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## Towards a Human Ecology for the Middle Holocene in the Southern Puna

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### ABSTRACT

Human groups share their habitat with a multitude of life forms and, like them, must develop behaviors that enable long-term use of the environment, as well as the interaction between species and with other groups. The environmental basic conditions are largely shaped by natural factors, such as climate, geomorphology, soil properties and species diversity. However, humans change these basic conditions with the development of livelihood strategies, technological, organizational forms, corporate resolutions, etc. The mid-Holocene, the period from ca. 8200 to ca. 3700 BP, is a unique moment to study the interaction between human groups and their habitats. Against the backdrop of directional climate change and its environmental consequences, the Middle Holocene human groups generated a series of innovations and strategies over time that changed the social settings and set the stage for later developments. This paper presents a model of environmental fragmentation to account for the social and cultural strategies developed by hunter-gatherers of the period, exemplified with the changes in the use of animal resources at the regional level in the Puna de Atacama of Chile and Argentina.

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### 1. Introduction

The Middle Holocene provides a good example of relatively synchronous global climatic change. The direction of this change was not the same across the whole planet, but in the lower latitudes drier conditions and, in some cases, high temperatures (the Alti-thermal) were produced. The Sahara, for example, was transformed from a savannah into a hyper-arid desert between 8000 and 4500 BP (Barham and Mitchell, 2008).

An abundance of information suggests that during the Middle Holocene there were long-term fluctuations with events occurring at the intervals of 2800–2000 and 1500 years (Mayewski et al., 2004), although the causes for these events are still not well documented. Some authors have proposed that changes in solar insolation and in the configuration of ice masses explain a substantial part of the climatic variability observed since 18,000 years ago (Dunbar, 2000). These changes in solar radiation in particular affected low-latitude regions in a special way, where the precipitation levels are a function of the anomalies in solar radiation (Bradley, 2005: 11). Mayewski et al. (2004) consider that this forcing, combined with migration towards the south of the Inter-tropical Convergence Zone, can perhaps explain the dryness in the low latitudes recorded for periods between 6000 and 4800 cal. BP. Against this background, regular fluctuations in temperature and

precipitation occurred in 200 year cycles (for example, during anomalies in atmospheric circulation such as the ENSO).

In South America's Puna region, the nature of climate change during the Middle Holocene was controversial for a time. Some authors proposed that it had been a generally arid period, in some cases extremely arid (Grosjean and Núñez, 1994), while others questioned this interpretation and instead proposed that it was actually a wetter period (Latorre et al., 2003). This latter hypothesis is limited in terms of the spatial scale required to maintain its regional validity, although it does appear to be valid for certain areas in the Salar de Atacama basin. On the other hand, a significant series of proxies suggest that the Middle Holocene was regionally arid in the Puna, at least after 7000 BP (Morales, 2011, Tchilinguirrián, 2009). Furthermore, there were different effects on either side of the Andean range, with an earlier and more abrupt onset of arid conditions on the western slopes (Morales, 2011). Climate is an organizing factor in the distribution of vegetation communities, so climatic changes obviously have an effect on these and on the rest of the trophic chain, above all affecting the abundance and distribution of particular species.

As can be seen from palaeoenvironmental data, the Middle Holocene created an environment that was more fragmented than that of the Early Holocene. Long-term environmental changes from the end of this period increased spatial heterogeneity, generating a series of strategic and/or behavioral modifications on the part of both the region's human population and the region's wildlife, in order to adapt to sudden local scarcities in resources (Dincauze, 2000).

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Consequently, hunter-gatherers in the Puna modified their mobility patterns by concentrating on locations where critical resources were available, while also expanding their ranges, introducing innovative technologies (for example, mortars and pestles, more diversified types of projectile points associated with new hunting techniques), and promoting economic changes (animal domestication and the introduction of cultivation) towards the end of this period (Table 1). These changes reveal the complex relationships between people and their environment during this long period. The transition between the Early and Middle Holocene can be characterized as a shift from a more stable and regular environment towards a more heterogeneous one, and for this reason it is worthwhile to explore the particularities of this environmental shift.

**Table 1**  
Relationships between the environment and the cultural characteristics.

Period	Environment	Cultural characteristics
Early Holocene (11,000–8200 BP)	Stable, wet and cold	- Small settlements - Low diversity of artifacts - Little movement of artifacts between localities - Opportunistic use of resources
Middle Holocene I (8200–6200 BP)	Fragmentation Short-term variations Long-term directional variation	- Diversity in projectile points - New hunting techniques - Grinding techniques - Changes in mobility - Expansion of ranges - Specialization
Middle Holocene II (6200–3500 BP)	Fragmentation with habitat loss Incremental short-term variation (ENSO) Long-term directional variation	- Diversification (includes Domestication of camelids, Use of cultivation) - Social “complexity” - Appearance of more permanent nucleated settlements

## 2. Environmental fragmentation

Fragmentation can be produced both by human actions and by natural phenomena, and is defined as a process of dissection of the natural system into isolated parts. The effects of such fragmentation on natural systems are amplified by habitat loss, in other words, when the area of amenable habitat for a species or community becomes diminished (Thompson Hobbs et al., 2008). Habitat loss also reduces the number of biotic interactions.

Fragmentation creates spatial heterogeneity, and consequently high levels of dependency, which means that the number of resources per spatial unit varies strongly with the locality (Thompson Hobbs et al., 2008). There are two degrees of heterogeneity: one low, where the average number of resources is independent in each area, and another more accentuated pattern, which is produced when there is high resource variability with respect to the location. The latter is the case that best describes the spatial distribution of resources during the drier segment of the Middle Holocene.

Ecological processes in arid and semi-arid environments are also shaped by temporal variation in primary productivity and by the availability of surface water (Thomas, 1997). This temporal variation is analogous to the spatial variation. Environmental pulses of resource availability may be interrupted by periods of scarcity on a seasonal, annual, or decadal scale. When heterogeneity is high (that is, the number of resources varies significantly in space and time), resource consumers (whether wildlife or human hunter-gatherer communities) must overcome the possibility of having

to face resource insufficiencies in order to sustain a population in a certain habitat or patch.

For this reason, the degree of connectivity between patches can produce significant effects in terms of population dynamics, which causes movements between areas in a fragmented landscape. However, the degree of connectivity depends not only upon the scale of mobility, but also upon the configuration of the landscape. When heterogeneity is fine grained, one area of the landscape can contain the majority or even the totality of the resource types, whereas when heterogeneity is course grained, each segment of the landscape may contain only one portion of the resources, and in order to supply existing demand, use of a large area may be required. Such differences in landscape configuration, combined with the characteristics of the resources (storability, predictability, etc.) will have an influence over the intensity of mobility, measured in terms of the number of times human groups move their residential base, or in terms of distributions of habitat usage by wild camelids (*Vicugna vicugna* and *Lama guanicoe*). Below, an analysis is presented in terms of how use of animal resources varied, and whether the changes that occurred can be explained by environmental fragmentation.

## 3. Animal resources

The samples discussed here come from 28 sites and levels in cases where there may be multiple occupations of the same site during the same period (Fig. 1 and Table 2). In the Puna region of Atacama in Chile, no site was occupied for more than one period, whereas on the Andean slopes in Argentina the panorama is different, with two sites showing occupation in three periods and various others in two periods, although in most cases these periods are not contiguous.

**Table 2**  
Sites with available archaeofaunal samples, by period of occupation.

Region	Early Holocene	Middle Holocene I	Middle Holocene II
Puna of Argentina	Pintoscaïoc	Pintoscaïoc	
	Inca Cueva 4		Inca Cueva 4
	Huachichocana III		Huachichocana III
	Hornillos 2	Hornillos 2	
	Alero Cuevas	Alero Cuevas	Alero Cuevas
Puna of Chile	Quebrada Seca 3	Quebrada Seca 3	Quebrada Seca 3
	Tuina 1	Puripica 13–14	Chiu Chiu
			Cementerio
	Tuina 5	Huasco 2	Puripica 1
	Tambillo	Tulán 67	Puripica 33
	San Lorenzo		Tulán 52
	Tulán 68		

This raises interesting questions regarding the regional use of space and mobility patterns. Given that environmental changes had different impacts on either side of the Andean range, a comparative analysis is performed here on faunal samples from the two areas (Tables 3, 4 and 5). In the Puna in Chile (PCh), use of camelids increases rapidly, from 45.5% to 85.9%, between the Early Holocene and Middle Holocene I, while on Argentina's side of the Puna (PA), the increase seen is from 60% to 76%. During the Middle Holocene II in PA, camelid remains increase to 88.9%, reaching 91.6% on the Chilean side.

A more marked and abrupt process of specialization existed in Chile, prior to this process also taking place in Argentina, where a more gradual change can be observed. This could be related to an earlier installation of dry conditions in the west (~8000 BP), as well as to the greater degree of habitat diversity available towards the east of the Andean range for hunter-gatherer groups.

This difference is easy to discern in the artiodactyl index (Broughton et al., 2008), which in this case is a camelid index

**Table 3**  
Faunal record of the Early Holocene in the Puna of Chile and Argentina.

Texa		Site	Artiodactyla	Camelidae	Cervidae	Chinchillidae	Lagidium sp	Chinchilla sp	Caviidae	Ctenomys sp	Cavia sp	Rodentia indet	Avis	Carnivora	Casipodidae	Total NISP	
Early Holocene	Argentina	Pintoscaycoc	998		25	39	234	70	1382	602		81	64	5		<b>3500</b>	
		CHIIIIE3	5	751	2	98									3		<b>859</b>
		Ina Cueva 4	127	107	15	741				4		1		8	1	10	<b>1014</b>
		QS3 LL		687		74				1			38	16	1		<b>817</b>
		Hornillos 2	480	113	18	1314						53					<b>1978</b>
	Chile	Acuevas F4	532	575	1	55						50					<b>1203</b>
		San Lorenzo 1		5		43						16		4			<b>68</b>
		Tuina 1		25		7						9					<b>41</b>
		Tuina 5		393	12	85						226		38			<b>754</b>
		Tulán 68		165		24						25		926	11		<b>1151</b>
	Tambillo		1047		33				969		57		93			<b>2199</b>	

**Table 4**  
Faunal record of the Middle Holocene I in the Puna of Chile and Argentina.

Texa		Site	Artiodactyla	Camelidae	Cervidae	Chinchillidae	Lagidium sp	Chinchilla sp	Caviidae	Ctenomys sp	Cavia sp	Rodentia indet	Avis	Carnivora	Casipodidae	Total NISP	
Middle Holocene I	Argentina	Hornillos 2	890	271	8	603						110			713	<b>1772</b>	
		QS3 ML		537		44				2			5			51	<b>539</b>
		Pintoscaycoc 5		62	2	24			12	49			24	1			<b>150</b>
	Chile	Acuevas F3	128	243		14							39	1	1		<b>386</b>
		Tulán 67		283		76							17	38		131	<b>545</b>
		Huasco 2		64		12				1				2		15	<b>84</b>
	Puripica 13–14		238									5	9		14	<b>266</b>	

**Table 5**  
Faunal record of the Middle Holocene II in the Puna of Chile and Argentina.

Texa		Site	Artiodactyla	Camelidae	Cervidae	Chinchillidae	Lagidium sp	Chinchilla sp	Caviidae	Ctenomys sp	Cavia sp	Rodentia indet	Avis	Carnivora	Casipodidae	Total NISP	
Middle Holocene II	Argentina	Acuevas F2	371	327		18						41				<b>716</b>	
		QS3 UL		1708		63					15		41	18			<b>1804</b>
		Inca Cueva 7		20													<b>20</b>
		Unquillar		45		5											<b>50</b>
		CHI II E2		57													<b>57</b>
	Chile	Tomayoc		365													<b>365</b>
		Puripica 33		932								1		4		5	<b>942</b>
		Tulán 52		12096			1558			277		14		68			<b>14013</b>
		Puripica 1		3426			711			21		93		1	143		<b>4395</b>
		ChiuChiuCem		5861								48		42			<b>5951</b>

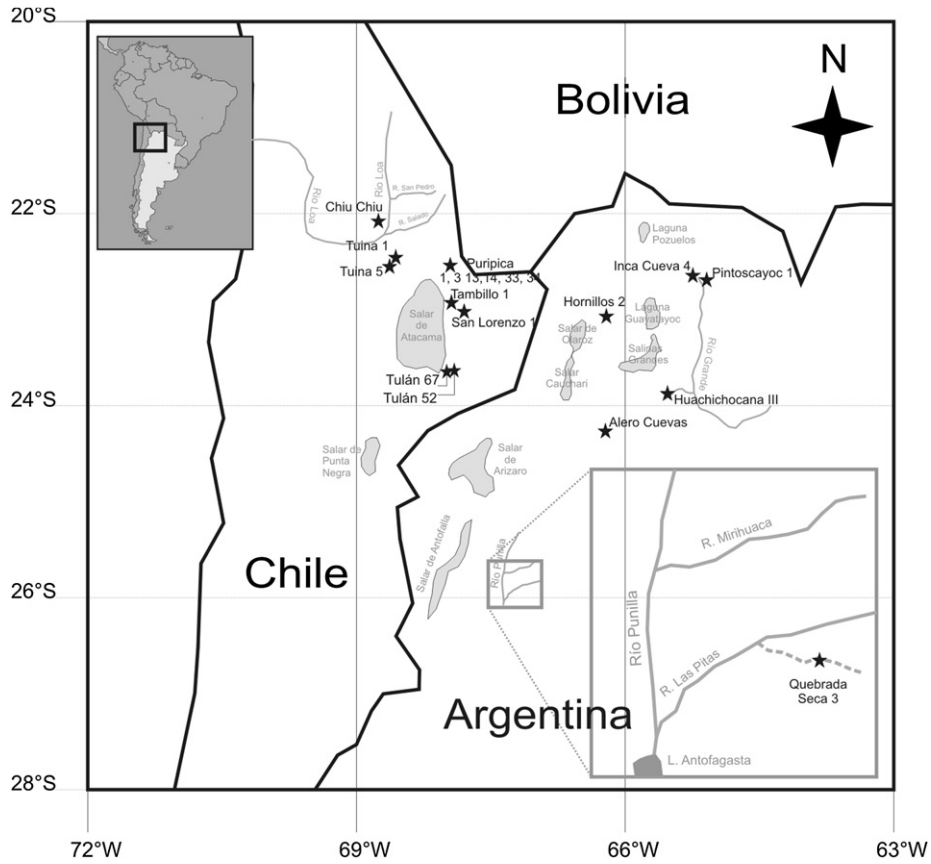


Fig. 1. Location map of the sites discussed in the text.

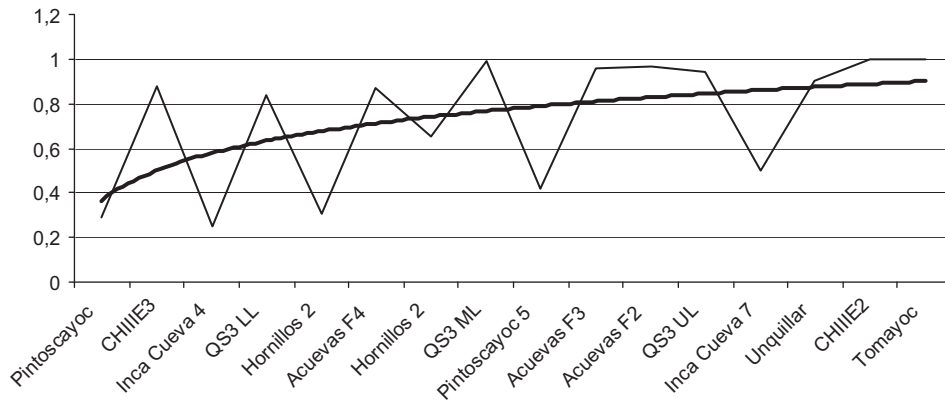


Fig. 2. Artiodactyl index, and logarithmic mean of faunal samples from Argentina.

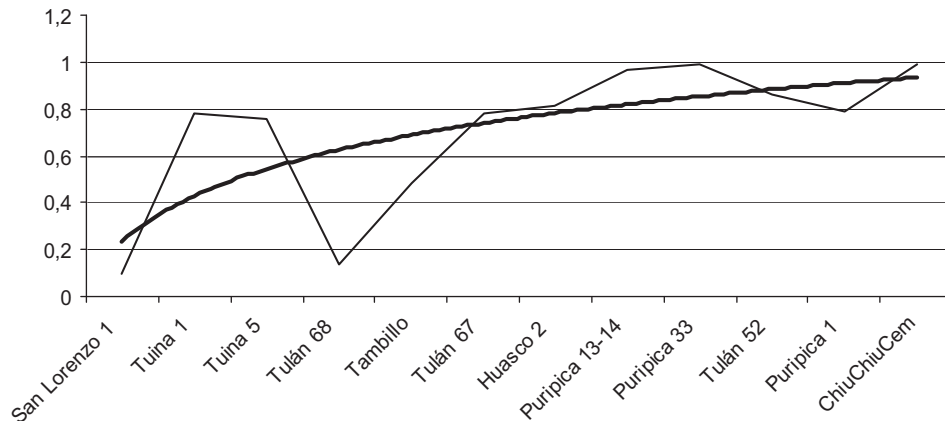


Fig. 3. Artiodactyl index, and logarithmic mean of faunal samples from Chile.

because cervids have low frequencies along the entire sequence. These indexes shows a more gradual increase among localities on the Argentina side for the entire period, while in Chile, camelids rapidly came to regularly dominate the faunal remains found at archaeological sites (Figs. 2 and 3). In Chile, except for a slightly higher percentage of camelid remains, no other differences are seen between the Middle Holocene I and Middle Holocene II phases. In contrast, there are substantial differences between these two periods in the sites from Argentina.

The specialization process is also noted because of the appearance of new projectile point types. It has been emphasized that

increasing diversity in the design of weapons is a function of their more specialized utilization of a reduced number of high yield species (Binford, 2001: 392). In the Early Holocene, only 3 types of projectile points are recorded in the region; 8 new ones appear in the next period, considerably increasing the complexity of weaponry systems (Fig. 4). New hunting strategies started to be employed in the Middle Holocene, including communal hunting techniques with tending facilities (Aschero and Martínez, 2001).

The use of small mammals and birds also show different patterns in both countries. In the Puna in Argentina, the presence of Chinchillidae (*Lagidium viscacia* and *Chinchilla laniger*) decreases over

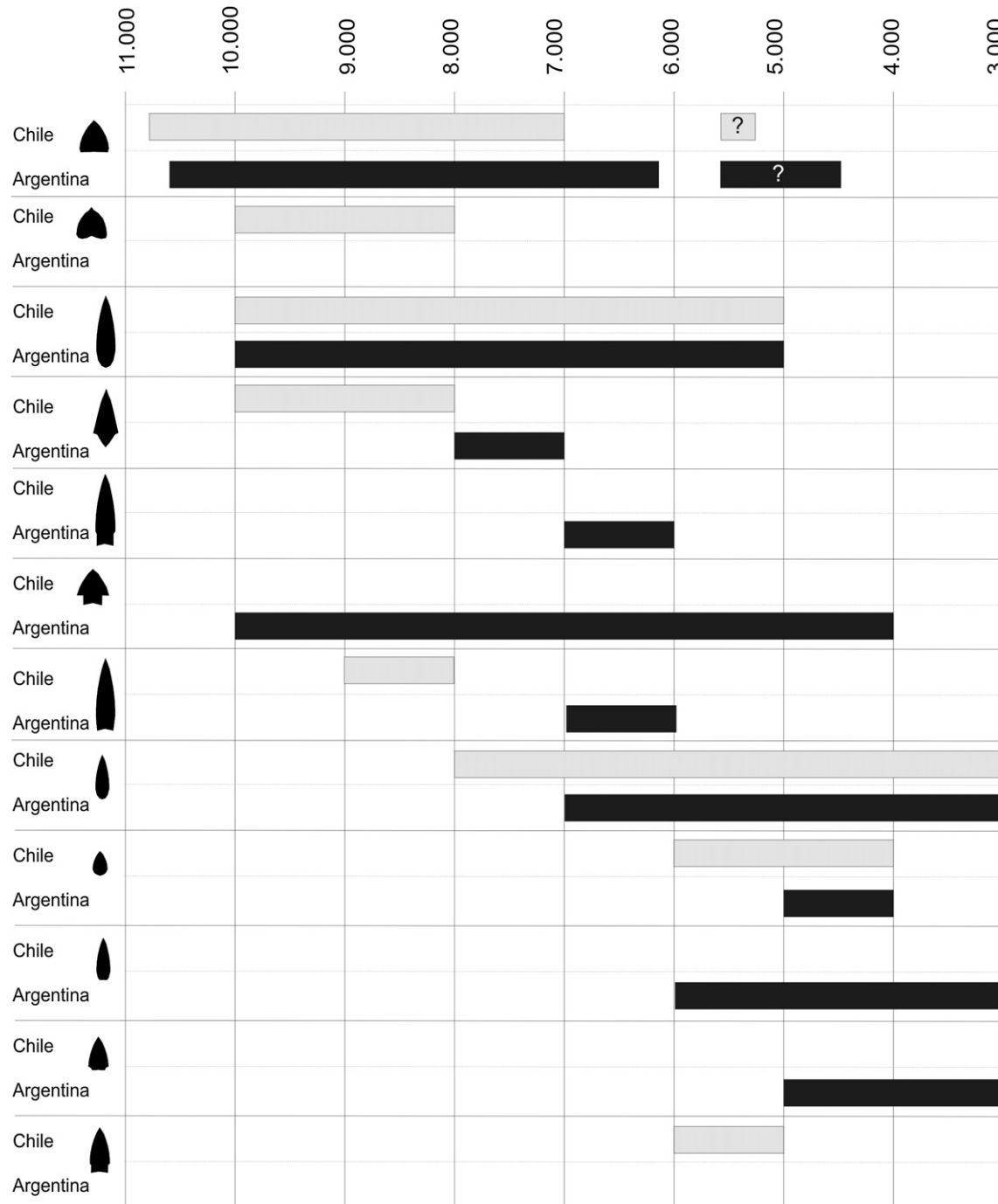


Fig. 4. Temporal trajectories of projectile point types in Chile and Argentina.

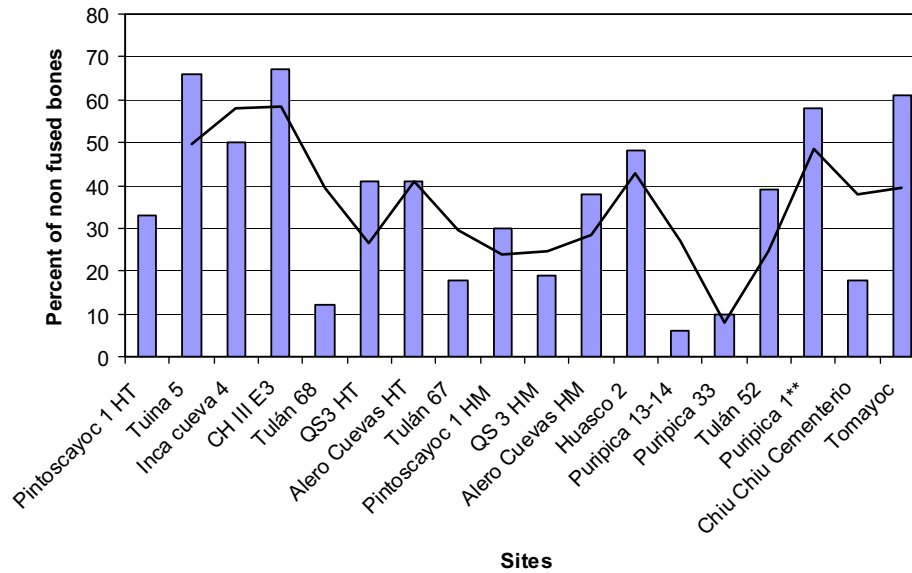


Fig. 5. Percent of unfused bones and mobile mean in Chile and Argentina.

time, while in the PCh sites it increases towards the Middle Holocene I and then later decreases. However, these remains still represent a greater proportion in the Middle Holocene II than in the Early Holocene. The remains of small mammals other than *viscachas* and *chinchillas* are concentrated in only a few sites in the PCh, reaching a level of 54.5% in the Early Holocene, while in the PA there is a mean of 39.6%. As with the camelids, an abrupt change was produced with small mammals in Chile, but here in the opposite direction, as the earlier percentage falls to 14.0% in the Middle Holocene I and then further to 8.4% in the Middle Holocene II. In Argentina this process appears more gradual and irregular, due to the high variation among localities. However, the earlier percentage drops to 23.9% in the MH I and then to 11.0% in the MH II.

The proportions of non-fused camelid bones also reveal some interesting contrasts, although a similar trend is observed in both countries. However, the data is still scarce for a detailed analysis. Table 6 and Fig. 5 show the exact sample, and the temporal trend for the entire region, respectively. The high diversity of projectile points along with the increment in camelid utilization in the sites,

suggests an increase of adult specimens in the Middle Holocene, which could reflect a focus on hunting bachelor groups of camelids, which have numerous individuals, through communal hunting techniques. Although a decrease of unfused bones in that period (45% in the Early Holocene vs. 32% in the Middle Holocene I) is observed (Fig. 5), the difference with the Early Holocene is not statistically significant ( $F = 2.96$   $p = 0.25$ ). There is high variability between sites, and some of them (e.g. Huasco 2) have very small bone samples. Thorough research on the mobility pattern and role of each locality is needed before sustaining any explanation about the meaning of age-classes pattern.

#### 4. Conclusion

The Middle Holocene has drawn the attention of archaeologists because of the anomalies detected in the archaeological record. In general, these consist of a decrease in the intensity of usage of a region, or a segment of it, on the part of hunter-gatherer populations. This is reflected by a decrease in the frequency of radiocarbon dates and/or a lower quantity of sites, compared to the previous period. Changes in resource use have also been recorded, along with broadening of the diet in many cases and, finally, the appearance of new technologies.

Within this general perspective, there are also particularities. There is debate regarding the environmental characteristics of the Puna in Chile's Atacama (wetter or drier), and also the scope of the "depopulation" of the region, as interpreted from the absence or scarcity of archaeological evidence. At first, a hypothesis of regional depopulation was proposed based upon an upsurge in volcanic activity (Núñez and Santoro, 1990). Later, as regional palaeoenvironmental evidence became more abundant, the hypothesis of an "archaeological silence" was proposed, which would explain the relatively low or even absent signs of occupation of certain areas of the Puna with extremely arid characteristics, and indicating that human groups, based upon evidence from Puripica in Chile, had been displaced to more favorable areas known as "ecorefuges" (Grosjean and Núñez, 1994). However, a few years later sufficient evidence had been accumulated to support the realization that the overall picture was much more complex, and that human occupation of the Puna in the Middle Holocene was spatially and socially diversified (Yacobaccio, 1998).

Table 6  
Exact samples of NISP and percent of unfused bones by site.

Site	NISP	%NF	Layers	<sup>14</sup> C Dates
Pintoscayoc 1 HT	998	33	6b–6c	10720 – 9190 BP
Tuina 5	353	66	E IV	10060 – 9840 BP
Inca Cueva 4	163	50	2	10620 – 9230 BP
CH III E3	410	67	E3	10200 ± 420 BP
Tulán 68	150	12	E IV, E III–II	9290 ± 1000 BP
QS3 HT	631	41	2b25–2b12	9410 – 8670 BP
Alero Cuevas HT	575	41	F4	8838 ± 52 BP
Tulán 67	247	18	E VII, E VI, E V	8190 ± 120 BP
Pintoscayoc 1 HM	62	30	5b	7850 ± 110 BP
QS 3 HM	543	19	2b11–2b6	7130 – 5380 BP
Alero Cuevas HM	243	38	F3	6510 ± 80 BP
Huasco 2	58	48	–	6320 ± 50 BP
Puripica 13–14	238	6	–	6130 ± 80 BP
Puripica 33	932	10	–	5880 ± 100 BP
Tulán 52	1668 <sup>a</sup>	39	E IV–II	4580 – 3860 BP
Puripica 1	3426	58	–	4816 – 4050 BP
Chiu Chiu Cementerio	431	18	–	4115 ± 105 BP
Tomayoc	341	61	Fase II	3480 – 3250 BP

<sup>a</sup> MNE.

How can such spatial-temporal heterogeneity in the distribution of archaeological evidence be best explained? The mosaic-like spatial and temporal distribution of archaeological evidence agrees with the characteristics of a fragmented environment. In locations with greater environmental flexibility, there was continuity in occupation between the Early Holocene and Middle Holocene I. Modeling of fluvial systems above and below 4500 m asl (Tchilinguirían, 2009) has shed light on some of the mechanisms involved in the generation and maintenance of such favorable habitats. Other systems, in contrast, disappeared around the middle of the MH I period (~7000 BP), and this caused human populations to disperse. There are two general issues to be considered:

- 1 Archaeological evidence that shows continuity between the EH and MH I is generally found above 4000 m asl. Palaeoenvironmental evidence indicates, in turn, that during the better part of the Middle Holocene, only areas at this altitude had permanently developed wetland areas (Morales, 2011; Tchilinguirían, 2009).
- 2 Below this altitude level, aridity was very pronounced. Also, the western section of the Puna showed greater heterogeneity, along with a reversed pattern at the same time, with slightly wetter conditions between 2300 and 3200 m asl, and with drier conditions above 3000 m asl (Morales, 2011: 107). This would explain the absence of archaeological evidence between 8200 and 5100 BP in the southeastern section of the Salar de Atacama, around 3200–3300 m asl. However, some more hospitable habitats may have existed, such as, for example, in the Quebrada de Puripica valley to the north of the Salar (Núñez et al., 2005). Recently, at the headwaters of the Grande river in the Quebrada de Humahuaca valley, a few hundred metres upstream from the mouth of the Inca Cueva gorge, an extensive profile was revealed that shows the development of peat bogs between 7000 and 6000 BP, which would indicate the existence of relatively extensive meadowlands. Early excavations conducted at Gruta de Chulín or Inca Cueva 1, although undated, show the presence of large spear points, spear points with notched bases, and triangular points with straight sides and bases (Fernández, 1968–1971), which have been dated in other sites to the Middle Holocene II. This would argue against the hypothesis that the Quebrada de Humahuaca was depopulated during the Middle Holocene as stated by Hernández Llosas (2001:79).

Binford (2001: 395) stated that the use of tending facilities for hunting is useful in environments with moderate to high artiodactyl densities, and increase in settings in which residential mobility is reduced. The faunal record of the Middle Holocene supports this contention, and the increasing diversity in the weaponry system, “corresponds to a decrease in residential mobility for groups dependent upon either plants or terrestrial animals” (Binford, 2001:390). Hunter-gatherers dependent on terrestrial fauna may use a large range, but not necessarily this implies a high residential mobility (Kelly, 1995: 130). The development of logistical mobility in the Middle Holocene is a consequence of the spatial heterogeneity and the specialization on high ranked resources (camelids). The decreasing trends in the use of small fauna reflect the specialization process. The presence of small fauna is minimal in the Middle Holocene II sites. The targeting of adults through collective hunting techniques could also be indicative of both economic specialization and changes in the mobility pattern (reduced residential mobility), which could have been led

by the environmental changes (landscape fragmentation). Interdisciplinary research, together with theoretical concepts derived from the field of Human Ecology, can provide explanatory tools applicable to the challenges inherent in the research issues discussed.

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