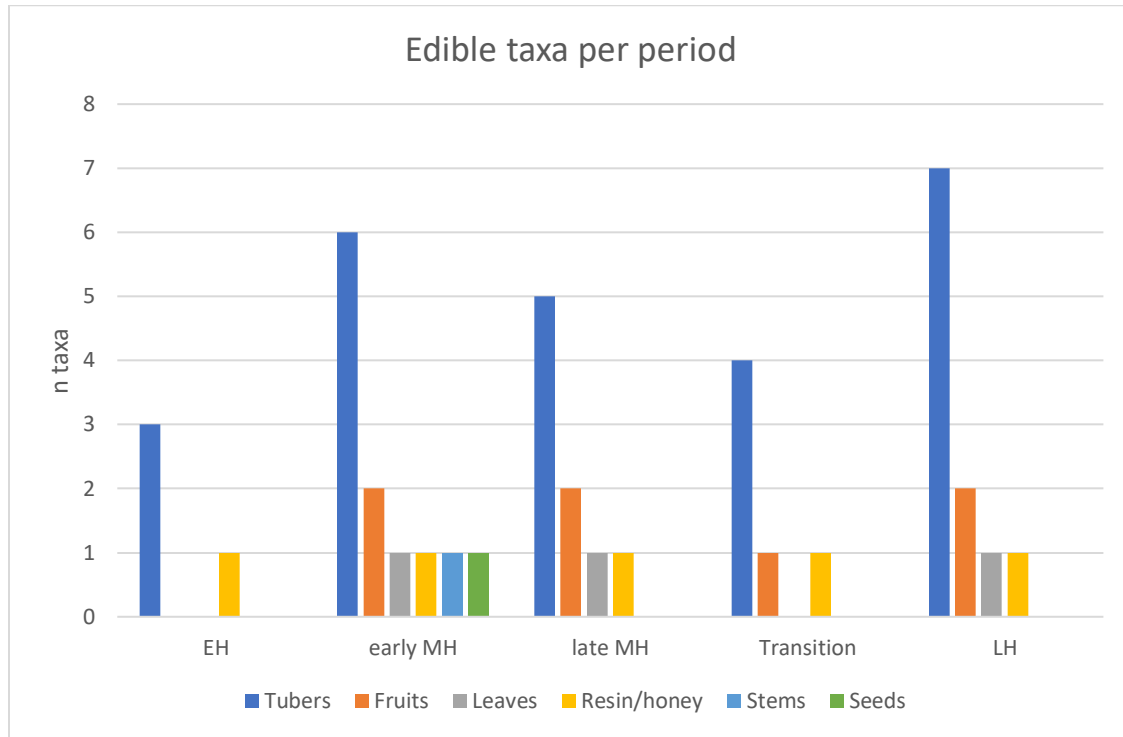
Figure 1

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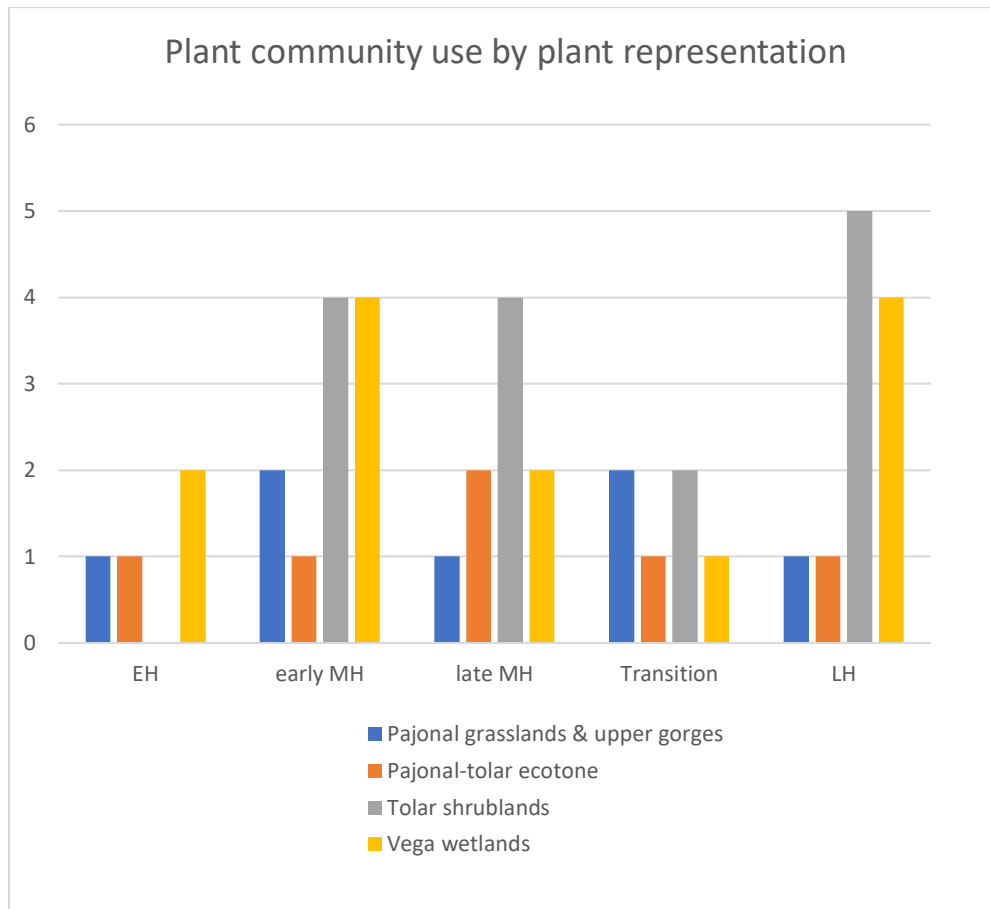41
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Legend for Figure 1:

1: Peñas de las Trampas 1.1; **2:** Cueva Cacao 1A; **3:** Quebrada Seca; **4:** Punta de la Peña (includes sites Punta de la Peña 3, 4, 9, 11); **5:** Cueva Salamanca; **6:** Peñas de la Cruz; **7:** Peñas Chicas; **8:** Casa Chávez Montículos 1

Figure 2: Edible wild taxa per period

Note: Early Holocene (EH), early Middle Holocene (early MH), late Middle Holocene (late MH), Transition between Middle and Late Holocene (Transition), Late Holocene (LH).

Figure 3: Plant community use by plant representation

Plant community use by plant representation

Note: Early Holocene (EH), early Middle Holocene (early MH), late Middle Holocene (late MH), Transition between Middle and Late Holocene (Transition), Late Holocene (LH).