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On head lice and social interaction in archaic Andean coastal populations

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Abstract

Archaic mummies from northern Chile were examined for the presence of *Pediculus humanus capitis*. The excellent preservation of mummies and louse nits/eggs permitted a study of the degree of head lice infestation. We studied 63 Chinchorro mummies (ca. 5000–3000 years B.P.) from the Arica-Camarones coast. An area of 2 cm × 2 cm on each mummy's head was systematically inspected for louse nits/eggs. Hairs with nits/eggs and lice were collected and analyzed using optic and scanning electronic microscopy. About 79% (50/63) of the mummies resulted positive for pediculosis, with an average of 2.1 nits/eggs/cm² per positive individual. Microscopic analyses revealed the micromorphology of all developmental stages, including eggs/nits, nymphal instars and adults. Chinchorro people lived in small huts increasing the transmission of ectoparasites. Considering that head lice thrive in crowded conditions, their prevalence could be used as an bioindicator to assess and debate cultural behavior (e.g., degree of crowdedness and sedentism) and to study paleoepidemiology in prehistoric populations.

Keywords: Mummies, Pediculosis, Bioarchaeology, Atacama Desert

1. Introduction

Head lice, *Pediculus humanus capitis* De Geer (1767), have been a part of mummy studies for decades. Zinsser (1935) presented the importance of lice in mummy studies in his classic publication *Rats, Lice and History* (republished in 2007). Previously, Ewing (1924) had published the discovery of lice from Peruvian mummies. Both authors pointed out the comparative value of mummy louse studies in documenting the intra-population variation of lice as they adapted to different hair morphology in diverse human populations. Although Zinsser and Ewing highlighted the potential of population-based studies, such potential went unexplored for decades. Recently, a series of case reports have been published, drawing on small, or single mummy samples (Araújo et al., 2000; Arriaza et al., 2012a, 2012b; Raoult et al., 2008; Rivera et al., 2008). Most studies were not quantitative, but were successful in painting a general picture of the arrival of head lice in the New World. Araújo et al. (2000) reported head lice from hair associated with an archaic human skeleton in northeastern Brazil. The finding was radiocarbon dated to more than 10,000 years ago indicating that the introduction of lice into the New World probably occurred with the earliest migrants. Based on molecular analysis of

Chiribaya head lice (960 B.P. Peru) from two individuals, Raoult et al. (2008) showed that pre-conquest head lice populations likely had haplotype links to the Old World, pointing to ancestral migrations of host and parasite into the New World. Rivera et al. (2008) found louse nits/eggs on six of seven 4000-year-old mummies from Camarones, on the coast of northern Chile, however they did not report nit/egg density. This small sample hinted that high levels of head lice infestation were reached in archaic coastal Andean populations.

Levels of infestation of 44% were documented in mummies from Canyon de Chelly, Arizona, dating to 800–900 years ago (El-Najjar et al., 1998). In general, louse infestation was relatively rare in the Southwestern United States in prehistory. These case studies have been important in documenting louse distribution through time and space.

The first ancient population-based study on head lice infestation was performed by Reinhard and Buikstra (2003), who analyzed 146 Chiribaya culture mummies from the Moquegua valley of southern Peru. They found that 92 of the mummies were sufficiently preserved for analysis. They then assessed the distribution of parasites in host populations, searching for a pattern of over-dispersal—which means that a very small percentage of hosts harbor

the majority of parasites. In parasitological terms, this phenomenon is best described by a negative binomial distribution (Anderson, 1993), or “wormy hosts”, in the case of intestinal parasites, when few hosts carry a great number of parasites who contribute to continuing transmission dynamics in endemic communities (Croll and Ghadirian, 1981). This phenomenon has been observed with other ectoparasitic diseases such as tungiasis, where a small number of individuals carried most of the parasites in a community (Heukelbach et al., 2007). In order to validate the paleoepidemiological value of parasite data, this characteristic distribution had to be demonstrated with archaeological remains. Reinhard and Buikstra (2003) were able to quantify infestations on an individual basis by calculating the maximum number of eggs and nits cemented to hair shafts on the scalps of the 92 Chiribaya mummies. The infestation of nits and eggs on Chiribaya hosts reflected the negative binomial distribution. This supports the statistical value of louse parasitological data when large numbers of human remains can be evaluated.

Following this population-based approach, we have studied several hundred mummies from all cultural phases of the Arica region in northern Chile. In this paper, we focus on the presence of *Pediculus humanus capitis* (*P. humanus capitis*) in Chinchorro populations (5000–3000 years B.P.; $n = 63$ individuals) that inhabited the arid coastal region of the Atacama Desert. The Chinchorro were fishers and hunter-gatherers who lived along the dry but fertile coast at the fringes of the Atacama Desert in northern Chile and southern Peru (Arriaza, 1995; Aufderheide et al., 1993; Santoro et al., 2012). They are known for their elaborated mortuary practices, including artificial mummification (Arriaza, 1995; Arriaza et al., 2012c; Marquet et al., 2012; Rivera, 1991; Standen, 1997). The Chinchorro were expert morticians who transformed the corpses of the dead into polychromous preserved bodies (mummies). They used various techniques and mummification styles that changed through time to preserve individuals of both sexes and all ages, including fetuses. Even though there were regional and chronological variations, two types of artificially prepared mummies stand out: the *black* and the *red style* (Arriaza, 1995). The black mummies were the earliest (ca. 7000–5000 years B.P.) and are basically clay modeled or reconstructed bodies. They have an inner structure of bones, sticks, clay and reeds. Clay masks and short black wigs made of human hair adorn the heads. Externally, the bodies are completely painted black, including the face, using manganese pigments. The red mummies (ca. 5000–4000 years B.P.), in contrast, have incisions for organ removal, stuffing of cavities and externally are fully painted with red ochre, except the face mask which is painted with manganese. These red mummies have long wigs of black human hair. In addition to these types of mummies, there are also Chinchorro bodies with natural mummification, especially after the red style period. Independent of mummification procedures, most bodies were wrapped in reed mats and buried lying on their back with a few grave goods (fishhooks, harpoons and net bags) in the sands of the Atacama Desert. In general, mummification techniques faced cultural changes, but the maritime subsistence and technology for fishing and gathering remained the same. Also, later Chinchorro populations (ca. 3500 years B.P.) no longer practiced complex artificial mummification, annular skull deformation increased, heads were adorned with colored threads (headbands), and fine basket weaving and horticultural products appeared (Rivera, 1991; Standen, 1997).

Scholars have studied many aspects of Chinchorro ways of life and endoparasitism, but ectoparasite studies and their cultural relevance have been minimally addressed so far. Rivera et al. (2008), at the Camarones-15 site, found 98 operculated *Pediculus capitis* eggs and 265 non-operculated eggs. Arriaza et al. (2008, 2012a, 2012b) also reported three positive cases of pediculosis in ten pre-

Columbian mummies of different periods from Arica and Iquique (northern Chile) and a heavily infested late agropastoral Chiribaya mummy (ca. 1280–960 years B.P.). Likewise, Reinhard and Buikstra (2003) reported pediculosis in three Chiribayan sites from Peru, with prevalence ranging from 20% to 70%.

The general archaeological evidence posits that Chinchorro populations were composed of small bands of hunter-gatherers and collectors who lived in semi-permanent camps along the coast (Núñez, 1983; Muñoz and Chacama, 1982; Rivera, 1991). Based on this information, it is thought that the Chinchorros were highly mobile groups. Using pediculosis as a bioindicator, we provide evidence in this paper that the Chinchorro daily life was more sedentary and that social bonding was likely strong and enduring. Yet, there are still several questions regarding archaic lice infestations: Why is Rivera’s reported frequency so high for this Chinchorro site? Is this value unusual, or did all Chinchorro sites have similar infestation rates? What is the social significance of pediculosis in these early populations? To answer these questions we systematically expanded the sample size and chrono-geographic framework to describe the extent that archaic coastal populations were affected by pediculosis, in order to discuss its bioarchaeological significance.

2. Materials and methods

The samples studied came from eleven coastal archaeological sites in the city of Arica in northern Chile, ranging from one to twenty-two individuals per site. In total we studied 63 mummies, 41 naturally mummified and 22 artificially prepared bodies. All are housed at the Museum of Archaeology of the Universidad de Tarapacá, Arica, Chile. The latter included the addition of a hair wig as part of the artificial mummification procedures (Arriaza, 1995; Standen, 1997). In artificially prepared bodies of newborns and infants, clearly the wigs were not made from their own hair, but probably from the hair of older relatives (Arriaza, 1995; Standen, 1997). Two broad, main age categories were considered: adults and subadults. The latter includes ages around 15 and younger. Thus, the demographic profile of the total sample can be subdivided into 42 adults and 21 subadults (26 males, 25 females and 12 individuals whose sex it was not possible to determine). A summary of the study sample demographics per site is presented in Table 1.

2.1. Macroscopic analysis

At the Museum of Archaeology, all mummy heads were examined for the presence of head lice (nits or empty egg-shells, embryonated eggs and lice). If heads were detached by previous autopsies, they were carefully deposited on a 60 cm × 60 cm sheet of acid free paper and inspected visually with the aid of a 10× magnification glass. Complete bodies were studied in their storage trays.

Nits/eggs are affixed to the hair shaft, hence they are less sensitive to loss by handling. To determine the presence and amount of nits/eggs on each mummy’s head we slightly modified the methodology of Reinhard and Buikstra (2003), gently lifting the hair in the temporal and occipital areas and placing a 2 cm × 2 cm (4 cm²) cardboard cutout to count nits/eggs on hair shafts within 1 cm of the scalp (Figure 1). However, to follow conventions, here we are reporting the observations scored as per 1 cm² area.

As the mummies’ hair is not always clean but may contain dirt and debris, we undertook six independent observations and counts of nits/eggs: three at the temporal area (anterior, superior, and retro-auricular) and three at the occipital area (two lateral and one medial) where lice are frequently found (Borges and Mendes, 2002; Gairi et al., 2007; Heukelbach, 2010). In addition, on mummies

Table 1. Pediculosis using light microscopy: samples studied and results according to archaeological site ($N = 63$).

Archaeological site	Result	M		F		U		Sub total	Prevalence (%)	Total sample
		Subadult	Adult	Subadult	Adult	Subadult	Adult			
Acha 4	(+)	0	0	0	1	0	0	1	100	1
	(-)	0	0	0	0	0	0	0	0	
Morro 1	(+)	2	4	2	6	5	0	19	86.4	22
	(-)	1	1	1	0	0	0	3	13.6	
Morro 1–5	(+)	1	0	0	0	0	0	1	100	1
	(-)	0	0	0	0	0	0	0	0	
Morro 1–6	(+)	0	5	0	5	1	0	11	91.7	12
	(-)	1	0	0	0	0	0	1	8.3	
Morro Estación Sanitaria	(+)	0	0	1	0	0	0	1	100	1
	(-)	0	0	0	0	0	0	0	0	
Maderas Enco	(+)	0	0	0	0	0	0	0	0	1
	(-)	0	0	0	1	0	0	1	100	
Yungay	(+)	0	0	0	0	1	0	1	25	4
	(-)	0	1	0	1	1	0	3	75	
Quiani 7	(+)	0	4	0	4	0	0	8	100	8
	(-)	0	0	0	0	0	0	0	0	
Camarones 15, 15C, 15D	(+)	1	3	0	3	1	0	8	61.5	13
	(-)	0	2	0	0	2	1	5	38.5	
Total positive	–	4	16	3	19	8	0	50	79.4	63
Total negative	–	2	4	1	2	3	1	13	20.6	

M = Male; F = female; U = sex was not possible to determine.

Figure 1. Illustration of nit/egg counting technique with a 2 cm × 2 cm square on a mummy head.

with detached hair (due to previous autopsies), three counts were undertaken in similar areas, whenever possible, and recorded separately. Hair from archaeological settings (including mummies) is often brittle and crumbles easily as the head is inspected; therefore, we collected all sediments (hair fragments, soil debris and ectoparasitic developmental stages) that fell on the acid-free paper during examination for an in-depth analysis. We also measured the length of the hair per individual (from the scalp to maximum length). We considered a mummy to be positive for pediculosis if any stage of

the ectoparasite was found, even if only hatched eggs or cementing residues were present. In contrast, we considered a mummy to be symptomatic for active pediculosis if nymphs, adults, or unhatched eggs were found on an individual.

2.2. Microscopic analysis

We cut and collected small locks of hair where nits/eggs were observed for further microscopy studies at the Bioarchaeology Laboratory of the Instituto de Alta Investigación of the Universidad de Tarapacá, Arica. We recorded the number of nits/eggs, louse nymphal instars and adult lice found in the hair samples collected. All specimens were stored in acid-free tissue and sterile tubes. We first used stereomicroscopy (Olympus SZX-7) to separate all hair and parasites from other debris. Then all samples were observed using another microscope with a higher magnification (Olympus BX-41) to verify sex and to determine whether unhatched eggs contained embryos. Sex of lice was determined when possible according to morphological characteristics (Heubelbach, 2010; Nuttall, 1917).

To complement this study and yet preserve precious material for subsequent molecular analyses, a subset of selected samples (9 lice and 37 nits) were further analyzed using environmental scanning electron microscopy (Zeiss, EVO-LS 10) to pursue ultrastructural analysis of the micromorphology of nits/eggs and adults of *P. humanus capitis* (Arriaza et al., 2012a). The samples were mounted on aluminum stubs without gold/palladium alloy coating and viewed under variable pressure mode (VP). The chamber pressure was 150 Pascals, the working distance 4–8 mm and the acceleration voltage 15 kV. Undesired charging of dried, uncoated specimens was controlled by careful choice of incident beam energy and nitrogen gas levels.

3. Results

Chinchorro people had an overall prevalence of pediculosis of 74.6% (47/63) in the macroanalysis of the mummies, and a slightly higher prevalence of 79.4% (50/63) in the light microscopy analysis of locks of hair and sediment samples. There was an 88.9% (56/63) concordance of positive cases between the macro and microscopic analyses and a discrepancy of 11.1% (7/63), in cases that presented very low nits/eggs counts (1 or 2 nits/eggs). The positive mummies presented a mixture of hatched (empty) and unhatched (embryonated) eggs, indicating ongoing infestations throughout the lifetime of the individual (active pediculosis). The microanalysis was more accurate; thus, for the prevalence data we present the results obtained in the bioarchaeology lab.

3.1. Temporal analysis

Subdividing the archaic sample by early (ca. 5000 years B.P), middle (ca. 4000 years B.P.) and late Chinchorro (ca. 3500 years B.P.) mummies resulted in 66.7% (2/3), 75% (15/20) and 82.5% (33/40) head lice prevalence respectively. The small sample of the early archaic period includes two mummies with artificial preparation (black style) and one with natural mummification. The middle archaic Chinchorro period includes mummies with artificial mummification (red style) while the late archaic sample includes naturally mummified bodies. Unfortunately, breaking down the mummies by chronology reduces the sample size for in-depth statistical analyses. However, all periods show high prevalence of pediculosis. Also, when comparing the prevalence of the two larger samples (middle vs. late) no significant differences were found in head lice infestations (Chi-squared test, $p = 0.49$).

3.2. Group data

Using the microscopic data, and grouping the three Camarones sites as one sample (Table 1), about 90% (8/9) of all Chinchorro archaeological sites resulted positive for the presence of pediculosis. Combining all the types of samples collected (hair and sediments) and positive mummies from all archaeological sites resulted in a 79.4% (50/63) prevalence of pediculosis. This value decreases to 77.8% (49/63) if only the collected locks of hair samples are considered.

Regarding the visual macroscopic count, the mean nits/eggs density on the whole population was 2.05 eggs/nits/cm² per infested mummy (S.D.: 2.6), with a range of 0.1–12.5 nits/eggs/cm² (Table 1, Table 2 and Table 3).

3.3. Pediculosis by sex

Males (adults and subadults) had a prevalence of 76.9% (20/26), females of 88% (22/25) and those of undetermined sex of 66.6% (8/12). The difference between males and females is not statistically significant (Table 2). Similarly, there were no significant differences between the mean louse nit/egg densities: males had 2.2 nits/eggs/cm² vs. females 2.3 nits/eggs/cm² per positive mummy (Table 3).

3.4. Pediculosis by age category

By analyzing the data independent of mummification style, subadults (≤ 15 years) had a prevalence of 71.4% (15/21) and adults of 83.3% (35/42) (Table 2). In contrast, adults had significantly more louse nits/eggs than subadults: 2.4 nits/eggs/cm² vs. 1.2 nits/eggs/cm² per positive case, respectively (t test, $p = 0.01$, Table 4).

Table 2. Pediculosis using light microscopy: infestation cases by mummification type, sex and age categories ($N = 63$).

Condition	Naturally mummified (N = 41)										Artificially mummified (N = 22)										Total male	Total female	Total sub-adults	Total adults	Grand Total
	Subadult					Adult					Subadult					Adult									
	Total natural mummies					Total sub-adults					Total sub-adults					Total adults									
	M	F	U			M	F	U			M	F	U			M	F	U							
Positive	1	1	4	6	13	15	0	28			3	2	4	9		3	4	0	7		20	22	15	35	50
Negative	1	1	1	3	3	1	0	4	7		1	0	2	3		1	1	1	3	6	6	3	6	7	13
Total	2	2	5	9	16	16	0	32	41		4	2	6	12		4	5	1	10	21	26	25	21	42	63

M = Male; F = female; U = sex was not possible to determine.

Table 3. Macroscopic results of mean nit/egg density “in situ” in all positive cases (N = 47).

Nit/egg counts reduced to 1 cm² area*	M	F	U	Total sample
Mean	2.2	2.3	1	2.1
S.D.	3.1	2.5	0.8	2.6
Median	0.8	1.7	0.9	1
Min	0.3	0.1	0.1	0.1
Max	12.5	10.8	2.1	12.5
N	19	21	7	47

M = Male; F = female; U = sex was not possible to determine.
* The density scoring was mathematically reduced to 1 cm². All values should be multiplied by 4 to obtain observed “in situ” mean nit/egg density mummy values.

Table 4. Macroscopic results of mean louse nit/egg density by age. All positive cases (N = 47).

Nit/egg counts reduced to 1 cm² area*	Subadult	Adult	Total sample
Mean	1.2	2.4	2.1
S.D.	0.7	3	2.6
Median	1	1.2	1
Min	0.1	0.1	0.1
Max	2.5	12.5	12.5
N	13	34	47

M = Male; F = female; U = sex was not possible to determine.
*The density scoring was mathematically reduced to 1 cm². All values should be multiplied by 4 to obtain observed “in situ” mean nit/egg density mummy values.

3.5. Pediculosis by mummification type

Separating the positive samples by natural vs. artificial mummification resulted in similar prevalences of 82.9% (34/41) and 72.7% (16/22) respectively (Table 2). However, the mean nit/egg density was significantly higher in natural mummies compared to artificially prepared bodies: 2.6 nits/eggs/cm² vs. 1.0 nits/eggs/cm² per infested mummy (*t* test, *p* = 0.004, Table 6).

Naturally mummified subadults and adults had prevalences of pediculosis of 66.7% (6/9) and 87.5% (28/32) respectively (Table 2). However, this difference was not statistically significant. Subadults had a significantly lower mean of 1.6 nits/eggs/cm² per positive case, as compared to the adult mean of 2.9 nits/eggs/cm² per positive case (*t* test, *p* = 0.04, Table 5). Artificially mummified subadults had 75% (9/12) head lice prevalence and adults 70% (7/10), with a similar mean nits/eggs/cm² density: 0.8 vs. 1.1 respectively (Table 5).

After controlling for sex, naturally mummified bodies of both sexes had similar mean values around 2.8 nits/eggs/cm² per positive mummy. Artificially mummified females had nearly double the nit/egg density than artificially prepared males: 1.5 nits/eggs/cm² vs. 0.7 nits/eggs/cm² per positive case, respectively (*t* test, *p* = 0.016, Table 6). Naturally mummified males and females had similar prevalence of pediculosis [77.7% (14/18) vs. 88% (16/18)]. Likewise artificially mummified bodies of both sexes showed similar prevalence values [75% (6/8) vs. 85.7% (6/7)].

4. Pediculosis by lice only

Microscopically, of the 63 mummies analyzed 21 of them presented lice (33.3%) in various regions of the head (e.g. temporal and occipital). Fifty microscopically examined mummies were positive for pediculosis (nits/eggs or lice) compared to 47 positive cases macroscopically analyzed. From these 21 positive Chinchorro mummies we collected 232 head lice (94 adults and 138 nymphs). Of the 232 lice, 228 were found on 20 naturally mummified bodies and one of these mummies (Quiani 7 T9, adult male) accounted for nearly half of the total (110 lice). On these positive natural mummies, 18 were adult individuals (221 lice) and 2 were

Table 5. Pediculosis microanalysis: density of louse nits/eggs (in 1 cm² area) by mummification type, sex and age categories in positive cases (N = 47).

Density:-	Naturally mummified (N = 31)								Artificially mummified (N = 16)							
	Subadult				Adult				Subadult				Adult			
	Total natural mummies															
	M	F	U	Total sub-adults	M	F	U	Total adults	M	F	U	Total sub-adults	M	F	U	Total adults
Mean	0.8	2.5	1.6	1.6	3	2.7	0	2.9	0.7	1.4	0.4	0.8	0.7	1.6	0.2	1.1
S.D.	0	0	0.5	0.7	3.7	3.1	0	3.4	0.3	0.5	0.5	0.5	0.3	0.9	0	0.9
Median	0.8	2.5	1.6	1.6	1.2	1.3	0	1.3	0.8	1.4	0.4	0.8	0.7	1.8	0.2	1
Min	0.8	2.5	0.9	0.8	0.3	0.1	0	0.1	0.4	1	0.1	0.1	0.4	0.1	0.2	0.1
Max	0.8	2.5	2.1	2.5	12.5	10.6	0	12.5	1	1.8	0.8	1.8	1	2.5	0.2	2.5
N	1	1	4	6	12	13	0	25	3	2	2	7	3	5	1	16

Table 6. Macroscopic results of mean nit/egg density by mummification type in 1 cm² area*. All positive cases.

	Naturally mummified (N = 31)				Artificially mummified (N = 16)			
	M	F	U	Total natural mummies	M	F	U	Total artificial mummies
Mean	2.8	2.7	1.6	2.6	0.7	1.5	0.3	1
S.D.	3.6	3	0.5	3.1	0.3	0.8	0.4	0.7
Median	0.9	1.5	1.6	1.4	0.7	1.8	0.2	0.9
Min	0.3	0.1	0.9	0.1	0.4	0.1	0.1	0.1
Max	12.5	10.8	2.1	12.5	1	2.5	0.8	2.5
N	13	14	4	31	6	7	3	16

M = Male; F = female; U = sex was not possible to determine.

* The density scoring was mathematically reduced to 1 cm². All values should be multiplied by 4 to obtain observed "in situ" mean density mummy values. **Figure 2.** Hatched egg (top left), hatching egg (top right), unhatched egg (bottom center). Embryonated eggs are clearly visible in light microscopy.

subadult individuals (7 lice). In contrast, only 4 lice were found in an artificially mummified child (Camarones 15D T16C1). The adult head lice subsample had the following sex distribution: 34 female, 56 male and 4 indeterminate specimens. Considering the 21 positive mummies (or with head lice), each Chinchorro individual hosted on average 11 lice (S.D. = 23.8; Median = 4; Min = 1; Max = 110).

5. Discussion

Nearly all Chinchorro sites investigated presented evidence of *P. humanus capitis*. Prevalence was high and endemic. On average, four out of five Chinchorro individuals presented louse nits/eggs and adult specimens. Density, however, was variable with a mean of about 2.05 nits/eggs/cm² nits/eggs/cm² per individual. The presence of a living louse in the hair is considered an active infestation (Heukelbach, 2010:48). While this is not possible to score in the mummies, unhatched eggs are good proxies for potential active infestations.

Figure 3. Egg in the process of hatching. Age: circa 3000 years. B.P. (SEM image, 215×).

Although the average number of nits/eggs/cm² is relatively low, this is not the case if we consider the complete head surface. Using a rough estimate that an adult individual has an area of 500–600 cm² of scalp with hair, and each Chinchorro had on average 2.05 nits/eggs/cm², then each Chinchorro had the potential to host at least 1025–1230 nits/eggs. Also, considering that we found 26.6% (119/448) embryonated eggs and 73.4% (329/448) hatched eggs (Table 7), then each Chinchorro had between 748 and 898 eggs that finished the life cycle of the ectoparasite and 267–320 eggs that were likely to convert to infestation.

Also it is interesting to note that despite the low average density of 2.05 nits/eggs/cm², unhatched eggs or adult lice were present in all positive cases, indicating an active infestation. This contrasts with current studies by Williams et al. (2001) on recent populations, which found that only seven percent of children with fewer than 5 nits/eggs per 0.6 cm actually developed an active infestation. The calculated average number of 11 lice per mummy is likely an underestimation, because lice are prone to falling off the head while handling the mummy. Still, some individuals were carrying extremely high parasite loads, following the negative binomial distribution (over-dispersal) typical for parasite epidemiology in endemic communities (Figure 4), and confirming previous results on mummy headlice (Reinhard and Buikstra, 2003). Three mummies presented 7.5 nits/eggs/cm², accounting for 32.2% of all the nits/eggs observed in the hair (Figure 5).

Even though cultural attitudes toward head lice vary, symptoms depend on the duration of the infestation and the number of lice and unhatched eggs present on the scalp (Heukelbach, 2010:44). Head lice feed several times per day on their host, which may provoke mood changes and sleeping disturbances. Repeated exposure to antigenic compounds in louse saliva can cause sensitization, with intense itching and subsequent scratching. Although this is known to facilitate secondary bacterial infection (Feldmeier and Heukelbach, 2009), no obvious evidence of scalp infectious

Figure 4. Graph of percentage of mummies plotted by nit/egg density.

Table 7. Microscopic results of nits/eggs in hair samples ($N = 49$) taken from positive individuals.

Nits/eggs	Male ($N = 19$)				Female ($N = 22$)				Indeterminate ($N = 8$)				Total sample	%
	N	%G	%T	%TT	N	%G	%T	%TT	N	%G	%T	%TT		
Operculated	78	15.0	65.5	5.7	27	3.4	22.7	2.0	14	21.5	11.8	1.0	119	8.7
Hatched	200	38.4	60.8	14.6	111	14.1	33.7	8.1	18	27.7	5.5	1.3	329	23.9
Fragmented	111	21.3	32.7	8.1	212	26.9	62.5	15.4	16	24.6	4.7	1.2	339	24.7
Cementing substance	132	25.3	22.5	9.6	438	55.6	74.6	31.9	17	26.2	2.9	1.2	587	42.7
Total	521	100	37.9	37.9	788	100	57.4	57.4	65	100	4.7	4.7	1374	100

Note: %G: Percent according to the total number of nits/eggs accounted by sex. %T: Percent according to the total number of nits/eggs in a given category. %TT: Percent according to total numbers of nits/eggs counted ($N = 1374$)

were noted in the Chinchorro mummies of this study. We also did not observe *plica polonica*, a typical condition of strong infestations, which Reinhard and Buikstra (2003) reported in a Chiribaya mummy. However, we did not systematically inspect the mummies for scalp dermatitis, in part because we were focusing on prevalence and density calculations and also to minimize specimen manipulation. Considering the high prevalence of pediculosis in the Chinchorros, and the fact that each female louse lays on average five eggs daily for about a month (Heukelbach, 2010), the values reported here indicate that infestation was highly endemic in all Chinchorro periods, common to all ages and both sexes with a high parasitic load. It is therefore reasonable to assume that pediculosis affected their quality of life.

Regarding head lice analysis and the wigs of the mummies, it is necessary to point out that the wigs, in some cases, do not necessarily represent the person's own hair. This is obviously so in the mummified fetuses who have long hair. However, if the wig had nits/eggs present, this would suggest that ectoparasites affected the living. We assumed that each wig represents one individual, because hair length, color, and thickness of the hairs tend to be homogeneous. The Chinchorro mummies analyzed were chosen based on good preservation of hair, with goals to understand the extent archaic populations were affected by pediculosis.

Head lice are not a life-threatening affliction, and attitudes and practices of communities toward head lice differ culturally (Catalá et al., 2005; Cazorla et al., 2007; Parison, 2010). In this context, one question remains: Which factors could have contributed to the high prevalence of head lice in ancient populations? It is hard to know what the Chinchorro attitude toward head lice was, but the prevalence and density data show they clearly were losing the battle against lice infestation. Perhaps during early times they considered the pediculosis as normal rather than an infestation problem that would need treatment. In any case, treatment seems to have been rather ineffective.

Figure 5. Graph of percentage of nits/eggs by mean density.

Social and individual attitudes are important variables to be considered for transmission dynamics in endemic communities (Burkhart and Burkhart, 2007; Catalá et al., 2005; Cazorla et al., 2007; Heukelbach, 2010). Pediculosis thrives in highly aggregated populations, as in contact-rich and sedentary settings with large families and extended social groups (Cazorla et al., 2007; Harper and Armelagos, 2010; Sultana et al., 2009). Hunter-gatherers, like the Chinchorro are often thought of as having low intra and inter-population density, with ephemeral housing. Therefore, it is somewhat surprising that they show a high mean prevalence of pediculosis among all studied sites. One possible explanation is that the Chinchorro had long hair, providing more surface area and a suitable environment for lice to hide in and reproduce, but other cultural variables, such as overcrowding and group gathering should be considered.

Nits/eggs are firmly attached to hair by a proteinaceous substance (Burkhart and Burkhart, 2005) making them difficult for people to remove or eliminate without combs or complex treatment. Clearly, all louse nits/eggs analyzed were part of the individual host, and there is no doubt that the individual had been infested during his/her life time.

The human head louse is morphologically adapted to live on the head, navigating the structural space provided by human hair. Particularly, the presence of strongly modified claws on the first pair of legs aids in holding onto human hair. Head lice are wingless, and do not jump (e.g., like fleas), and are poor self-dispersers. Therefore, propagation is mediated mainly by direct head-to-head contact. Fomites may increase propagation (Cazorla et al., 2007; Burkhart and Burkhart, 2007), but Chinchorro people did not have sophisticated headgear or hats that could have facilitated or increased head lice transmission. In Arica, most of these types of possible fomites (e.g. hats, turbans and combs) appeared during the Formative Period (ca. 3000 years B.P. or later). In addition, some authors have pointed out that fomites play a minimal role in head lice transmission in endemic settings (Heukelbach, 2010). Other cultural practices may be more relevant. Having long hair without braiding and combing may leave the nits/eggs and lice undisturbed, permitting development of most eggs. In recent studies hair length has been shown to be a risk indicator for pediculosis. For example, an observed higher prevalence of pediculosis in female schoolchildren has been discussed in context with long hair and gender specific behavior, like social playing (Catalá et al., 2005; Canyon, 2010; Hengge, 2010; Zúñiga and Caro, 2010).

Chinchorro males and females had long hair, providing a suitable environment for *P. humanus capitis* to flourish. Pediculosis thrives when haircare is minimal or nonexistent and when delousing is inefficient (Catalá et al., 2005; Willems et al., 2005), causing infestations to potentially reach epidemic levels. If undisturbed, the full life cycle is completed in about 30–45 days and the newly hatched nymph will immediately begin searching for suitable places to feed.

Table 8. Microscopic results of nits/eggs in hair samples ($N = 49$) taken from positive individuals by mummification type and age categories.

Nits/eggs	Naturally mummified ($N = 33$)				Artificially mummified ($N = 16$)				Total	
	Subadult ($N = 6$) %		Adult ($N = 27$) %		Subadult ($N = 9$) %		Adult ($N = 7$) %		Nit/egg count %	
Operculated	16	6.8	86	8.4	9	22.5	8	9.9	119	8.7
Hatched	24	10.2	276	27.1	10	25.0	19	23.5	329	23.9
Fragmented	39	16.6	244	24.0	12	30.0	44	54.3	339	24.7
Cementing substance	156	66.4	412	40.5	9	22.5	10	12.3	587	42.7
Total	235	100	1018	100	40	100	81	100	1374	100

Personal hygiene, such as bathing, and swimming in the ocean could have been common for the Chinchorro, but these measures do not eliminate lice nor nits/eggs. Head lice can endure for 36 h under water by closing their spiracles and by reducing their metabolism (Zuñiga and Caro, 2010). Lice need to be removed manually, by picking them or by combing the hair.

It is worth highlighting the good preservation of these ancient ectoparasites. Despite the fact that the samples are more than 4000 years old, light and low vacuum scanning electron microscopy revealed all main components of their life cycle: nits/eggs, nymphs and adults. Most specimens presented very well-preserved morphological structures. Unhatched eggs presented opercula with aeropyles, structures that play a crucial role in embryo respiration. Some nits had smooth rims (Figure 2), demonstrating that the larvae had hatched; others were frozen in time, in the process of hatching (Figure 3). The attachment of nits/eggs to the hair by a solid and resistant matrix was clearly present (Burkhart and Burkhart, 2005). A similar substance also can be observed in contemporary samples and other archaeological samples from all over the world (Fornaciari et al., 2009). The remaining substance sheds light into cleaning attempts and nit/egg removal. The fact that of all microscopically studied nits/eggs 42.7% had cementing substance only, suggests nit picking and social cleaning efforts were practiced (Table 7). Nits and eggs may have been removed from the hair using fingers and nails. No evidence of specialized combs for removing lice or nits/eggs has been found at Chinchorro sites.

Despite sample size differences, our prevalence data are similar to those of Rivera [79% (50/63) vs. 85.7% (6/7)]. Unfortunately, Rivera did not provide density values. However, the percentages of egg stages were strikingly similar. We found 26.6% (119/448) unhatched and 73.4% (329/448) hatched eggs while Rivera found 26.7% (98/366) unhatched and 73.2% (268/366) hatched eggs. Thus, the data are giving solid evidence that the Chinchorro were highly affected by pediculosis.

In contrast to modern data, adults (naturally mummified) were significantly more affected than subadults (= children), with a higher mean nit/egg density (2.9 nits/eggs/cm² vs. 1.6 nits/eggs/cm² respectively). In addition, Chinchorro children had significantly fewer lice specimens than adult individuals (7 vs. 221 lice). Probably the Chinchorro were focusing on removing the crawling and blood sucking adult specimens (lice) from their children's heads, thus minimizing egg laying and infestations. The data presented in Table 8, suggest little attention was given to nits, and that nit picking was not a thorough task because compared to adult individuals, subadults presented a higher percentage of cementing substance on the hair shafts [66% (156/235) vs. 40.5 (412/1018)].

Naturally mummified bodies had a significantly higher mean nits/eggs/cm² density than those that were artificially prepared (2.6 vs. 1.0). Also naturally mummified bodies had a significantly higher lice count than artificial mummies (228 vs. 4). In addition, the hair shafts of naturally mummified bodies had a significantly higher cementing substance frequency than the wig hair shafts of bodies with artificial mummification [45% (568/1253) vs. 16% (19/121)]. The data suggest that Chinchorro morticians were car-

ing for their dead and that the hair locks were cleaned postmortem during wig preparation and manufacture. In fact, this mortuary care should not come as a surprise, considering the great energy and effort the Chinchorro undertook in adorning their dead and making the wigs (Arriaza, 1995, 2005; Standen, 1997). It also suggests that the Chinchorro preferred an afterlife without lice which contrasted with the lousy reality of their corporeal existence.

At the population level, our data show that all Chinchorro sites were highly infested (Tables 1–9). In modern urban populations, pediculosis can reach 100% prevalence in certain settings (Meinking et al., 1986; Taplin and Meinking, 1996.). Chinchorro archaeological evidence coming from numerous cemeteries (complex mummification techniques and extended sites), large shell middens, paleopathological data (presence of external auditory exostosis, fish parasites and marine dependent diet), fishing technology (shellfish hooks, sinkers and harpoons) and radiocarbon chronology (continuous dates without gaps) points toward year-round coastal occupation (Aufderheide et al., 1993; Arriaza, 1995; Muñoz and Chacama, 1982; Standen, 1997). Pediculosis is a highly contagious condition and thrives in crowded surroundings, often brought on during social disruptions (Willems et al., 2005). We have observed important levels of trauma in Chinchorro, reflecting permanent conflicts (Standen and Arriaza, 2000; Standen, 2011). However, these permanent conflicts were likely the results of small scale, intermittent violence among groups, such as raidings or perhaps revenge killing, rather than organized warfare which would have facilitated overcrowding of those participating in combat or those being attacked. We hypothesize that significant Chinchorro head lice prevalence and louse density resulted from living year-round at the coast (as evidenced by archaeological information) and because they were thus less mobile than previously thought. In addition, we hypothesize Chinchorro head lice pediculosis infestations were probably a consequence of the following conditions: *Housing conditions and crowding*: Chinchorro communities lived in small semi-subterranean huts along the slopes of coastal hills (Muñoz and Chacama, 1982). The lack of rain made water resources very restricted; thus, settlements were highly localized. Their houses were made with a base of stone cobbles, encased by wooden frameworks of sticks, and covered with sea lion skins and reeds. The coastal environment offers limited building resources; as such, their huts were small, on average about 9 m², and they were neither totally enclosed nor windproof (Muñoz and Chacama, 1982). At night, the northern Chilean coast is foggy, extremely windy, and temperatures drop significantly. Thus, Chinchorro people (close kin and/or parents and children) likely slept very close to each other to keep warm, given the fact that adults and subadults (children) were both affected. In brief, small houses and nucleation probably increased the likelihood of ectoparasite transmission. *Social behavior*: Hunter-gatherers had plenty of time to engage in leisure activities (Barnard, 2004; Howell, 2010). Adults playing with children certainly could have contributed to head lice transmission, although games and toys have not been explored in Chinchorro archaeology. Head-to-head contact is the most common mode of transmission across age lines. *Mummification practices*:

Table 9. Summary of macroscopic and microscopic Pediculosis analysis (*N* = 63).

Cemetery	Tomb	Sex	Age (years)	Age category	Mummification type	Chinchorro chronology	Hair length (cm)	Macroscopic (museum) pediculosis result	Macroscopic (museum) pediculosis density (avg 1 cm ²)	Microscopy (Lab) Pediculosis result (nits, eggs or lice in hair and sediment samples)	Total number of nits/eggs (lab microscopy)*	Total number of lice (lab microscopy)*
Quiani 7	9	Male	40–45	Adult	Natural	Late	22	Positive	12.5	Positive	225	110
Quiani 7	12	Male	35–40	Adult	Natural	Late	27	Positive	0.5	Positive	11	0
Quiani 7	13	Female	25–35	Adult	Natural	Late	12	Positive	1.2	Positive	15	0
Quiani 7	16	Female	40–45	Adult	Natural	Late	5	Positive	0.1	Positive	7	0
Quiani 7	17	Female	30–35	Adult	Natural	Late	31	Positive	5.6	Positive	33	28
Quiani 7	22	Male	50–55	Adult	Natural	Late	10	Positive	2.8	Positive	140	22
Quiani 7	16A	Female	40–45	Adult	Natural	Late	20	Positive	4.8	Positive	302	4
Quiani 7	Expo 334	Male	Adult	Adult	Natural	Late	15	Positive	0.7	Positive	12	1
Cam 15	C109 Niño1	Indeterminate	7–12	Subadult	Artificial	Middle	5	Negative	0	Negative	0	0
Cam 15	C109 Niño2	Indeterminate	Newborn	Subadult	Natural	Late	4	Negative	0	Negative	0	0
Cam 15 SC	C5	Male	40	Adult	Natural	Late	6	Negative	0	Negative	0	0
Cam 15D	20	Female	Adult	Adult	Artificial	Middle	14	Positive	2.5	Positive	7	0
Cam 15D	22	Indeterminate	0–6	Subadult	Red?	Middle	Not measured	Negative	0	Positive	6	0
Cam 15D	23	Male	30–35	Adult	Artificial (face)	Middle	34	Negative	0	Negative	0	0
Cam 15D	7–87	Female	20–25	Adult	Artificial	Middle	10	Positive	1.8	Positive	14	0
Cam 15D	16C1	Male	0–6	Subadult	Artificial	Middle	7	Positive	1	Positive	8	4
Cam 15D	C11	Female	30–40	Adult	Natural	Late	20	Positive	0.8	Positive	15	0
Cam 15D	U111C5	Indeterminate	18–20	Adult	Artificial	Middle	15	Positive	0.2	Negative	0	0
Cam 15D	U112C1	Male	30–40	Adult	Artificial?	Middle	11	Positive	1	Positive	48	0
Cam 15D	U112C2A	Male	>45	Adult	Artificial, mud coated	Middle	9	Positive	0.7	Positive	16	0
Cam 15D	U112C3	Male	30–35	Adult	Natural	Late	4	Positive	0.8	Positive	10	0
Morro 1–5	XIII	Male	7–12	Subadult	Natural	Late	16	Positive	0.8	Positive	15	0
Morro 1–6	18	Male	40–45	Adult	Natural	Late	26	Positive	0.9	Positive	11	1
Morro 1–6	19	Indeterminate	0–6	Subadult	Natural	Late	Not measured	Positive	1.5	Positive	36	0
Morro 1–6	22	Male	40–45	Adult	Natural	Late	Not measured	Negative	0	Positive	4	0
Morro 1–6	27	Male	35–40	Adult	Natural	Late	10	Positive	1.4	Positive	9	8
Morro 1–6	32	Female	35–40	Adult	Natural	Late	14	Positive	0.5	Positive	16	0
Morro 1–6	39	Female	18–20	Adult	Natural	Late	8	Positive	5.2	Positive	56	2
Morro 1–6	41	Male	45–50	Adult	Natural	Late	11.5	Positive	4.7	Positive	134	3
Morro 1–6	44	Female	30–35	Adult	Natural	Late	9	Positive	1.3	Positive	16	0
Morro 1–6	45	Male	0–6	Subadult	Natural	Late	4	Negative	0	Negative	0	0
Morro 1–6	46	Female	35–40	Adult	Natural	Late	8	Negative	0	Positive	8	0
Morro 1–6	50	Male	30–35	Adult	Natural	Late	Not measured	Positive	3	Positive	37	3
Morro 1–6	53	Female	20–25	Adult	Natural	Late	32	Positive	0.6	Positive	13	3

Table 9. Summary of macroscopic and microscopic Pediculosis analysis (*N* = 63), (continued)

Cemetery	Tomb	Sex	Age (years)	Age category	Mummification type	Chinchorro chronology	Hair length (cm)	Macroscopic (museum) pediculosis result	Macroscopic (museum) pediculosis density (avg 1 cm ²)	Microscopy (Lab) Pediculosis result (nits, eggs or lice in hair and sediment samples)	Total number of nits/eggs (lab microscopy)*	Total number of lice (lab microscopy)*
Morro 1	24	Female	2-3	Subadult	Natural	Late	5	Negative	0	Negative	0	0
Morro 1	26	Female	25-30	Adult	Natural	Late	25	Positive	2.5	Positive	12	18
Morro 1	12B	Male	18-20	Adult	Natural	Late	30	Positive	7.8	Positive	41	0
Morro 1	1C6	Male	Adult	Adult	Artificial, black	Early	17	Positive	0.4	Positive	18	0
Morro 1	22C1	Male	0-6	Subadult	Artificial, red	Middle	Not measured	Positive	0.4	Positive	44	0
Morro 1	23C10	Indeterminate	0-6	Subadult	Bandage	Middle	9	Negative	0	Positive	1	0
Morro 1	25C5	Female	0-4	Subadult	Artificial, red	Middle	13	Positive	1	Positive	1	0
Morro 1	28C17	Female	30-35	Adult	Natural	Late	Not measured	Positive	1.7	Positive	189	5
Morro 1	28C22	Male	35-40	Adult	Natural	Late	13	Positive	0.3	Positive	20	4
Morro 1	28C24	Female	30-35	Adult	Mud coated	Middle	10	Positive	1.5	Positive	9	0
Morro 1	28C25	Indeterminate	Fetus	Subadult	Natural	Late	5	Positive	0.9	Positive	5	0
Morro 1	28C8	Female	Adult	Adult	Natural	Late	15	Positive	10.8	Positive	65	2
Morro 1	28PO	Female	25-30	Adult	Natural	Late	8	Negative	0	Positive	6	1
Morro 1	2C2	Indeterminate	2-3	Subadult	Natural	Late	9	Positive	1.7	Positive	35	2
Morro 1	7C2	Female?	14-16	Adult	Artificial, red	Middle	20	Positive	2	Positive	26	0
Morro 1	7C3	Male	0-6	Subadult	Artificial, red	Middle	14	Negative	0	Negative	0	0
Morro 1	7C5	Male	6-7	Subadult	Artificial, red	Middle	33	Positive	0.8	Positive	12	0
Morro 1	CH15	Male	40-45	Adult	Natural	Late	5	Positive	0.4	Positive	9	1
Morro 1	Cr 01	Indeterminate	Fetus	Subadult	Artificial, red	Middle	17	Positive	0.8	Positive	2	0
Morro 1	Cr 02	Indeterminate	Fetus	Subadult	Artificial, red	Middle	27	Positive	0.1	Positive	1	0
Morro 1	R2	Male	25-35	Adult	Natural	Late	21	Negative	0	Negative	0	0
Morro 1	21C1	Female	10-12	Subadult	Natural	Late	5.5	Positive	2.5	Positive	401	5
Morro	Estación sanitaria	Female	6-12 months	Subadult	Artificial, red	Middle	25	Positive	1.8	Positive	10	0
Yungay 372	EST2C3	Female	Adult	Adult	Natural	Late	5	Negative	0	Negative	0	0
Yungay 372	EST2C4	Indeterminate	8-10	Subadult	Natural	Late	11	Positive	2.1	Positive	15	0
Yungay 372	EST2C6	Male	>45	Adult	Natural	Late	12	Negative	0	Negative	0	0
Yungay 372	EST3C2	Indeterminate	13-17	Subadult	Artificial	Middle	7	Negative	0	Negative	0	0
Maderas Enco C2		Female	>25	Adult	Artificial, black	Early	12	Positive	0.1	Negative	0	0
Acha 4	C1	Female	Adult	Adult	Natural	Early	7.5	Positive	0.3	Positive	43	5

* The total number of nits/eggs and the total number of lice recorded in the Lab (microscopy) were calculated by adding up the total amount of specimens found in the samples of hair and sediment which had fallen off.

Figure 6. Delousing comb. Case PLM4 T171. Age: circa 550 years. B.P., Arica region, Chile.

Figure 7. Graph of nit/egg density by hair length in naturally mummified bodies.

Chinchorro rituals for the dead certainly brought people together to manufacture, display, and honor their highly decorated mummies. Similar mummification techniques and a common maritime technology spread along the coast from Ilo in Peru to Antofagasta in northern Chile. Burial practices and gathering to honor the ancestors increased the likelihood of crowded events and transmission of head lice. Thus, cultural diffusion and occasional long distance coastal mobility may have contributed to lice propagation among these early people. *Cultural aspects:* As pediculosis was extremely common and not life threatening, the Chinchorro probably did not perceive head lice as a serious problem. They did not develop artifacts (combs) to delouse as we have found in post-Chinchorro cultural groups (Figure 6). In addition, most Chinchorro had long hair, which increased their risk of acquiring and housing head lice. We calculated a 0.3 correlation coefficient between hair length and Chinchorro nit/egg louse density for all bodies with natural mummification (Figure 7). However, the fact that they removed louse nits/eggs from hair in the mummification process indicates that they likely perceived lice as a nuisance, and their world view did not include louse infestation in a preferred or ideal state.

6. Concluding remarks

These ancient mummies provide important additional evidence on the presence of parasites in antiquity (Aufderheide et al., 1998, 2008), as well as the biocultural aspect of past cultures. In northern

Chile, the bioarchaeological record and the Arica Museum of Archaeology house important mummy collections with excellent cultural and biological materials. This, along with light and scanning electron microscopy provide a unique opportunity to carry out in-depth paleopathological studies of microsamples. Pediculosis capitis was clearly a recurrent and endemic problem for the archaic coastal populations, with four out of five Chinchorro individuals affected. Permanent settlement patterns, small huts, funerary gatherings, and nighttime overcrowding may have played important roles in maintaining a high prevalence and transmission of pediculosis. We propose that evidence of pediculosis and its strong prevalence among the Chinchorro is a useful biological indicator relevant to debates about population density and social behavior in antiquity. Various cultural behaviors apparently increased the likelihood of ectoparasites' proliferation during Chinchorro times. In particular, small houses, early sedentism, and cold nights increased the chances of head-to-head contact and head lice infestations during resting periods. Lack of rain made fresh water resources very restricted, thus Chinchorro settlements were highly localized and crowded. Occasional distance travel by a few infested individuals to collect complementary resources and visit kinship likely contributed to the long distance dispersal of lice to surrounding areas. Ritual gatherings and a more relaxed view about ectoparasites could be additional factors.

In conclusion, our data from the Chinchorro of Arica and surrounding areas in northern Chile indicate that pediculosis capitis was highly endemic in the population that settled along this arid coast. Head lice were a common nuisance in antiquity, as they are for us today. The data further indicate that the Chinchorro lived in very close contact with each other, forming high density hunter-gatherer assemblages with intermediate mobility. Our findings support previous studies which suggested that the Chinchorro people lived year-round at the coast and had highly nucleated sites and cyclical social gathering. Daily contact among Chinchorro people for play and parental care possibly increased the risk of head lice transmission. The infestation data on natural mummies hint that adults were taking care of their children, grooming and delousing them, as the children had lower levels of lice.

The coastal environment provided the day-to-day basic subsistence, which in turn allowed year round occupation, increasing population density, social relationships and complexity. This is in concordance with other interdisciplinary research. For example, the presence of treponematosi, *Diphyllbothrium pacificum*, external auditory exostosis, Chagas disease, a marine diet, fishing artifacts, extensive shell middens, and complex funerary practices all suggest intense fishing and cyclical gathering as well as permanent coastal occupation (Arriaza, 1995; Aufderheide et al., 1998; Marquet et al., 2012; Standen, 1997). The Chinchorro lived in a harsh coastal desert environment, but the abundance of marine wildlife allowed for continuous gathering, feasting, time for socializing, and complex mortuary rituals for their dead. Considering that the Chinchorro were the first known inhabitants of the region, further population studies should be done in Arica to evaluate head lice infestations, as they should be equal to or greater in subsequent sedentary and agropastoral cultures from this region.

The excellent preservation of louse material provides opportunities for further studies. For instance, aDNA techniques using population level informative markers (e.g. microsatellite, SNPs) could elucidate the question of population connectivity among the different Chinchorro populations (Dittmar et al., 2003). Furthermore, Chinchorro head lice could provide an interesting glimpse into more general human migration patterns on the American continent, because they are older than previously studied Chiribaya mummies (Raoult et al., 2008). One question would be whether louse genotypes of the Chiribaya and the older Chinchorro match, suggesting not only continuity of settlement of the area, but also continuity of social contact among coastal populations through time.

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