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ABSTRACT
The high Andes of western South America feature extreme ecological conditions that impose important physiological constraints on humans including high-elevation hypoxia and cold stress. This leads to questions regarding how these environments were colonized by the first waves of humans that reached them during the late Pleistocene. Based on previous research, and aided by human behavioral ecology principles, we assess hunter-gatherer behavioral strategies in the Andean highlands during the late Pleistocene and early Holocene. Specifically, we formulate three mobility strategies and their archaeological expectations and test these using technological and subsistence evidence from the six earliest well-dated highland sites in northern Chile. Our results suggest that all of the studied sites were temporarily occupied for hunting, processing animals, and toolkit maintenance. The sites also exhibit shared technological features within a curatorial strategy albeit with different occupation intensities. From this evidence, we infer that the initial occupations of the highlands were logistical and probably facilitated by increased local resource availability during a period of environmental amelioration.

KEYWORDS
Mobility strategies; foraging; hunter-gatherers; Andes; northern Chile

Introduction

The Andean highlands situated above 3000 masl extend from Colombia to central Chile and Argentina. This region is often considered a crucial natural barrier for early hunter-gatherers because of the important physiological constraints to human habitability that characterize high-elevation environments such as cold temperatures and atmospheric hypoxia (Lanning and Hammel 1961; Lanning 1967; Lanning and Patterson 1967; Lanning 1970; Aldenderfer 1998; Llanos et al. 2007; Aldenderfer 2008). Archaeological research suggests that humans have occupied the region since at least the late Pleistocene (12,700–9500 CAL B.P.), but despite a better understanding now of its paleoecology, how this region was initially inhabited remains poorly understood (Aldenderfer 2006; Aldenderfer and Flores Blanco 2011). Here, we explore the technological and subsistence decisions made by the late Pleistocene and early Holocene hunter-gatherers who occupied the Andean ecosystems in terms of their mobility and resource utilization and influenced by environmental change.

By describing and formulating three distinct mobility strategies, we aim to improve our understanding of early highland landscape utilization. We define these strategies by combining previous seminal regional interpretations (often based on ethnographic analogies) with evolutionary ecology principles applied to highland foraging behavior. We then test these mobility strategies using data from stone artifacts and faunal analyses from the six oldest well-dated highland sites in northern Chile.

Paleoclimate of the Western Andean Cordillera

The western slope of the Andean highlands of northern Chile is characterized by a semi-arid climate. Rainfall decreases abruptly to the west, ranging from ~300 mm in the high puna (see below) (~5000 masl) to less than 10 mm/year in the prepuna (3200–2500 masl) and is practically absent from the hyperarid core of the Atacama Desert (Houston and Hartley 2003). In contrast, temperature decreases at a rate of 6.5°C every 1000 m of elevation gain. Hence, water availability limits the spatial distribution of biological communities at lower elevations whereas low temperatures act at higher elevations. Below 2500 masl the so-called Absolute Desert (devoid of plants) (*sensu* Arroyo et al. 1988) occurs, which gives way to well-developed vegetation belts from 2600 to 4800 masl (Villagrán et al. 1983) as precipitation increases gradually with the elevation. The resulting distribution of plant species richness and cover is typically unimodal and peaking at intermediate to upper elevations (3300–4000 masl), declining towards lower and higher elevations (Arroyo et al. 1998; Holmgren et al. 2008). A clear latitudinal change in precipitation and temperature patterns at ~20°S from wet and temperate weather (north) to drier and colder conditions (south) define two main ecological units referred to as the Dry and Salt Puna, respectively (Troll 1958; Santoro and Núñez 1987; Núñez and Santoro 1988) (FIGURE 1).

Paleoclimate records show prominent variations in hydroclimatic conditions during the late Quaternary along the

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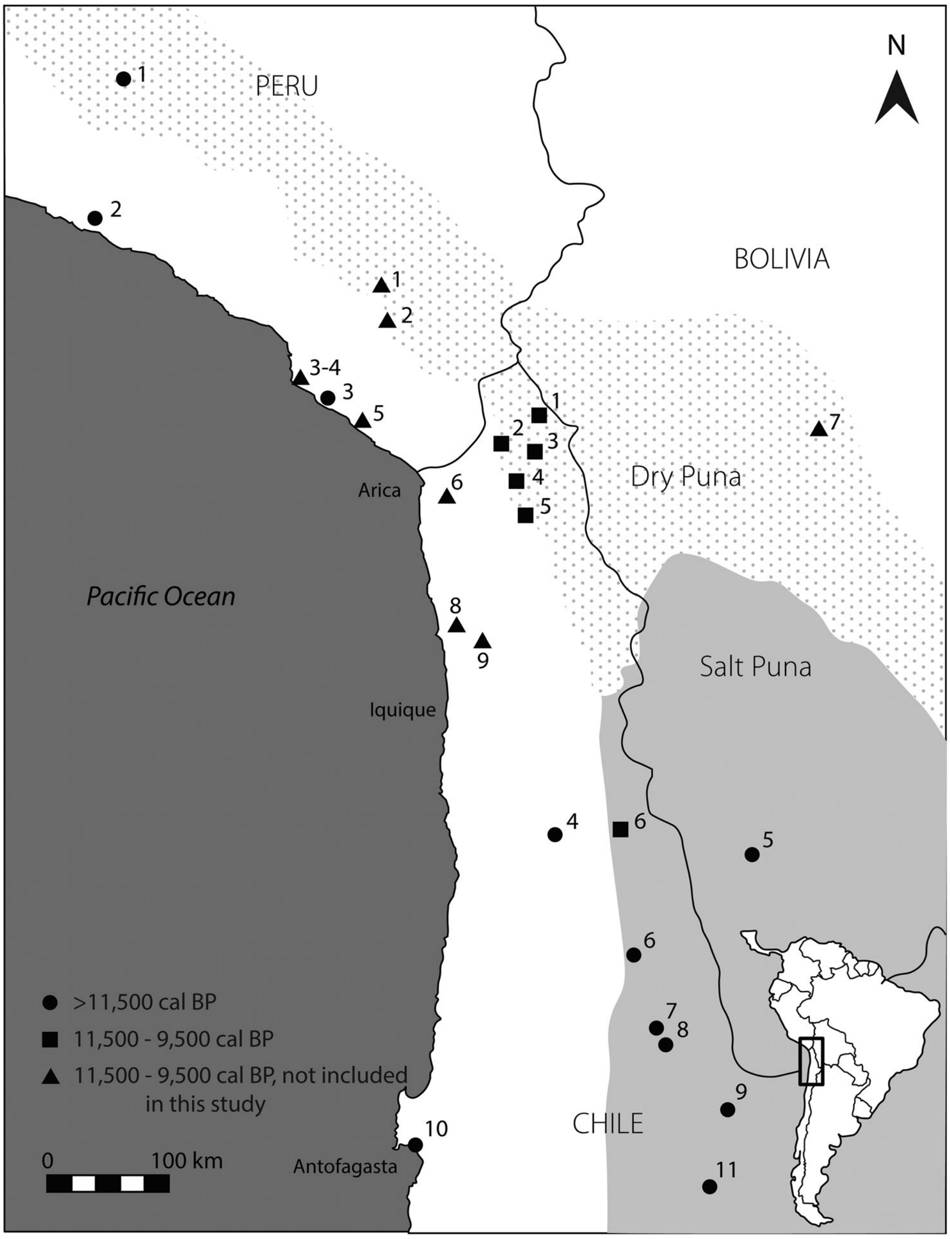

Figure 1. The High Andes of northern Chile showing sites mentioned in the text in the context of late Pleistocene-early Holocene Transition. Circles (sites older than 11,500 CAL B.P.): 1) Cuncaicha; 2) Quebrada Jaguay; 3) Quebrada Tacahuay; 4) Quebrada Mani 12; 5) Cueva Bautista; 6) Alero El Pescador; 7) Tuina 1; 8) Tuina 5; 9) San Lorenzo 1; 10) La Chimba 13; 11) Tulán 109. Squares (sites between 11,500–9500 CAL B.P.): 1) Hakenasa; 2) Patapatane; 3) Las Cuevas; 4) Pampa El Muerto 15; 5) Ipilla 2; 6) Quebrada Blanca. Triangles (sites between 11,500–9500 CAL B.P. not included in this study): 1) Asana; 2) Toquepala; 3) Ring Site; 4) Ilo Km-4; 5) Quebrada de los Burros; 6) Acha; 7) Iroco KCH20; 8) Tiliviche; 9) Aragón.

western Andean flank (Sylvestre et al. 1999; Betancourt et al. 2000; Latorre et al. 2002; Placzek et al. 2006; Moreno et al. 2009). The most prominent was the Central Andean Pluvial Event (or CAPE) that coincided with a prolonged phase of amplified sea surface temperature gradients across the Tropical Pacific (Latorre et al. 2006; Quade et al. 2008; Placzek et al. 2009; Gayo et al. 2012). Two wet pulses have been dated to 17,500–14,200 CAL B.P. (CAPE I phase) and 13,800–9700 CAL B.P. (CAPE II phase), which are approximately equivalent to the Tauca and Coipasa paleolake cycles, respectively (Quade et al. 2008; Placzek et al. 2009; Gayo et al. 2012). These wet pulses were interrupted by a prominent arid phase at ~14,000 CAL B.P. known as the Ticaña event (Sylvestre et al. 1999).

Additional supporting data for the intensity of the CAPE events include rodent middens from northernmost Chile, which indicate that during the interval 14,400–11,600 CAL B.P., rainfall was greater than today (Latorre et al. 2003; Mujica et al. 2015). Similarly, paleowetland deposits show sustained increases in groundwater recharge rate during the interval >15,400–9000 CAL B.P. (Rech 2001; Rech et al. 2002). Small endorheic basins in the Chilean Altiplano evidence lacustrine transgressions at Miscanti, Lejía, and Tuyajto during the late Glacial period into the earliest Holocene, although the potential contribution of a freshwater reservoir effect precludes the establishment of more accurate chronologies (Grosjean et al. 1995; Geyh et al. 1999; Grosjean et al. 2001). Most records agree that climate became significantly drier by 9000 CAL B.P. and perhaps slightly earlier in certain areas of the Atacama Desert (Baied and Wheeler 1993; Schwalb et al. 1999; Betancourt et al. 2000; Latorre et al. 2006; Pintar 2014).

Glacial reconstructions for the Altiplano show that deglaciation likely started after 20,000 CAL B.P. but was interrupted by glacial advances during CAPE I (17,000–15,000 CAL B.P.) and CAPE II (13,200–12,300 CAL B.P.) (Seltzer et al. 2002; Blard et al. 2009; Bromley et al. 2011; Blard et al. 2013).

The positive moisture anomalies prevalent during the late Pleistocene and early Holocene would have also increased groundwater recharge of high Andean aquifers (Rech et al. 2003; Schittek 2014). As a result, the coverage and bioproductivity of high-elevation peat-accumulating wetlands (*bofedales*) would have sustained sizable herds of wild camelids as well as other smaller faunal resources (Squeo et al. 2006; Schittek et al. 2015).

Highland Foraging Strategies in the Andes

The early peopling of the Andean highlands is poorly documented by archaeological research in western South America. The finding of rockshelters and open-air sites containing abundant stone tools and bone remains throughout the 20th century suggested that hunter-gatherers occupied the highlands at an early date (Lanning and Hammel 1961; Cardich 1964; Lanning and Patterson 1967; Lanning 1970). Until the 1970s, however, high-elevation habitats were considered marginal for Andean prehistory given their "harsh" conditions, and were only given a passing glance for explaining trends in the more complex late Prehispanic agricultural societies (Bird 1943; Ravines 1967, 1972). As archaeologists and other scientists acquired a better understanding of the Andean paleoclimate and biodiversity, it became increasingly clear that the highlands could potentially have attracted human hunter-gatherer groups from the beginning of the peopling of South America (Rick 1980; Santoro and Núñez 1987; Aldenderfer 1990, 1998; Kaulicke 1999; Lavallée 2000; Aldenderfer and Flores Blanco 2011; Capriles and Albarracin-Jordan 2013; Rademaker et al. 2014). Furthermore, local environmental conditions at high elevations would have been more favorable especially after the collapse of the ecosystems located in the hyperarid core of the Atacama Desert at the end of the CAPE phases (Gayo et al. 2012; Latorre et al. 2013).

Human behavioral ecology models have proven helpful for addressing questions related to prehistoric hunter-gatherer decision-making (Binford 1980; Kelly 1995; Bettinger 2001; Bird and O'Connell 2006). The application of these models to the Andes (Aldenderfer 2006; Neme and Gil 2010) has helped to explain human adaptation in this diverse, patchy, and often extreme environment. Here, instead of applying a specific formal model to our archaeological case studies, we rely on the principles that underlie the adaptive behavior of hunter-gatherers such as opportunity costs, resource availability, and risk minimization to advance previous interpretations about the nature of the early peopling of the Andean highlands. Thus, we connect ad hoc models with evolutionary ecology principles as predicted by formal synthetic models (Kuhn 2004; Bettinger 2009). Mobility strategies described below for the high Andes imply different and contrasting solutions that people may have adopted depending on behavioral and environmental factors (Table 1). We link our proposed mobility strategies with environmental parameters derived from existing regional paleoenvironmental reconstructions.

Strategy 1: Seasonal Inter-ecological Mobility

Niemeyer and Schiappacasse (1963) first proposed a version of this strategy for northern Chile by using analogies from North America's southwestern hunter-gatherers. They applied it to the archaeological record of an open camp in one of the *quebradas* (deeply incised canyons) of northern Chile, 35 km inland from the coast (Núñez et al. 1975). Independently, for the central Andes, Lynch (1971, 1981) using data from Guitarrero Cave (2400 masl and at ~9° S latitude) proposed an Andean transhumance adaptive model that involved seasonal cyclical mobility between the coast and the high Andes. Since then, a number of scholars have used, evaluated, and built on the concept that the initial highland occupations were part of seasonal cycles of mobility by hunter-gatherers who wandered between the coast (winter) and the highlands (summer).

This strategy, however, is more suitable for the Salt Puna in northern Chile where Prehispanic mobile groups of hunter-gatherers seasonally occupied the highlands (>3000 masl and ~23° S latitude) during summer to procure certain available resources and as a buffer against depletion of lowland resources. For instance, Núñez and colleagues (Núñez 1978; Núñez and Dillehay 1979; Núñez et al. 2002) have suggested that the earliest occupations in the Atacama basin in the Salt Puna consisted of seasonally occupied camps of hunter-gatherers settled in lower and more productive elevations.

Similarly, in the Dry Puna, this strategy was adopted in an environment with highly seasonal ecological regimes with predictably dry winters and wet summers. Arguably, for lowland peoples the most likely time to visit the highlands would have been during the summer-wet season, as camelid herds became increasingly abundant near sources of fresh water. In addition to wildlife, the highlands also had important sources of high-quality lithic raw materials such as obsidian (Tripcevich and Contreras 2013).

Such strategies should be readily testable using the archaeological record (Table 1). For example, one should expect that seasonally occupied residential bases would include lithic assemblages exhibiting the full range of manufacture and maintenance processes, local raw materials, prepared hearths, heavy lithic items, and the presence of exotic raw materials (Meltzer 1989) in their final stages of manufacture and maintenance. Procured animals should be dominated by locally available fauna, particularly artiodactyls of adult age (e.g., guanaco [*Lama guanicoe*], vicuña [*Vicugna vicugna*], and *taruca* [*Hippocamelus antisensis*], an Andean deer species), which would not only be increasingly abundant in the highlands, but would also constitute the prey with the highest post-encounter returns in terms of nutrition (Aldenderfer 1998, 2006). If hunter-gatherers alternated repeatedly between the coast and highlands then exotic artifacts and ecofacts (e.g., marine shells, non-local lithic raw materials) should also be expected.

Strategy 2: Permanent Inter-ecological Mobility

Cardich (1964) proposed that the early inhabitants of Lauricocha (3500 masl and 10° S) in the Peruvian central Andes developed a form of regional nomadism, sustained solely by puna (or highland) resources. Later, Rick (1980) claimed that the "prehistoric hunters of the high Andes" inhabited the region on a permanent basis by specializing in hunting vicuñas that formed part of the highly productive puna environment, which he considered did not fluctuate substantially throughout the year. Although proposed for the central Andes, this strategy could potentially be applicable to regions such as the Bolivian Altiplano, and the Dry Puna of northern

Table 1. High Andes mobility strategies and their archaeological expectations.

Mobility strategy	Group movement	Settlements	Paleo-environment	Lithic raw material	Lithic technology	Fauna
Seasonal inter-ecological mobility	Transhumant	Seasonally occupied residential bases	Marked seasonality, mostly dry	Local and non-local	Full range of reduction processes on local raw materials and final stages on non-local raw materials	Locally available and diagnostic of dry season (e.g., mostly adult camelids)
Permanent intra-ecological mobility	Forager	Residential bases and locations	Moderate seasonality, mostly humid	Mostly local	Full range of reduction processes of local raw materials	Highland taxa including camelids of all age classes
Intermittent mobility	Collector	Logistical camps, stations and base camps	Instable, high coefficient of variation	Mostly local, some non-local	In base camps: full range of reduction processes on local raw materials and final stages on non-local raw materials. In logistical camps: final stages of reduction processes	Heterogeneous taxa from different seasons

Chile, where large spans of ecologically diverse and rich territory occur at 3000–4500 masl. Today, Aymara peoples still inhabit the Altiplano (i.e., Dry Puna) and maintain a pastoral life throughout the year, moving from the Altiplano to the Precordillera during the wet season (summer). Hunter-gatherers could have followed this seasonal cycle (Santoro 1989), but the idea of a mobile foraging system which would include the Bolivian and Chilean Altiplano is a provocative hypothesis that has received little attention (Aldenderfer and Flores Blanco 2011; Capriles and Albarracin-Jordan 2013; Fehren-Schmitz et al. 2015).

Archaeological evidence could aid in revealing what routes were taken by semisedentary hunter-gatherers specializing in highland resources such as guanaco and vicuña. Indeed, forager mobility and recurrently visited residential bases and locations would have facilitated permanent habitations in the highlands. Residential base camps would be comprised of complete lithic reduction sequences of local raw materials for the manufacture of both formal and expedient tools and maintenance of formal ones. In contrast with the previous model, these assemblages would show little or no evidence of foreign lithic raw materials. We would also expect to find evidence of domestic activities such as prepared hearths and heavy lithic items in greater quantity than in the previous model. Faunal assemblages that are specific to the highlands and of all age classes should occur, as people would have procured these resources throughout the year. Goods from the coast and lowland valleys could be present but at very low frequencies.

Strategy 3: Intermittent or Opportunistic Mobility

An intermediate strategy between seasonal mobility and permanent highland foraging suggests that mobile hunter-gatherers visited the highlands depending on fluctuating resource density, abundance, and distribution (Aldenderfer 1993, 1998, 2002). An initial version of this strategy proposed that changing ecological conditions could have either encouraged or discouraged lowland populations to visit the highlands depending on a number of factors such as seasonal productivity, resource abundance, and social circumscription (Santoro and Núñez 1987; Santoro 1989; Dillehay et al. 2003). Later, Aldenderfer (1998) used principles from behavioral ecology to evaluate the Archaic occupation of the well stratified open-air site of Asana (3400 masl), located in southern Peru, and suggested that the decision to venture to the puna would be directly dependent on the reduction of economic risk, which was subject to factors such as ecological suitability and resource availability. We add that lowland peoples would be drawn to the highlands by social exchanges, information, and mating prospects (V. G. Standen, personal communication, 2015).

Such a strategy implies that occupational patterns in the highlands would not be strongly determined by seasonality and would not necessarily involve long-distance movements of entire social groups (Santoro 1989). Hunter-gatherer groups would have occupied the high puna probably in winter for hunting, and then moved across the Dry Puna to different resource areas reactivated by summer rains (Santoro and Núñez 1987). Hence, the archaeological record left by these early hunter-gatherers would consist of intermittently occupied logistical and residential (base) camps. The residential sites should concentrate around specific resource patches suitable for procuring wild game and high quality raw materials. Lithic assemblages should comprise complete reduction sequences of local raw materials including manufacture of both formal and expedient tools and maintenance of formal ones. Lithic reduction at logistical sites would have mostly involved re-sharpening transported and multifunctional tools, particularly bifaces, within a curatorial strategy (Kelly 1988, Nelson 1991). Compared to residential camps, artifact density would be lower due to decreased discard rates. A heterogeneous, seasonally available fauna would be present at both types of sites. Alternatively, if procuring wild game was the goal of foraging trips, then faunal assemblages would be dominated by large artiodactyls and, if necessary, complemented by small game (*vizcacha* [*Lagidium viscacia*], *cholulo* gophers [*Ctenomys opimus*], wild guinea pigs [*Cavia tschudii*], and birds such as Andean geese [*Chloephaga melanoptera*]). Exotic items could also be present. Large fluctuations in environmental conditions would have prompted visiting or abandoning the highlands, and would be one of the drivers behind such an intermittent mobility strategy.

Materials and Methods

We analyzed and integrated archaeological data from six archaeological sites in northern Chile located between 3000 and 4500 masl and dated to the Pleistocene and early Holocene (~11,500–9500 CAL B.P.). Five of these sites (Las Cuevas, Hakenasa, Patapatane, Ipilla 2, and Pampa El Muerto 15) are located in the Dry Puna (3174–4485 masl) of the Arica and Parinacota region (18–19° S), whereas the Quebrada Blanca site is situated further south (~21° S) at 4500 masl within the Salt Puna in the Tarapacá region (FIGURE 1) (Supplemental Material 1). We focused on the earliest levels documented for each one of these sites but we note that most of them also have later occupations (Osorio et al. 2011; Santoro et al. 2011; Ugalde et al.

2012; Herrera et al. 2015; Osorio et al. 2016). Cultural contexts and chronologies for these six sites derive from field reports and AMS radiocarbon dates (Supplemental Material 2).

We compared settlement features with lithic technology and faunal utilization. Stone artifacts were initially sorted into tools, cores, and debitage. Technological, morphological, and functional attributes were analyzed within each category to establish reduction sequences. Our analyses included identifying raw materials as well as recording standard technological attributes related to morphology, size, manufacture, reduction techniques, and macroscopic use wear (Bate 1971; Inizan et al. 1999; Jackson 2002; Andrefsky 2005, 2008; Aschero and Hocsman 2004). Faunal specimens were analyzed using standardized zooarchaeological procedures and identified by taxonomic and anatomic categories (Lyman 1994; Reitz and Wing 2008). Cultural and non-cultural modifications such as worked bone, cut marks, and burning were also recorded.

Results

Lithic Assemblages

Various raw materials were identified in the studied assemblages and attributed to six general categories (FIGURE 2). Although there is a degree of heterogeneity in the relative proportion of each of these raw materials among the different sites, fine-grained siliceous rocks dominate most assemblages. Many different kinds of siliceous rocks were present, most of high quality. Siliceous outcrops are distributed along the Precordillera and valleys below 3500 masl, but so far, have not been systematically surveyed (Osorio et al. 2016). Consistent with a local use of raw materials, Pampa El Muerto 15 (10,720 CAL B.P.), Ipilla 2 (9670–9541 CAL B.P.), and to a lesser extent Patapatane (9030–9400 CAL B.P.), are adjacent to seasonally activated ravine courses where nodules of adequate siliceous rocks for knapping are readily available. In contrast, the siliceous rocks found in Las Cuevas (11,490 CAL B.P.) and Hakenasa (10,890–11,340 CAL B.P.) had to be transported from lower elevations, which would have required journeys of at least 30 to 40 km.

Obsidian, which is ubiquitous at Hakenasa and Las Cuevas, is probably of local origin but of unknown source. Small nodules (< 5 cm) mixed in with surface gravels and consistent with the size of artifacts, however, are common near these sites, and occur throughout the Altiplano. In contrast, obsidian is exotic at the other four sites where it is also infrequent. In addition, the occurrence of other exotic raw materials at most of our sites is less frequent and mainly consists of specific high-quality siliceous rocks. In contrast with these patterns, the most important raw material in Quebrada Blanca (10,925 CAL B.P.) is a local medium-quality basalt. Other raw materials found at this site are from lower elevations, but still within the puna.

Stone tools occupy a narrow range of techno-morphological variability (TABLE 2), and most of them are highly standardized and well maintained, which is consistent with the large amount of retouching waste recorded (FIGURE 3). Projectile points are the most frequently observed stone tool, but they are only present in three of the studied sites (Patapatane, Hakenasa and Ipilla 2), and correspond to five morphological types: stemmed with shoulders (known as Patapatane); triangular with either straight, convex or concave bases; and tetragonal. Many of these projectile points show evidence of maintenance by re-sharpening of the edges (versus the bases), with consequent changes in initial size and morphology and some of them bear evidence of recycling (Herrera et al. 2015). The presence of maintained and recycled projectile points, added to the types of debitage, suggests disposal activities at the sites and that hunting tasks were probably carried out from these sites. Moreover, at Patapatane and Hakenasa, preforms of projectile points and abundant debitage are also present indicating the final stages of the manufacturing processes, probably linked to hunting near these sites.

Sidescrapers are the most important tool observed in Hakenasa; their form is simple or double convex and shows high standardization and maintenance (FIGURE 3D). Semidiscoidal scrapers and end scrapers are also common and highly maintained. Rare artifacts include hammerstones found at Patapatane and Ipilla 2, and core fragments that have only been identified at Hakenasa. Informal or expedient tools are rarely present and include used flakes at Ipilla 2 and retouched flakes at Pampa El Muerto 15. The latter site also includes one notched piece, possibly related to processing plants according to morpho-functional templates (Winchkler 2006; Hocsman 2009; Osorio et al. 2016).

Debitage, or knapping derivatives, dominate the lithic assemblages (~98%) and are mostly derived from late, and to a lesser extent, middle stages of reduction (Supplemental Material 3). Most of the observed debitage is characterized by the absence of cortex (81–98%), small size (< 20 mm, excluding the broken debris), and a preponderance of broken, reduced, and flat platforms (Inizan et al. 1999; Duran and Soler 2006). We also found bifacial trimming flakes with faceted or "complex" platforms, lips, flake curvatures, and dorsal scars in different directions (Andrefsky 2005). Together, these attributes suggest that the activities consisted primarily of shaping and final manufacturing tools, and secondarily bifacial reduction. This is consistent with the absence of complete cores. Only four fragments of exhausted cores were observed in Hakenasa.

The lithic debitage from Patapatane and Ipilla 2 is mainly retouching debitage and to a lesser extent, flakes and other fragments. Most lithic debitage does not have feature cortex and consists of small sizes (< 20 mm). Patapatane differs from Ipilla 2 in its greater number of reduced platforms and a low frequency of bifacial waste. In contrast, bifacial trimming indicates middle stages of the chaine operatoire at Ipilla 2. Additionally, at Las Cuevas three flakes with red pigment were identified. The reduction sequences are very similar among the studied sites, with a preponderance of final formalization (as defined by Andrefsky 2005) and to a lesser extent, re-sharpening of worn out edges. Bifacial knapping was observed at all the sites as well as a low frequency of blades.

Together, the stone tools and debitage suggest that certain activities were carried out at these sites. At Hakenasa, stone pieces indicate final stages of the reduction sequence corresponding mostly to retouching and resharpening of edges. Medium phases of bifacial trimming are also present. In either case, the low frequency of cortical platforms, small sizes of core fragments of siliceous rocks, and obsidian fragments without cortex suggest advanced stage of core reduction. Formal tools show macroscopic wear traces in their active edges and were probably used for hunting animals as well as for processing hides and meat. The frequency of projectile points, scrapers, sidescrapers and knives, suggest animal procurement and meat (and to a lesser extent, plant) processing activities,

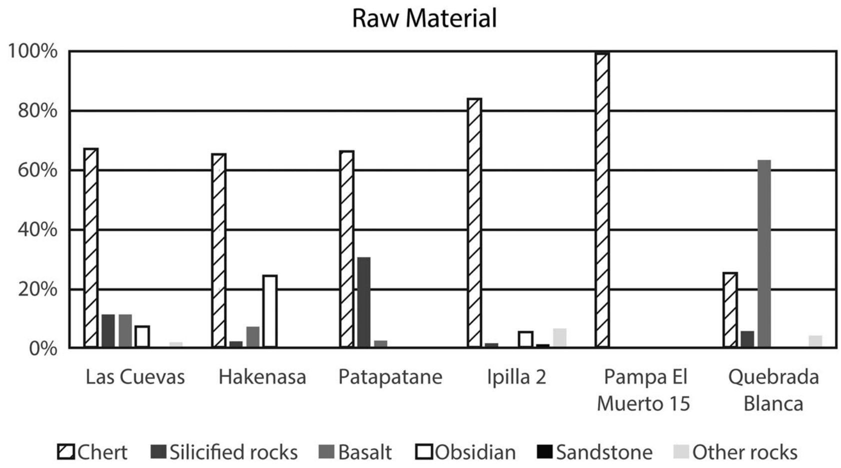

Figure 2. Proportions of raw materials at the studied sites.

which is consistent with the finding of abundant faunal remains, and particularly, camelid remains, found in association with the stone tool assemblages (see below).

Similarly, at Las Cuevas we observed the predominance of the final stages of manufacturing, re-sharpening of worn edges, and to a lesser extent, bifacial knapping. The stone tools are scarce and suggest activities related to scraping and maintenance. As with Patapatane, the final stages of reduction and bifacial trimming during initial manufacture were common at Las Cuevas.

At Ipilla 2, the predominance of medium and mostly final stages of reduction during manufacturing, especially of bifacial artifacts, as well as knives and sidescrapers, indicates diverse activities such as hunting, animal processing, and probably leather scraping. There are also a few expediently manufactured used flakes (with the presence of macroscopic wear traces) and a denticulate scraper possibly used in woodwork (Herrera et al. 2015).

At Pampa El Muerto 15 knapping activities were rare, as this is the site with the most ephemeral occupation. The stone tools and debitage are in their final stages of manufacture; they were used for cutting and processing meat and other soft materials such as plants. The occupation of Quebrada Blanca was probably equally ephemeral, and a retouched fragment (bearing evidence of retouch in its edges) possibly used as a scraper was found along with debitage from the final stages of reduction during manufacturing, particularly re-sharpening of artifacts made from the locally available basalt.

Fauna

Zooarchaeological analysis shows a heterogeneous distribution of faunal remains among the six studied sites (TABLE 3). The broad range of identified specimens suggests divergent depositional trajectories. Hakenasa and Ipilla 2 have the highest number of identified specimens and bone weights, whereas Quebrada Blanca and Las Cuevas have the lowest. Although each site has its unique taphonomic history, observed differences are probably linked to behavioral processes as well as to preservation conditions, as fairly similar areas were sampled at each site. During excavation and analysis, no significant erosional or attritional agents were identified, but soil humidity may be the possible cause for the poor preservation of bones at the Las Cuevas site. The Quebrada Blanca open camp shows no stratigraphic signs of fluvial erosion. The fact that soil formed after human occupation attests to the stability of the post-occupational surface, perhaps as flood energy decreased in the environment.

Although taxonomic richness is low and abundance appears to be fairly even, particularly at Hakenasa and Ipilla 2 where the largest samples are available, specific identifications reveal that artiodactyls, and more specifically camelids, are the dominant taxa. Even without the recourse to an artiodactyl index (Broughton 1994), it is clear that the vast majority of the faunal remains correspond to camelids, particularly guanacos and vicuñas, as suggested by incisor morphology and size of well-preserved epiphyses of fused elements. The finding of dozens of diaphysis fragments of

Table 2. Frequencies of stone tools and debitage from the studied sites.

Lithic tools	Las Cuevas	Hakenasa	Patapatane	Ipilla 2	Pampa El Muerto 15	Quebrada Blanca	Total
Projectile point		6	11	3			20
Biface			2	1	1		4
Preform	1	6	1				8
Scraper	1	10		1			12
Sidescraper		11	1				12
Knife				2	3		5
Used flake				3			3
Notch					1		1
Abrader			2				2
Hammer			1	1			2
Denticulate scraper				1			1
Retouched fragment	1	4		5	1	1	12
Core fragment		4					4
Tools subtotal	3	41	18	17	6	1	86
Debitage	354	1246	893	1870	20	133	4516
Total	357	1287	911	1887	26	134	4601

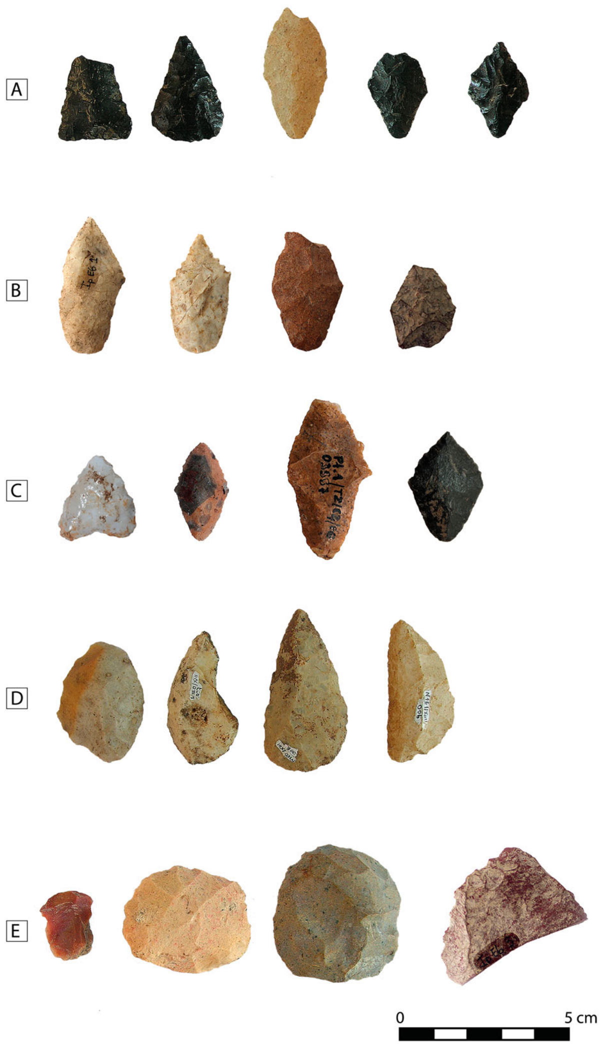

Figure 3. Examples of stone tools from the studied sites. A) Projectile points from Hakenasa: triangular with straight base, triangular with convex base, stemmed with shoulders (Patapatane type), and tetragonal; B) Projectile points from Ipilla 2: stemmed with shoulders; C) Projectile points from Patapatane: triangular with concave base, and stemmed with shoulders; D) Sidescrapers from Hakenasa; E) Scrapers from Hakenasa and denticulate from Ipilla 2.

both fused and unfused long bones, also supports the dominance of camelids in the assemblages. A few deer bones, probably corresponding to taruca, were identified at Hakenasa, the site with the largest sample.

Mid-sized rodents from various taxa including vizcachas, wild guinea pigs, cholulo, and others are occasionally present, particularly at Hakenasa. Several of the identified bones show evidence of burning and fragmentation marks consistent with human consumption. The most frequent identified rodents are vizcachas, which are fairly conspicuous and abundant in the highlands, and were probably captured as a secondary food item. The same is true for the other species of rodents such as wild guinea pigs and cholulo, which are easily snared (Santoro and Núñez 1987; Santoro 1989; Capriles 2014).

Birds are fairly ubiquitous, and are present in half of the studied sites. Unfortunately, most of the assemblages consisted of fragmented long bone diaphyses, which are difficult to identify taxonomically. Based on size alone, however, some of these bones seemingly correspond to middle-sized aquatic fowl such as ducks, teals, grebes, and coots. In fact, several duck and coot specimens were identified at Hakenasa, but only in later occupation levels.

In addition to the highland artiodactyls, mid-size rodents and birds, only a few exotic taxa were found at some of the studied sites. For instance, shark teeth were identified at Las Cuevas and Patapatane. Several unidentified fish bones (presumably from the Pacific Ocean) and mussel shell fragments (*Choromytilus chorus*) were also recorded at Patapatane. Two of the shell fragments had some retouch and evidence of polishing on the edges that suggests these marine items were possibly transported for utilitarian purposes (Santoro and Núñez 1987; Santoro 1989).

Discussion

The six studied sites were located within relatively well-circumscribed microenvironments found at different elevations and possibly occupied for different but related purposes. These sites were initially occupied during the late Pleistocene-early Holocene transition, a period during which the highlands benefited from favorable environmental conditions (Seltzer et al. 2002; Blard et al. 2009; Moreno et al. 2009; Bromley et al. 2011; Santoro et al. 2011; Gayo et al. 2012; Blard et al. 2013; Pintar 2014; Mujica et al. 2015). Diverse highland fauna populated dense patches of grasslands and wetlands in the Dry and Salt Puna and made the region attractive to humans for exploring, extracting resources, and eventually residing at high-elevations for longer periods of time.

As part of the resource utilization strategies of these early hunter-gatherers, we identified a particular pattern of raw material use that involved intensive utilization of a diverse array of fine-grained siliceous rocks from lower elevation puna locations (3000–3750 masl) and igneous rocks (such as obsidian and basalt) from high-elevation puna locations (3750–4500 masl). Specifically, raw materials at the lower puna sites (Patapatane, Pampa El Muerto 15 and Ipilla 2) were mostly locally sourced cryptocrystalline siliceous rocks, whereas at higher Puna sites (Las Cuevas, Hakenasa, Quebrada Blanca) raw materials consisted of a mix of local igneous and non-local cryptocrystalline siliceous rocks, suggesting reliance on an embedded procurement strategy (*sensu* Binford 1979).

The evidence of tool maintenance is present at all sites given the high frequency of retouching flakes, the high ratio of debitage to tools, and the recurrent evidence of changes in sizes and shapes of the tools because of their continuous use and maintenance. The final stages of manufacturing, the high degree of maintenance, the use and preparation of bifacial tools (all of them showing macroscopic wear traces), the scarce number of cores, the low discard rate of tools, and the absence of heavy artifacts allow us to classify the sites as logistical camps (*sensu* Binford 1980), occupied for hunting and processing animals as well as exploring new areas. Moreover, for most of our sites artifacts are few and in many cases exhibit intensive use and high investment in their manufacture (i.e., final stages of manufacturing, re-sharpening, and to a lesser degree, the active use of edges and recycling), all of which are typical of curatorial strategies (Nelson 1991) and often associated with high mobility.

As with the stone assemblages, faunal remains are also few and unevenly distributed among sites. Artiodactyls, especially camelids, dominate the faunal assemblages of all of the sites, but mid-size rodents and birds were also regularly procured. Given the small and fragmented faunal collections,

Table 3. Number of identified specimens (NISP) of faunal remains from the studied sites.

Taxa	Las Cuevas	Hakenasa	Patapatane	Ipilla 2	Pampa El Muerto 15	Quebrada Blanca	Total
Mammalia							
Artiodactylia							
Camelidae	1	310	67	6	2	2	388
Cervidae		14					14
Indeterminate	4	1948	280	278	97	5	2612
Carnivora							
Indeterminate		2			2		4
Rodentia							
Lagidium sp.		27	2	1	6		36
Cavia sp.		28					28
Galea sp.		1					1
Ctenomys sp.		1					1
Mid-size rodent		69	57	2			128
Small-size rodent			1	1			2
Birds							
Indeterminate		96	1		18	1	116
Anura							
Indeterminate		3					3
Osteoichtyes							
Indeterminate			2				2
Chondrichthyes							
Elasmobranchii	1						1
Mollusca							
Choromytilus chorus			8				8
Macrofauna							
Indeterminate		203	136	>50	12	3	404
Microfauna							
Indeterminate		147	32			1	180
Total (NISP)	6	2849	586	338	137	12	3928
Weight (grams)	3.34	2493.64	401.94	960.3	61.29	6.71	3927.22

information regarding seasonality is scarce, but the presence of abundant unfused bone remains along with waterfowl remains, suggests the possibility that some sites were occupied during the wet summer season (Moore 1998). Together, these attributes suggest that the bones accumulated during sporadic occupational episodes. Furthermore, although a few smaller animals such as mid-sized caviomorph rodents and birds are common, the preponderance of artiodactyl remains suggests that the dietary breadth was relatively narrow and specialized. In fact, small mammals and birds, especially waterfowl, were probably procured opportunistically as complementary dietary items during artiodactyl hunting expeditions.

Comparing the density of stone tools and faunal remains across the different sites suggests that some sites were also used for diverse activities and that reoccupation at some sites was significant (FIGURE 4). For instance, whereas Las Cuevas and Quebrada Blanca have similarly low densities of bone remains, the former has a substantially larger stone assemblage. In contrast, although Hakenasa and Ipilla 2 have high densities of both stone artifacts and faunal remains, the techno-typological analysis of lithic tools and debitage suggests that diverse activities such as tool maintenance, hunting, and processing animals were carried out at each of these sites.

At Hakenasa and Ipilla 2, a dense and diverse faunal assemblage dominated by wild camelids is correlated with an equally dense lithic assemblage where high quality raw materials and the manufacture of easily transportable bifaces, projectile points, and scrapers are prevalent. This seems to indicate that these sites were strategically reoccupied over time. The likely frequent reoccupation of these sites and association with different, but productive, microenvironments could have made these locations attractive for mobile hunter-

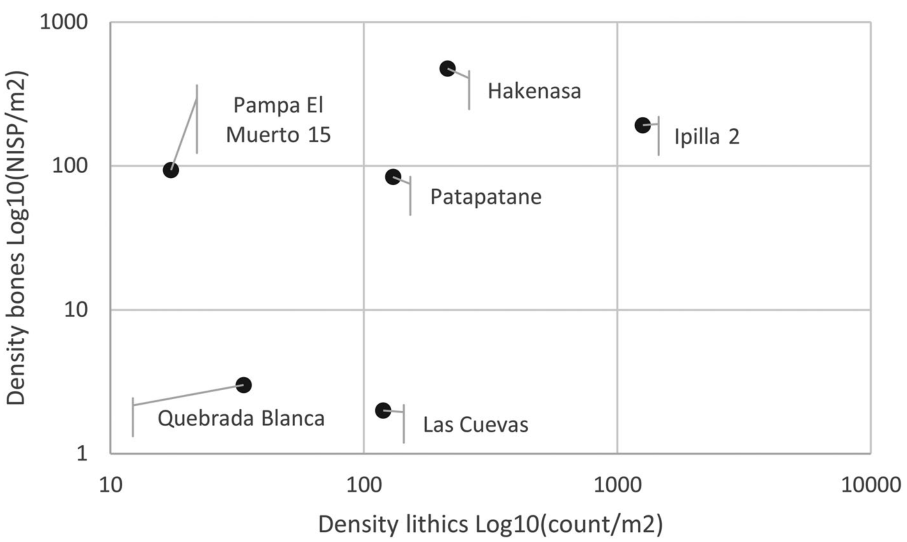

Figure 4. Densities of faunal remains and lithics among the studied sites. NISP = Number of Identified Specimens.

gatherers groups (Santoro and Núñez 1987; Santoro 1989; Osorio et al. 2011; Herrera et al. 2015; Santoro et al. 2016).

Las Cuevas, Quebrada Blanca, and Pampa El Muerto 15 could have been occupied as logistical resource exploitation sites, where small groups of people camped during hunting explorations. These sites show evidence of low-intensity occupation with small faunal assemblages, minimal presence of finished tools, and the final stages of manufacturing artifacts, suggesting that mainly maintenance activities took place at these sites. The lack of projectile points and small faunal assemblages might mask their possible roles as hunting locations, although hunting camps are known for their ephemeral nature (Binford 1980). Alternatively, given the association of sites having short occupational histories with new resource areas (Steele and Rockman 2003), these settlements could also have been related to regional exploration by hunter-gatherer groups searching across fluctuating resource patches.

Finally, Patapatane is a site that is not only intermediate in terms of its lithic and faunal density and diversity, but it is also strategically located between the higher and lower portions of the highlands. The materials and tools found at Patapatane closely resemble those from Ipilla 2, and both were sites likely reoccupied by the same hunter-gatherer groups as they seem to be both environmentally and temporally associated. In addition, the potentially logistical occupation of Patapatane and Las Cuevas by people who visited or exchanged with peoples from the Pacific coast is further implied by the occurrence of marine items such as mussel shells and shark teeth, presumably used as scraping or cutting tools, and strontium isotope signatures (Santoro 1989; V. G. Standen, personal communication 2015).

Several authors initially suggested modeling mobility between the coast and highlands (Niemeyer and Schiappacasse 1963; Núñez 1975; Schiappacasse and Niemeyer 1984; Santoro and Núñez 1987). Muñoz and Chacama (1993) later pointed to a connection between the early Holocene Acha-2 and Patapatane sites, based on the resemblance of the Acha projectile points with the morphology of the Patapatane ones (Muñoz 1993). Similarly, Sandweiss and colleagues (1998) identified highland obsidian at the late Pleistocene coastal site of Quebrada Jaguay. More recently, Rademaker and collaborators (2014) verified a contemporary occupation at Cuncaicha, a rockshelter situated at 4500 masl near the Alca source in Arequipa, Peru. This evidence, however, could have also resulted from exchange between coastal and highland peoples, and technological analyses of artifacts from Patapatane and Acha-2 sites are required to verify this proposition.

We have documented a range of activities typically carried out at logistical camps, consistent with the findings of Aldenderfer (1998) at Asana, a site initially occupied as a logistical camp. It is remarkable that in so many of years of research, no residential base camps have been found. In part, this dearth of residential occupation is the result of a lack of systematic surveys in the Puna and a strong sampling bias in favor of caves and rockshelters, along with a lack of critical analyses of the indicators to identify these camps. It is, of course, possible that the earliest residential camps consisted of open-air sites that today are covered or even obliterated by alluvium (Borejsza et al. 2014). Based solely on the lithic technology, in a previous study we argued that the earliest occupation of Hakenasa corresponded to a logistical camp used for multiple activities (Osorio et al. 2011). We also reported that Ipilla 2 contained a diverse array of tools used in multiple tasks, including processing materials, cutting, scraping, and other tasks (Herrera et al. 2015). The zooarchaeological evidence reported here as well as the stone tool analyses from four additional sites lends further support for these hypotheses, and emphasizes that hunting and processing of wild fauna in a context of high mobility were the most significant activities carried out at these sites. The presence of logistical camps and therefore the development of a collector strategy may reflect a sort of highly dynamic mobility system that allowed people to connect over large regions within the remote high Andes, and thus constituted a mega-ecological patch for these early hunter-gatherers (Kelly 2003; Osorio et al. 2011).

Conclusions

The initial occupation of the highlands of northern Chile was part of an emergent Andean human mobility system that connected adjacent ecological environments spanning across different elevations. All the studied sites correspond to either logistical or temporary camps, and thus fit our proposed intermittent mobility model, Strategy 3. The other two models are based on residential mobility, which does not include the type of logistical camp we have identified in our sampled sites. Rather, these models only consider residential camps and locations. This suggests that groups of hunter-gatherers—who were already settled either at lower elevations within the Andes or within the surrounding Altiplano—dared to explore the studied area from time to time on an opportunistic basis. Over time, intermittent (and opportunistic) mobility included an increasingly prolonged and more permanent occupation of the highlands (Aldenderfer 1990, 1993; Sepúlveda et al. 2013). Hunter-gatherers who occupied the highland territories of northern Chile managed strategic environmental and technological knowledge and developed adaptions to both high-elevation hypoxia and cold stress (Santoro 1989; Núñez et al. 2002; Aldenderfer and Flores Blanco 2011; Osorio et al. 2011; Capriles et al. 2016).

All of the sites described here rely on the procurement of artiodactyls with a specialized bifacial and curatorial technology, represented by formal tools and debitage from the final stages of reduction. A strong sign of this technology is the Patapatane projectile point type, which has been identified in a number of early sites mostly in Peru (Santoro and Núñez 1987; Santoro 1989; Klink and Aldenderfer 2005. This particular type persisted for most of the early Holocene, suggesting some form of stability over time (Rick 1980). Retaining a similar design of projectile points might relate to information transmission within a common cultural background, and consequently serve as an identity marker that the earliest hunter-gatherer groups shared throughout most of the south-central Andes during the late Pleistocene to early Holocene. The Patapatane type resembles the projectile points in the high Andes, which gives a larger dimension to the sharing of ideas (Santoro 1989), technological procedures, subsistence and settlement organization, and other cultural patterns of these early highland hunter-gatherer groups.

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