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Late Intermediate Period Plant Use at a Colla Hillfort, Puno, Peru (AD 1300–1450)

BrieAnna S. Langlie

In the Lake Titicaca Basin during the Late Intermediate period (LIP; AD 1100–1450), people's lives were overwhelmingly structured by warfare. Previous research in the region has shed light on how martial conflict between and possibly among competing ethnic groups motivated people to live in fortified villages on defensive hilltops. At the same time, there was a centuries-long drought that threatened agricultural production. Little is known about the plant use of people living in hillforts during this arduous time. Drawing on macrobotanical information collected from Ayawiri, one of the largest hillforts in the northern Titicaca Basin, I argue that the food stuffs and plants used were locally grown. Additionally, these findings indicate a possible departure from earlier symbolically charged and ritually important plant consumption practices based on the lack of imported maize. This research sheds light on how people adapted their domestic and agricultural strategies to warfare and climate change during the LIP.

Keywords: Late Intermediate period, altiplano, war, climate change, paleoethnobotany

La vida de las personas que habitaron la cuenca del Lago Titicaca durante el período Intermedio tardío (LIP), entre 1100 y 1450 dC, estuvo atravesada por conflictos bélicos. Investigaciones previas en la región, han puesto de manifiesto cómo los conflictos marciales entre y, posiblemente, dentro de grupos étnicos incitaron a las personas a vivir en aldeas fortificadas en las cimas de colinas. Asimismo, estudios paleoambientales indican que existió una sequía de siglos que amenazó la producción agrícola. Sin embargo, es poco lo que se conoce acerca del uso de plantas por parte de las personas que vivían en estos lugares. Con base en información macrobotánica recolectada en Ayawiri, una de las mayores montañas en el norte de la cuenca del Titicaca, se determinó que las plantas utilizadas fueron cultivadas localmente. A partir de la comparación de restos paleoetnobotánicos de este sitio con otros recuperados en sitios con cronologías más tempranas de la cuenca del Lago Titicaca, se concluye que la falta de maíz importado indica un cambio, con una carga simbólica y ritual importante, en el consumo de plantas durante el período Intermedio tardío. Estos hallazgos muestran cómo las personas adaptaron sus estrategias domésticas en un contexto signado por la guerra y el cambio climático durante el período Intermedio tardío.

Palabras Clave: período Intermedio tardío, altiplano, guerra, cambio climático, paleoetnobotánica

During the Medieval Climate Anomaly, populations in the Lake Titicaca Basin of the highland Andes experienced reduced precipitation, colder temperatures, and fluctuations in lake levels that altered the local environment, as indicated by nearby paleoclimate proxies (Abbott et al. 1997; Binford et al. 1997; Calaway 2005; Melice and Roucou 1998; Thompson et al. 1986, 1998). Climate change during the Late Intermediate period (LIP; AD 1100–1450; also known as the Altiplano period) has been cited as one of the primary causes for collapse of the Wari and Tiwanaku civilizations, political balkanization throughout the highland Andes, and subsequent endemic conflict beginning around AD 1100 (Seltzer and Hastorf 1990; Stanish 2003). Although farmers in the region have always coped with interannual climate variation, long-term climate change increases the probability of crop failure (Arkush 2008; Augustine 2010; Howden et al. 2007).

Warfare also often leads to food procurement difficulties and nutritive hardships (Ferguson

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2006; LeBlanc 2006; Milner et al. 1991; Otterbein 1999; Wilson and VanDerwarker 2016). When laborers become soldiers and the threats to safety from violence and raids increase, concerns about local food security prompt changes in agricultural practice and foodways. Previous studies show that warfare during the LIP caused security concerns that fundamentally restructured the economy (Arkush 2011; Langlie 2018; Langlie and Arkush 2016).

Researchers working on the LIP have intensively focused on the causes, consequences, and severities of warfare in the region. We know from previous research that warfare during the LIP led people to relocate from lacustrine and riverine valley bottoms to fortified grassy hilltop villages (Arkush 2011; Guamán Poma de Ayala 1980 [1616]; Stanish et al. 1997). Yet, discussions of plant use during the LIP in the altiplano have speculatively drawn on climate proxies, rather than direct evidence of agricultural practice or foodways. This article characterizes LIP plant use patterns and discusses changes in plant usage from earlier Formative and Middle Horizon time periods, based on a macrobotanical analysis of samples from Ayawiri, one of the largest LIP hillforts in the altiplano. Key findings include a heavy reliance on locally grown chenopods and tubers and no evidence for trade crops like maize.

The Site: Ayawiri

Ayawiri is located west of Lake Titicaca at an altitude of 4,100 m asl (Figure 1). The residential sector of the site covers more than 13 ha of the southern portion of a flat mesa; it is surrounded by steep, rainfed terraced hillsides that were constructed and maintained throughout the LIP (Langlie 2016, 2018; Figure 2). Ayawiri was inhabited by the Colla, an ethnic group that presided over the northern Lake Titicaca Basin during the LIP. Although Ayawiri is just one hillfort in the region, this case study is reflective of broader LIP farming adaptations. Many other Titicaca Basin hillforts are similar in layout and architecture and are also surrounded by terraced field complexes (Arkush 2011).

Colla agricultural adaptation did not occur in direct response to the collapse of the Tiwanaku state and the Huari Empire that marked the end of the Middle Horizon; rather, it was formulated over generations of intensifying war and climate change throughout the course of the LIP. Like other Colla hillforts, the population living in the fortress at Ayawiri during the LIP was not significant until AD 1275 according to radiocarbon data (Arkush 2008, 2018), almost two centuries after the accepted date for the failure of Tiwanaku.

At Ayawiri, like many *pukaras* in the Colla region, there were concentrations of houses, kitchen structures, and storage structures that were similar in form and layout and organized into compounds separated by stacked stone compound walls packed densely onto one end of a mesa bounded by a series of defensive walls (Figure 3; Arkush 2008, 2011). There was very little wealth disparity between compounds, which possess similar goods and architecture (Arkush 2011, 2018). Sociopolitics among the Colla was seemingly heterarchical (sensu Crumley 1995), which is quite a departure from the hierarchy and command economies documented during the earlier Tiwanaku Middle Horizon period.

Along these same lines, the Colla at Ayawiri organized agricultural labor and logistics at the extended household level (Langlie 2018). This is evident in the radiating walls that ran from the top of the mesa, where Ayawiri was located, to the valley bottom, separating terraces into vertical tracts managed by extended families (apparent in Figure 2). This is also evident in the unworked and irregularly stacked fieldstones that compose the masonry of terrace retaining walls, in the lack of irrigation, and in the organic layout of the terraces that indicates a lack of centralized planning (see Langlie 2018 for a complete description of the terraces). The timing of the construction of agricultural terraces during the LIP points to the development of adaptive agricultural strategies during this time period (Langlie 2016, 2018). Thus, by providing a characterization of domestic plant use and foodways at Ayawiri and comparing these findings to the distributions in earlier time periods, broad economic changes over time can be documented that reflect farmers' adaptations to new sociopolitical and ecological realities of the era.

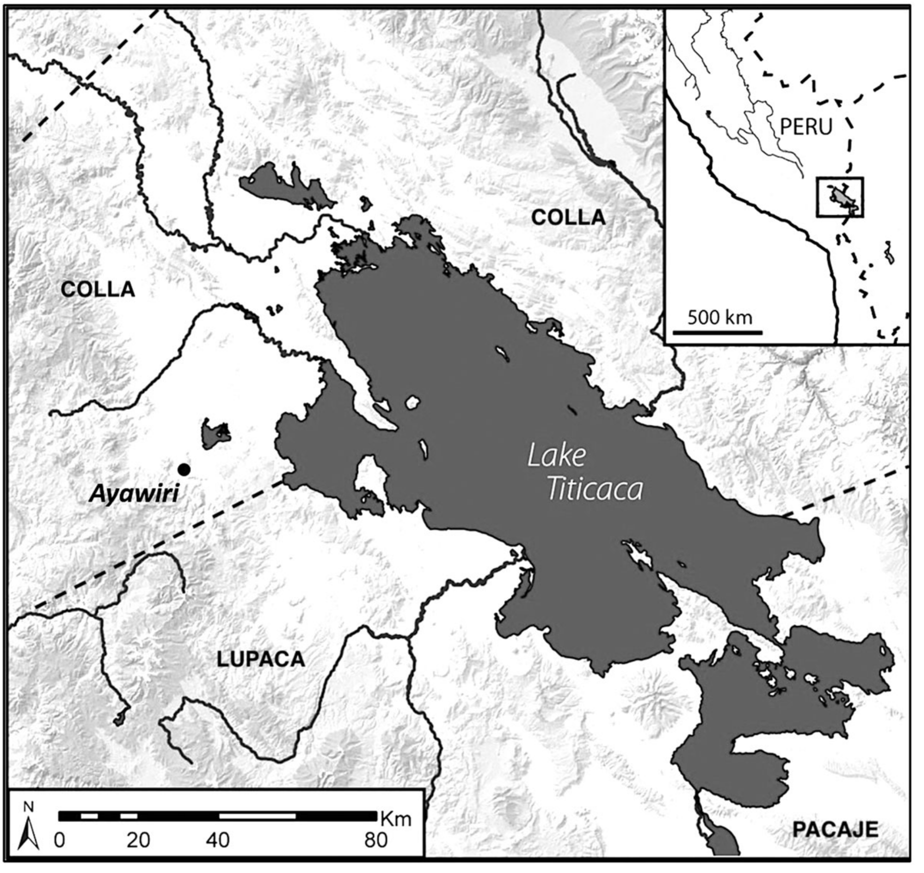

Fig. 1 - B/W online, B/W in print

Figure 1. Map illustrating the location of Ayawiri in the Lake Titicaca Basin (modified from Langlie and Arkush 2016: Figure 12.1).

Paleoethnobotanical Methods

Before excavations began in the domestic sector of Ayawiri in 2011, I designed a standardized paleoethnobotanical procedure as part of the excavation methods used by Proyecto Machu Llaqta. Using a blanket sampling strategy (d'Alpoim Guedes and Spengler 2014; Pearsall 2000), excavators collected approximately 10 L soil samples for flotation from almost every feature and depositional event. These contexts included middens, fill above structure floors and patio floors, and six structure floors. Point soil samples (also referred to as bulk samples; d'Alpoim Guedes and Spengler 2014; Pearsall 2000) were taken from smaller discrete contexts, including hearths, subfloor pits, and burials; pinch samples (also referred to as composite or scatter samples) were recovered from one tomb found in a structure and nine hearths located in structures.

I processed and floated macrobotanical samples in a modified version of a SMAP-style flotation machine (following Watson 1976). Of these samples, 106 were fully sorted with the aim of characterizing plant use across the site and finding evidence of rare and imported taxa that would only be present in small numbers. The remaining two samples from subfloor contexts were floated but contained very large quantities of seeds. A riffle box was used to divide these samples into a manageable volume for analysis; densities were extrapolated based on the proportion analyzed to determine the total quantities of material.

Only carbonized plant remains were analyzed in this study; uncarbonized remains are not preserved because of the seasonally wet

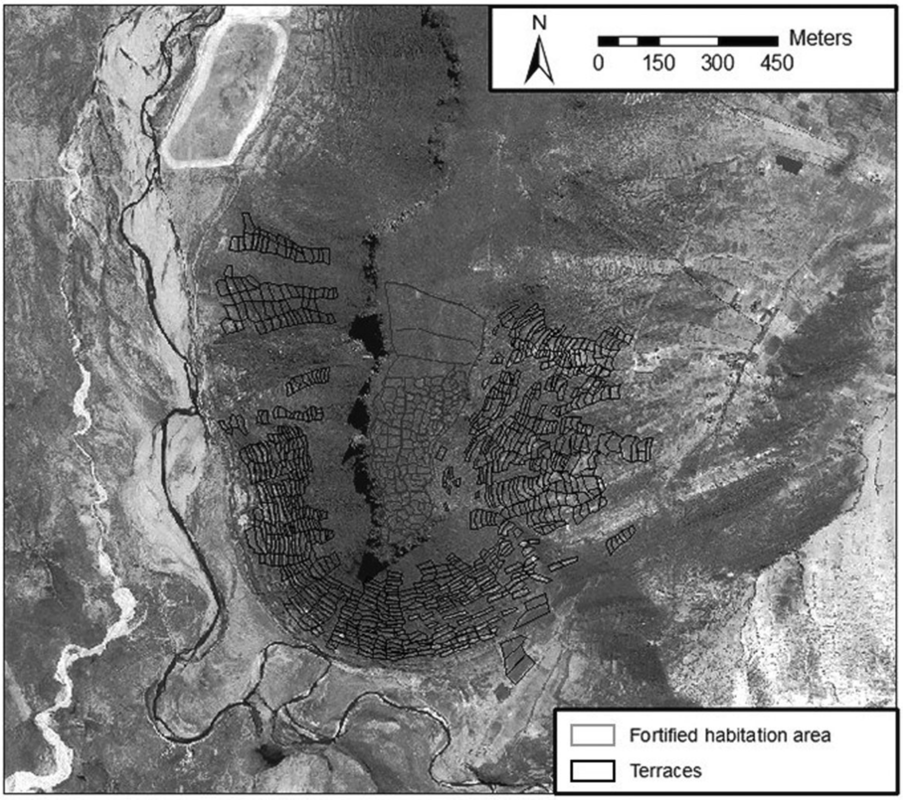

Figure 2. Map depicting the Ayawiri hillfort and surrounding terraces (modified from Langlie and Arkush 2016: Figure 12.3).

environment of the region. There were three possible modes of deposition and preservation of archaeobotanical material at Ayawiri: direct use, fuel, and seed rain. Some plants were directly used for food, medicine, and craft and construction material. These were intentionally discarded in fires or accidentally charred. Other plants were burned as fuel for cooking and warming fires. Because of the paucity of trees in the region, camelid dung is burned for fuel. In these contexts, partially masticated and undigested seeds eaten by camelids are preserved through carbonization (Hastorf and Wright 1998; Miller and Smart 1984). Less commonly, seeds could have been preserved in fires at the site through accidental inclusion due to seed rain, in which seeds are carried in by the wind or "hitchhike" on peoples' clothing or along with other intentionally used plants. Because of overlap in the ways in which plants enter the archaeological record, archaeobotanical data may reflect all three modes of deposition. I therefore present multiple interpretations of the data when appropriate.

This study uses two standard paleoethnobotanical descriptive statistics: ubiquity (expressed as percentage presence of a taxon) and density (expressed as specimens per liter of soil; Marston 2014; Miller 1988; Pearsall 2000). Density sheds light on differences in plant use within Ayawiri, whereas ubiquity is used to compare variation in plant use between sites, because it reduces the impact of sample size, preservation, and recovery issues on quantification as compared to density (Miller 1988).

Results

In this section, I present the types of macrobotanical remains found during analysis in alphabetical order by plant family, along with a brief summary of the known economic values of

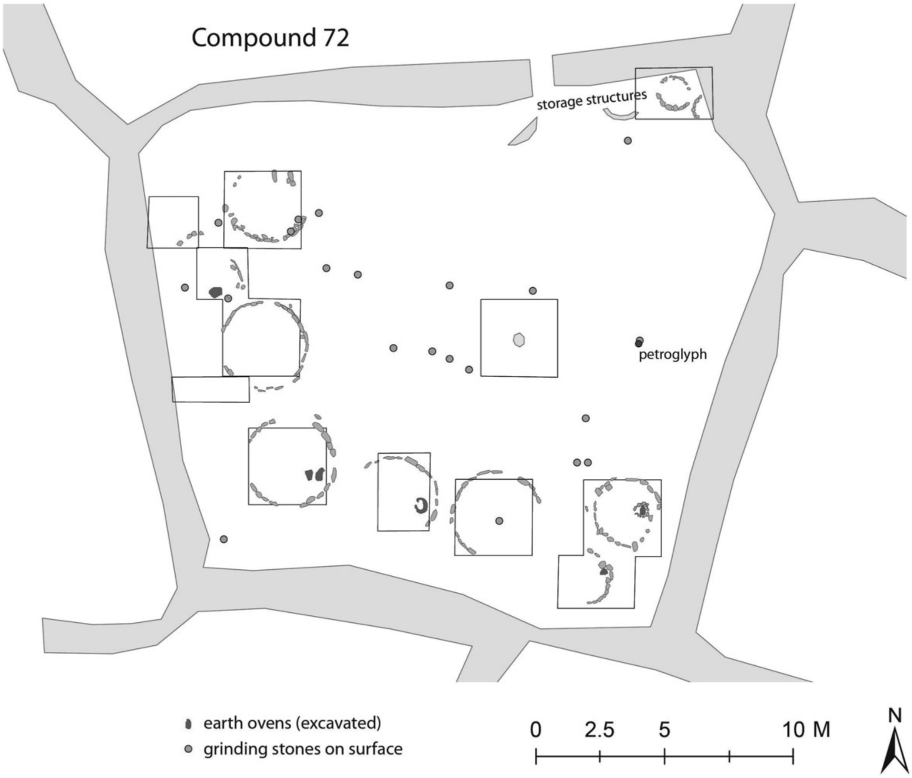

Figure 3. Map of a typical compound at Ayawiri with house structures, kitchen structures (identified by the presence of a cooking hearth), and storage structures around a central open-air patio (modified from Arkush 2018:Figure 3).

each taxon. This information is synthesized in Table 1. I also note possible modes of deposition and preservation of each taxon.

Amaranthaceae

Approximately 1,035,585 chenopod seeds were found in Ayawiri macrobotanical samples (Figure 4). This total includes two dense caches of charred chenopods and whole tubers found directly below house floors. Notably, if these caches are excluded from quantification, chenopods still had the highest standardized density at 21.4 seeds per liter of soil in every other context of the site. This stands in marked contrast to wood, which has the second highest standardized density of any botanical specimen at 1.66 fragments per liter of soil processed. The crop quinoa (*Chenopodium quinoa* var. *quinoa*) and the lesser known but drought-tolerant kañawa (sometimes spelled *cañihua*; *Chenopodium pallidicaule* Aellen) were domesticated in the Andean highlands near the study region for their nutritious grains (Bruno 2006; Bruno and Whitehead 2003; Wilson 1990). Paiko (*Chenopodium ambrosioides* L.) is a wild Andean species that has medicinal properties to treat parasites (Franquemont et al. 1990), and quinoa negra (*Chenopodium quinoa* var. *melanospermum* Hunz.) is a crop-companion weed suitable for fodder. Analysis of quantitative and qualitative traits of 1,017 of these chenopods from just about every context at the site—including hearths, structure floors, patio floors, and middens—and scanning electron analysis of the seed-coat thickness of 73 of these seeds indicate that Ayawiri residents were cultivating both quinoa and kañawa; residents were also meticulously weeding their fields or keeping crop stores clean based on the low presence of the quinoa negra weed type (see Langlie [2019] for a full description of these data). Chenopod seeds could have been preserved at Ayawiri as residues of human food or burned in camelid dung.

Table 1. Summary Table of Macrobotanical Remains from Ayawiri.

Family	Order	Genus species or morphotype	Common name	Absolute count	Standardized density (count/liter)	Ubiquity (expressed as % presence)
Amaranthaceae		*Chenopodium* spp.*	quinoa, kañawa	1,035,585	1,010.13	97
Brassicaceae		Brassica Type #2		5	<0.01	5
Cactaceae	Cactoideae		cactus	28	0.03	3
	Opuntoideae	*Maihuenoposis* cf. *boliviana*	cactus	1	<0.01	1
Cyperaceae		Type #1	cf. totora	7	0.01	6
		Type #2	cf. totora	2	<0.01	2
Fabaceae	Leguminoseae	*Trifolium amabile*		49	0.05	24
Malvaceae		Type #1	mallow family	93	0.10	36
		Unknown	mallow family	16	0.02	9
Plantaginaceae		*Plantago* sp.		1	<0.01	1
Poaceae		Type #1	grass	80	0.08	21
		Type #2	grass	102	0.10	30
		Type #3	grass	3	<0.01	1
		Type #4	grass	12	0.01	10
		Type #5	grass	10	0.01	8
		Type #6	grass	6	0.01	5
		Unknown	grass	150	0.15	27
		cf. *Piptochaetium* sp.	grass	1	<0.01	<1
Rubiaceae		*Relbunium* sp.		8	0.01	6
Solanaceae		cf. *Solanum* sp.	potatoes	4	<0.01	2
Verbenaceae		*Verbena* sp.		3	<0.01	2
Unknown seeds				14	0.01	13
Unidentifiable seed fragments				35	0.03	11
TOTAL SEEDS				1,036,215	1,010.74	N/A
Other botanical specimens		Tuber *Solanum tuberosum* +	potatoes	28	N/A	N/A
		Parenchyma > 2 mm*	cf. tuber tissue	375	0.37	28
		Peduncle		1	<0.01	<1
		Wood > 2 mm		1,667	1.66	80
TOTAL BOTANICAL SPECIMENS (Seed + Other)				1,038,288	1,012.76	N/A
Other		Dung > 2 mm	cf. camelid	15	0.03	4
Bone		Charred		1,270	1.21	25
		Uncharred		334	0.32	17
		Eggshell		3	<0.01	<1

Notes: $N = 108$ samples; 1,025.2 L of soil.
*Projected total
+Found during excavations

Brassicaceae

Five total Brassicaceae seeds were found in Ayawiri macrobotanical samples (Supplemental Figure 1). The seeds are a *Lepidium* species. The Andean root crop maca (*Lepidium meyenii* Walp.) is grown as a cash crop in the central Peruvian highlands today; its wild ancestors still grow throughout Peru, Bolivia, and Argentina (Balick and Lee 2002). Maca is globally sought after for its medicinal value; the powder produced from its dried roots is mixed into beverages and is also used as a stimulant and enhancer of male libido. Additionally, two native wild mustard species have been identified in botanical surveys in the altiplano, including *Lepidium chichicara* Desv. (Sempertegui et al. 2005) and *Lepidium bipinnatifidum* Desv. (Bruno 2008; Pestalozzi Schmid et al. 1998). The latter species has been noted to have medicinal properties (Brack Egg 1999) but is toxic in large quantities. The extremely low occurrence of this seed type at Ayawiri

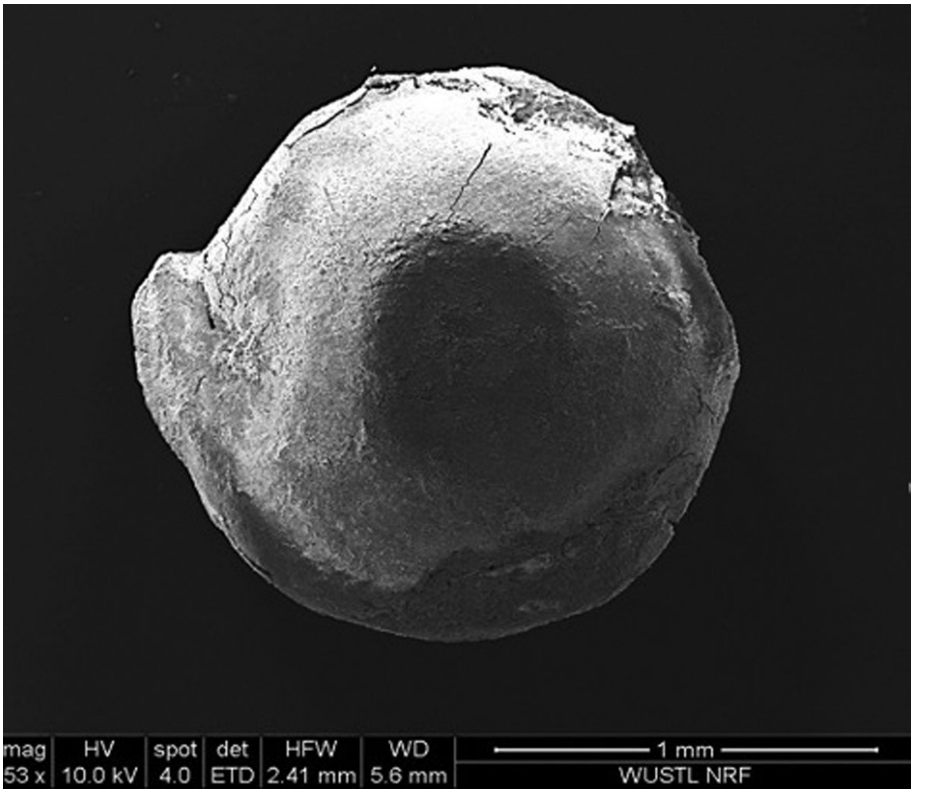

Fig. 4 - B/W online, B/W in print

Figure 4. SEM image of an archaeological *Chenopodium quinoa* seed.

may be attributed to the fact that the wild local *Lepidium* spp. are toxic, so foraging camelids (and humans) probably avoided it.

Cactaceae

Twenty-nine Cactaceae seeds were identified (Supplemental Figure 2). Sweet fleshy cacti fruits are often consumed by both humans and animals throughout the New World. Spines are used for tools, the dried stems are used for fuel (specifically in the Oruro region), and these plants can form a spiny defensive hedge to keep animals away (Browman 1989; Whitehead 2007). Using the spines for tools does not involve fire or using the fruit. Thus, the seeds were probably deposited in fires as waste matter from fruit consumption or in camelid dung burned as fuel.

Cyperaceae

Nine Cyperaceae seeds were found in Ayawiri macrobotanical samples (Supplemental Figure 3). Totora (*Schoenoplectus californicus* C. A. Mey. Soják) is a cultivated aquatic sedge in the Cyperaceae family (Banack et al. 2004; Orlove 1991) used as thatching for roofing material, boats, mats, tools, cordage, and animal fodder in the Titicaca Basin (Browman 1989; Orlove 1991; Whitehead 2007). Due to the paucity of trees in the region, totora has been a very important building material. Totora is also consumed as food (Browman 1989; Bruno 2008): the white, juicy rhizome located at the base is often eaten raw. It does not have much nutritional value, but it has a very fresh-tasting flavor otherwise rare in locally available plants. Although Cyperaceae seeds are regularly found in altiplano samples, archaeobotanists have yet to come up with a way to identify them to the species level. Based on its modern use, it is highly probable that the plant was used the same way in the past and that seeds found in samples derived from totora plants.

Fabaceae

Forty-nine Fabaceae seeds identified as *Trifolium amabile* were found in Ayawiri macrobotanical samples (Supplemental Figure 4). Livestock often consume these wild legumes (Brack Egg 1999), and they are frequently found in camelid dung burned for fuel, indicating that llamas preferentially forage for these plants (Hastorf and Wright 1998).

Malvaceae

There were 109 Malvaceae seeds in Ayawiri macrobotanical samples (Supplemental Figure 5). Bruno (2014:138) notes that members of the *Malva* genus thrive in disturbed agricultural environments in the Titicaca Basin (Graf 1981:364; Paduano et al. 2003:273–274; Pestalozzi Schmid et al. 1998:55). As a preferred forage food of camelids in the region (Hastorf and Wright 1998), these seeds may have also been preserved in burned dung.

Plantaginaceae

Only one *Plantago* sp. seed was found in Ayawiri macrobotanical samples. Young, tender leaves of *Plantago* spp. are sometimes eaten by humans in small amounts (Brack Egg 1999), although this would not necessarily lead to preservation in fires. These seeds are more likely to be preserved in burned dung.

Poaceae

Three hundred and sixty-four Poaceae seeds were identified in Ayawiri macrobotanical samples (Supplemental Figures 6–8) and include more than six distinct morphological types. Camelids heartily forage on grasses in the altiplano (Bruno 2008:246). Grasses are also used for fuel, rope, fiber for basketry, and thatching for roofing material (Bruno 2008:246–247; Whitehead 2007:224). There is also a local tradition of corbel vaulted houses made from stacked grass sod blocks (Chavez 1998). The identified charred Poaceae seeds may derive from burned construction material, chaff used to stoke fires, or the residues of burned dung.

Rubiaceae

Eight *Relbunium* sp. seeds were identified. These small shrubs are found throughout the Andes (Niemeyer and Agüero 2015). The macerated roots of a *Relbunium* sp. provided one of the main sources of red dye used in ancient Andean cotton and camelid fiber textile production (Cardon and Higgitt 2007). *Relbunium* spp. have also been noted as a common camelid forage food, even though they are not ubiquitous plants in the altiplano (Hastorf and Wright 1998).

Solanaceae

Four cf. *Solanum* sp. seeds were identified in Ayawiri macrobotanical samples. Potatoes, in particular, were domesticated in the highland Andes (Flores et al. 2003; Pearsall 2008). These seeds likely arrived at Ayawiri in camelid dung burned for fuel. Alternatively, based on the low density of this taxon, Solanaceae could have arrived as seed rain.

Verbenaceae

Three Verbenaceae seeds were found in Ayawiri macrobotanical samples (see Supplemental Figure 9). The low density and ubiquity of verbena seeds indicate that it was not an economically important plant. With no known uses, this plant was likely brought to the site in dung burned for fuel or as seed rain.

Potatoes, Tubers, and Parenchyma

There were 375 parenchyma fragments in Ayawiri macrobotanical samples (see Supplemental Figure 10). Paleoethnobotanists believe that the distinct parenchyma in archaeological samples from this region is derived from tubers. Additional studies are needed to identify these fragments to the species level. No fewer than 17 species of roots and tubers belonging to at least nine plant families were domesticated in the Andes (Flores et al. 2003). These include the potato (*Solanum tuberosum* L.), oca (*Oxalis tuberosum* Molina), mashwa *(Tropaeolum tuberosum* Ruiz I Pav.), ulluco (*Ullucus tuberosus* Caldas), and maca (*Lepidium meyenii* Walp.; Flores et al. 2003; Pearsall 2008). All of these tubers and roots are boiled or mashed in preparation for consumption. Given this preparation method and the high water content of tuber and root crops, they are rarely preserved in the archaeological record (Pearsall 2000).

As previously mentioned, during excavations two caches of carbonized commingled crops including quinoa, kañawa, and tubers were found below house floors. From these caches, 28 charred, almost complete, small potatoes were found. These were identified as potatoes based on their intact periderm and "eyes," or axillary buds (Figure 5). Based on the presence of these whole potatoes, we can conclude that at least a portion, if not most, of the parenchyma found is from potatoes, indicating these tubers were an important crop plant.

Wood

There were 1,667 fragments of wood in Ayawiri macrobotanical samples. Today, trees are sparse in the altiplano, and palynological studies from lake sediments indicate that this pattern was well established long before the LIP (Gosling and Williams 2013; Paduano et al. 2003). The landscape surrounding Ayawiri is almost completely devoid of native trees except for a few *Polylepis* sp.—locally referred to as *keñua* or *kewiña*—growing on the hillside near the base of the terrace complex.

Additionally, woody shrubs are predominant in the flora of the region and are common on agricultural terrace margins, on steep hillsides near the site, and on the top of the mesa just north of Ayawiri. These shrubs are referred to locally as *tholas* and include the species *Baccharis microphylla* Kunth and *Tetraglochin cristatum* (Britton) Rothm (Bruno 2008; Wright et al. 2003). Because of the scarcity of trees in the altiplano, woody shrubs were likely used as a complementary fuel source to dung in prehistory throughout the region (Bruno 2008). Browman (1989) notes that the roots of tholas are occasionally consumed as a famine food, the leaves are used in teas and tonics, and the shrubs have a few medicinal uses. Without contextual data pointing to medicinal use, the recovered woody fragments were likely evidence of woody shrubs burned to fuel fires.

Interpretation

The relocation of settlements from valley bottoms during the Middle Horizon to hilltop fortresses during the LIP meant that Ayawiri residents were inhabiting a new landscape and ecosystem. After this move, residents had regular access to mountaintops and hillsides; however, reaching riverine and lacustrine resources involved quite a hike and risked exposure to raiders. Characterization of the macrobotanical taxa present at Ayawiri compared to other local macrobotanical datasets from earlier time periods illustrates how humans adapted their agricultural strategies to cope with warfare and climate changes of the era (Table 2; Figure 6).

Diet

The macrobotanical remains found at Ayawiri indicate that residents primarily consumed chenopod crops, cactus fruits, and tubers, including potatoes. These plants continue to be part of a standard diet in the region today. Before humans even began domesticating these crops, natural selection resulted in hardy drought-tolerant varieties. Drawing on Bruno's (2014) research, we know that famers and their crops had adapted to these conditions long before the LIP. Chenopods, in particular, have been recovered from archaeological sites throughout the Andes, including Ecuador, the Peruvian coast, central Chile, Argentina, Bolivia, and the Peruvian highlands. The economic importance of chenopods has been documented in the altiplano region as early as the Archaic and Formative periods (1500 BC–AD 500; Bruno 2006; Bruno and Whitehead 2003; Eisentraut 1998; Langlie et al. 2011). The importance of chenopod crops in the region only grew through time. At Tiwanaku and other nearby sites dating to the Middle Horizon period, Wright and colleagues (2003) found chenopods in ritual and quotidian contexts, indicating the critical cultural importance of these crops.

Even though politics, social life, and the climate changed dramatically from the Middle Horizon to the LIP, the importance of chenopods did not. Indeed, the percent presence of chenopods at Ayawiri (97%) is even higher than that found at Tiwanaku during the Middle Horizon (93%; Wright et al. 2003). The ubiquity and standardized density of chenopods at Ayawiri—found in every compound, in every house structure, and just about every context—indicates that they were essential to the entire community living

Fig. 5 - B/W online, B/W in print

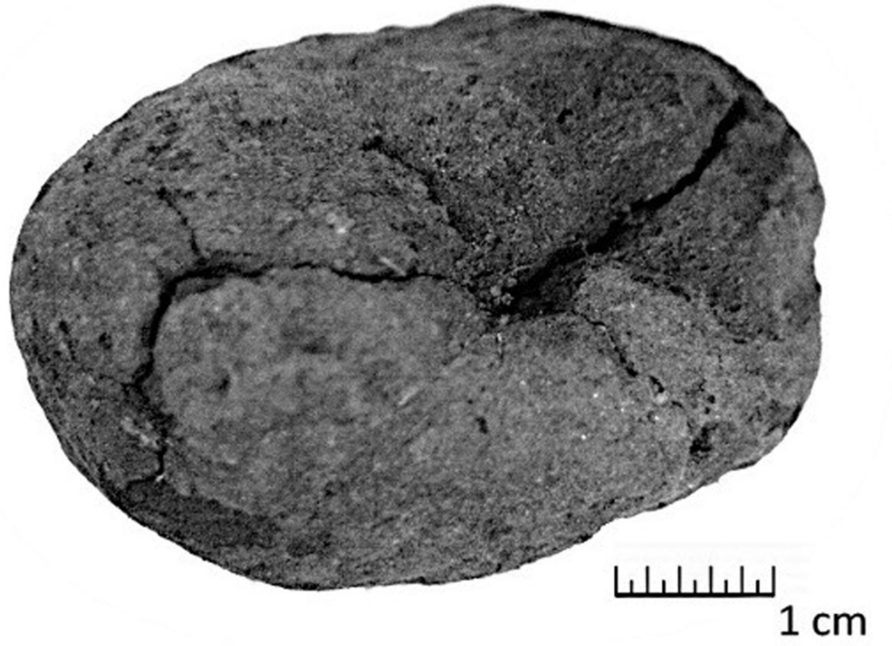

Figure 5. Photo of carbonized archaeological potato depicting the intact periderm and axillary bud.

at Ayawiri. Residents grew and consumed chenopods that are morphologically similar to modern examples of both quinoa and the more drought-tolerant kañawa (see Langlie 2019).

Chenopods in the diet were complemented by potatoes and probably other tubers. Although parenchyma fragments were less common than chenopods in Ayawiri samples, these data do not provide a good indicator of the relative importance of tuber crops. Parenchyma fragments, thought to be tubers, have been found in from 3% (Wright et al. 2003) to 96% of samples (Bruno 2008) from other nearby sites dating to earlier time periods. This variability more clearly illustrates the differential preservation of tubers than it does any quantifiable difference in tuber use.

Exceptionally preserved charred potato remains, like those that were found in the caches at Ayawiri, are a rare occurrence in the archaeological record. These remains may be evidence of charred stores of freeze-dried potatoes, called *chuño*. Freeze-dried potatoes can be stored for up to five years (D'Altroy 2002) and then reconstituted in soups and stews, retaining much of their caloric and nutritional benefits. Freeze-dried potatoes burn and are preserved archaeologically the same way as seeds. At the Formative period site of Chiripa, charred quinoa and chuño were found in ceremonial structures atop the mound there, along with ritual paraphernalia (Bruno and Whitehead 2003; Hastorf 2017:16; Hastorf et al. 2008). Caches of quinoa found at other sites in the southern basin dating to the Formative period have also been interpreted as evidence of hearths, seed saving, or discard of unwanted weedy seeds (Bruno 2008:283, 488–489). The context of these caches below house floors could indicate that they were burnt storage pits. It would not be surprising that Ayawiri residents would be storing grains and potatoes in their homes. Given that nothing around the pits was burned, it is likely that the firing that took place was done as targeted and isolated burning events. Alternatively, these caches could be food offerings made before the structure was built. In this case, these findings could point to the ritual importance of quinoa and potatoes during the LIP.

Vitamin-rich leafy greens would have been available to supplement a grain-and-tuber diet. Chenopod plants are quelites that have spicy edible leaves similar in flavor and texture to

Table 2. Ubiquity Expressed as Percentage Presence of Plant Remains from Titicaca Basin Sites Corresponding to Different Time Periods.

Site	Chiripa	Kala Uyuni and nearby sites	Tiwanaku	Tiwanaku	Tiwanaku	Ayawiri
Time period	Formative (1500–100 BC)	Formative (1500 BC–AD 200)	Late Formative 1 and 2 (200 BC–AD 500)	Middle Horizon (Tiwanaku IV AD 500–800)	Middle Horizon (Tiwanaku V AD 800–1100)	Late Intermediate Period (AD 1300–1450)
Number of Samples	560	213	24	113	204	108
Reference Cited	Whitehead 2007	Bruno 2008	Wright et al. 2003	Wright et al. 2003	Wright et al. 2003	
Crop and Food Plant Remains						
Chenopodium spp.	99	94/98*	96	99	92	97
	28					
Tuber fragments	67	92	16	6	3	28
Maize	0	0.4	20	43	24	0
Cactaceae	23	10	**	**	**	4
Crop Companion Weedy Plant Remains						
Fabaceae	59	92	**	**	**	24
Relbunium sp.	42	71	**	**	**	6
Malvaceae	93	97	**	**	**	39
Verbena sp.	37	81	**	**	**	2
Riverine and Lacustrine Plant Remains						
Cyperaceae	64	91	**	**	**	7
Herbaceous Plant Remains						
Poaceae	92	98	40	57	26	60
Plantago sp.	4	11	**	**	**	1
Other						
Wood	79	99	80	91	88	80
Dung	13	8	88	98	91	4

*Includes *Chenopodium quinoa* and *Chenopodium* spp., respectively (morphological analysis indicates very few seeds were weedy species); data from Langlie 2019.
**Authors lumped these taxa into a single weedy category.

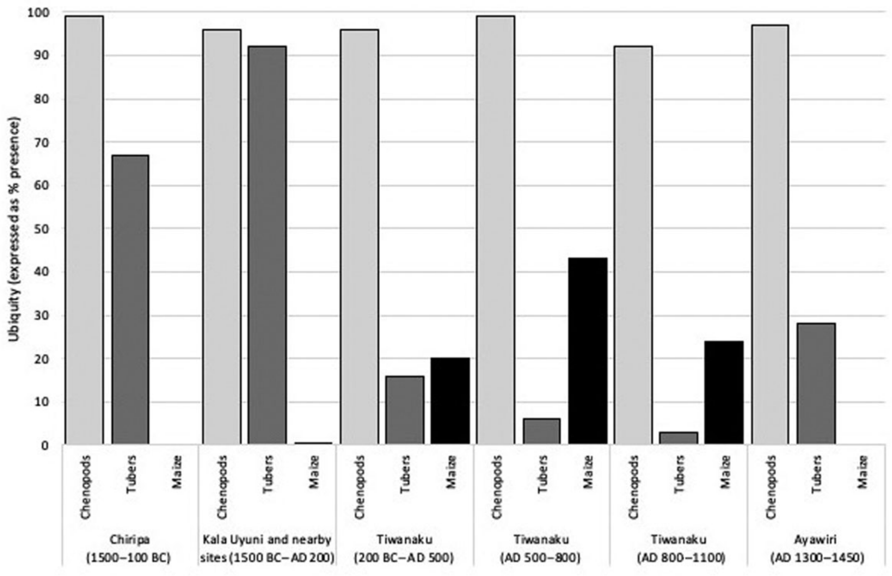

Figure 6. Changes in the ubiquity of food remains through time, derived from archaeological sites located in the Lake Titicaca Basin.

Fig. 6 - B/W online, B/W in print

arugula, and *Plantago* spp. can produce tender young edible leaves that can be eaten raw or added to stews. Leaves quickly disintegrate in the archaeological record; in leafy vegetable form, seeds would not regularly be included in cooking. Although these greens would have been available to residents at Ayawiri based on seeds recovered, it is unlikely that there would be an archaeobotanical trace of leafy greens due to issues of preservation.

Several crop plants were less ubiquitous in the Ayawiri assemblage compared to earlier time periods in the region. Cactus fruits, in particular, have been consumed by humans for approximately 8,000–10,000 years in the central Andes (Browman 1989); they have been found by every archaeobotanical research project in the altiplano, indicating that humans living in the region have been consuming and using this plant since the Archaic period (Browman 1989; Bruno 2008; Eisentraut 1998; Whitehead 2007; Wright et al. 2003). Nevertheless, differences in density and ubiquity between assemblages point to differential use or availability through time. With the intensive construction of terrace fields on the hillslopes surrounding Ayawiri for annual crop production (Langlie 2016, 2018), perennial cactus plants may have been eliminated, subsequently decreasing the availability of cactus fruits. Alternatively, the low density of cactus seeds could indicate a change in food choice or availability caused by a change in climate over time.

The crop notably missing from the Ayawiri assemblage is maize. Today, a maize variety adapted to the harsh altiplano environment is grown in small amounts near lake shores, where the microclimate of the littoral ecotopes protects the lowland crop from nighttime frosts. Generally, maize does not readily grow in the region because of persistent nighttime frosts and high elevation. Nonetheless, maize has long been valued in the altiplano. Logan and colleagues (2012) found microbotanical remains in ritual ceremonial contexts that date back to the Middle Formative period (800–250 BC) on the shores of the southern Lake Titicaca Basin at the site of Chiripa. Bruno (2008) identified a few morphologically nonlocal charred maize kernels from secure contexts at Kala Uyuni, a Formative period site on the southern shores of Lake Titicaca. During the Middle Horizon (AD 500–1100) large quantities of imported maize from the eastern and western slopes of the

Andes were a cornerstone of the local diet for residents at Tiwanaku (Hastorf et al. 2006), where researchers found macrobotanical corn remains to be the second most ubiquitous crop type recovered (Wright et al. 2003). Maize cupules, glumes, and kernels have been found in elite, commoner, domestic, and sacred architectural spaces at Tiwanaku. Drunk as chicha beer, maize also served as a quotidian and ritually important beverage in the past and today in the Andes. Whether drunk or consumed in soups or other recipes, maize has been an integral part of altiplano culture since the Formative period and continues to be important in the region today.

Based on the long-standing, prized use of maize, it would not have been a surprise to find that both its substantive and symbolical value endured during the LIP. Its complete absence at Ayawiri therefore points to a transformation of maize's importance and potentially a shift in sacred and profane plant use during the LIP. Perhaps trade networks broke down due to the fear of enemy attack, eliminating access to maize. Perhaps exotic perishable goods were no longer prized or valued during the LIP, and the absence of maize signals a transformation in culture and symbolism. Alternatively, the absence of maize at Ayawiri could be a result of both of these causes.

Utilitarian Plant Usage

Cyperaceae also decreased in importance during the LIP at Ayawiri based on the low ubiquity of seeds. Browman (1989:151) reports that at the Formative period site Chiripa in the southern Lake Titicaca Basin he found totora impressions in daub, and that Kidder and Bennet found totora thatch in the earliest levels at the site. Twelve seeds are an unusually small quantity of Cyperaceae in an archaeobotanical assemblage in the region. At other earlier sites, Cyperaceae seeds were found in up to 91% of the samples. An accidental house fire would have preserved any seeds attached to the inflorescence. Notably, it is at least an hour hike today to the nearest extant stands of totora in the valley below. Due to its limited local availability, perhaps Ayawiri residents were using it less for construction material than were residents living near littoral ecotopes where these plants thrive. Alternatively, if Cyperaceae seeds were burned in dung as the product of camelid forage food in cooking and heating fires, as is common today (Hastorf and Wright 1998), then camelids had less access to wetland ecotopes during the LIP.

The lower incidence of *Relbunium* sp. seeds compared to other time periods in the region is possibly attributed to changes in llama grazing patterns—given that this genus is a preferred camelid forage food (Hastorf and Wright 1998)—thereby resulting in a lower inclusion in dung burned for fuel. Alternatively, if *Relbunium* sp. plants were used as a textile red dye by Ayawiri residents, then the low density and ubiquity of this plant indicate it was less important during the LIP than previously, when higher ubiquities were reported. Numerous spindle whorls were found discarded on house floors (Arkush 2018; Arkush and Eyzaguirre 2012, 2013), indicating that residents were producing fiber within the residential area of the fort. Perhaps they substituted cochineal, a beetle commonly used to produce red colors, for relbunium dye during the LIP. Or perhaps, weavers produced fewer luxury textiles during the LIP due to the concerns of war and focused instead on making undyed quotidian pieces.

Weeds

There is a general decrease in the ubiquity of weedy seed plants at Ayawiri. There are two possible explanations: (1) residents might have intensively weeded their fields or (2) camelids might have been grazed in fields or foddered on crops more so during the LIP than in earlier time periods. Bruno and Whitehead (2003) noted a decrease in the incidence of crop-companion weeds throughout the Formative period in the central altiplano. There were very few weedy quinoa negra-type specimens in samples that contained upward of a million quinoa seeds (Langlie 2019). These findings corroborate the possibility that Ayawiri farmers were intensively weeding their fields.

Because animal dung, specifically camelid dung, is used for fuel in the Andes, analysis of small weedy species sheds light on grazing behaviors (Bruno and Hastorf 2016; Langlie and Arkush 2016; Miller and Marston 2012). The copious amounts of chenopods found in just about every sample and in every context, combined with a decrease in the abundance and ubiquity of weedy species in the LIP, indicates that camelids were largely grazed or foddered in agricultural fields. Research has demonstrated that, during times of war, farmers intensify agriculture adjacent to areas of settlement nucleation and they abandon fields near contested frontiers to reduce their chances of being attacked or having their fields raided (Netting 1973, 1974). As a part of this practice, farmers may have been intensively weeding their fields to decrease plant competition and increase space for crops. Subsequently, when farmers processed crops for consumption, there would be less weedy seeds mixed in with foodstuffs.

Conclusions

Researchers have speculated that the Medieval Climate Anomaly exacerbated the difficulties of growing crops in the highland Andes during the LIP. In contrast to this supposition, since the advent of agriculture in the region farmers have developed and implemented an array of strategies to overcome environmental and climatic hardships. Bruno (2014) documented farmers in the southern Lake Titicaca Basin practicing soil manipulation, management of soil quality, diversity of production, crop protection, and possibly water manipulation during the Formative period and then today. All of these strategies are aimed at increasing and ensuring crop yields from year to year. Furthermore, during the Formative period in the southern Lake Titicaca Basin, there were periods of drought; nonetheless, "farmers and herders persisted and even expanded at these moments" (Bruno 2014:141). This speaks to the time-tested ability of farmers to readily adapt to different situations.

At Ayawiri, the copious amounts of locally grown crops found in just about every context indicate that Colla farmers were productive. After all, it was in this harsh highland environment where these crops, including potatoes and quinoa, were originally domesticated. Farmers had also formed contingent plans to cope with interannual food shortages, such as storing quinoa and chuño for multiple years and practicing both plant agriculture and animal husbandry, so they could substitute one for the other in lean years. Although Ayawiri farmers surely endured hardships from time to time, the copious amounts of crop remains indicate that residents were, at least for a time during the LIP, successful famers. These resilient agricultural strategies speak to the resourcefulness and intelligence of farmers as active decision makers.

The inclusion of local foodstuffs in subfloor house offerings indicates that quinoa and potatoes may have held ritual importance during the LIP, whereas maize fell from favor. In comparison to the Formative period, these findings also point to a decrease in the number of food crops and in the ubiquity of all plant taxa during the LIP. Unfortunately, a comparison to the Middle Horizon is more difficult to obtain because researchers lumped weedy taxa into a single category for that time period. Archaeologists studying warfare in other parts of the world have documented a similar decline in the number of plants used associated with decreased access to fields and small ecotopes where particular plants were gathered (Kuckelman 2016; Kurin 2016; Milner 1999, 2007; VanDerwarker and Wilson 2016). Several of these researchers have also documented an associated decrease in overall human health (Kuckelman 2016; Kurin 2016; Tung et al. 2016) and declining nutrition (Kuckelman 2016; Kurin 2016).

But when considering this particular case of warfare, a decrease in the diversity of food plants should not necessarily correlate with a decline in general human health. Importantly, quinoa is one of the only crops in the world that provides all essential amino acids, and it is exceptionally high in protein compared to most grains (Repo-Carrasco et al. 2003; Vega-Gálvez et al. 2010). Potatoes contain high amounts of carbohydrates required for day-to-day energy expenditure and important minerals such as iron and vitamins B and C (Kolasa 1993). Based on this nutritional profile, there is no expectation that health would have been poor for the Ayawiri Colla, unless there were interannual food shortages. Bioarcheological analysis of human remains from the site is ongoing.

The low absolute quantity and low incidence of weedy seeds points to two, possibly interrelated, interpretations of farming practice at

Ayawiri. First, farmers may have been intensively weeding their fields. Analysis of landscape use indicates a general intensification of agricultural practice in the land around the site during the LIP (see Langlie 2018; Langlie and Arkush 2016). Meticulously weeding fields would have ensured that crop plants were not outcompeted by weeds, thus increasing food security for those living at Ayawiri. A second explanation, which does not necessarily exclude the first one, is that camelids were grazed in fields or foddered on stored crop plants. Grazing camelids in fields or on crops near the site would have reduced risk for those living at Ayawiri (Langlie 2016; Langlie and Arkush 2016).

Although other researchers have pointed out that an agropastoral lifeway is flexible and resilient to interannual weather variability (for example, Browman 1987), these paleoethnobotanical findings show that Andean agropastoral practices are also a durable subsistence strategy during times of war and climate change. Further studies are needed to understand the geographic and temporal dimensions of LIP agriculture. Rather than looking only at climate proxies and speculating on agriculture practice, it is important to look at how farmers adapted in the past. Farmers, after all, are intelligent and resourceful decision makers. Indeed, Andean agropastoral strategies have survived millennia. The landscape around Ayawiri is still being sown with quinoa and potatoes today.

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Data Availability Statement. Original samples are currently being curated in the Laboratory of Ancient Food and Farming at Binghamton University by the author. All data provided are in the results section of this article. Images of identified plant remains can be found in the supplemental materials.

Supplemental Material. For supplementary material accompanying this article, visit https://doi.org/10.1017/laq.2020.28.

Supplemental Figure 1. SEM image of archaeological Brassicaceae seed.

Supplemental Figure 2. SEM images of archaeological Cactaceae seed (left) and *Opuntia* sp. seed (right).

Supplemental Figure 3. SEM image of archaeological Cyperaceae seed Type #1(left) and Type #2 (right).

Supplemental Figure 4. SEM image of archaeological Fabaceae seed.

Supplemental Figure 5. SEM image of archaeological Malvaceae seed Type #1.

Supplemental Figure 6. SEM Image of Poaceae seed Type #1 (right) and Type #2 (left).

Supplemental Figure 7. SEM image of archaeological Poaceae seed Type #3 (left) and Type #4 (right).

Supplemental Figure 8. SEM image of fragmented archaeological Poaceae seed Type #5 (left) and *Piptochaetium* sp. seed (right).

Supplemental Figure 9. SEM of archaeological *Verbena* sp. seed dorsal side (left) and ventral side (right).

Supplemental Figure 10. SEM image of charred archaeological parenchyma.

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