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Inca Expansion and Parasitism in the Lluta Valley: Preliminary Data

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Assessing the impact of cultural change on parasitism has been a central goal in archaeoparasitology. The influence of civilization and the development of empires on parasitism has not been evaluated. Presented here is a preliminary analysis of the change in human parasitism associated with the Inca conquest of the Lluta Valley in Northern Chile. Changes in parasite prevalence are described. It can be seen that the change in life imposed on the inhabitants of the Lluta Valley by the Incas caused an increase in parasitism.

Key words: Inca - disease - archaeoparasitology - Chile

Parasite evidence from archaeological sites has been shown to provide unique insights into behavior and disease (Reinhard 1988, 1992a). The prevalence of parasites in coprolites is related to subsistence behaviors, settlement patterns, and sanitation. These in turn are influenced by large scale cultural developments such as agriculture, urbanism, and the development of complex social systems. There are many examples of how archaeoparasitology has shown the relation of behavior to emergence of parasitic disease. Fry (1977) demonstrated that hunter-gatherer use of uncooked insects as food caused thorny-headed worm infections. Ferreira et al. (1984) demonstrated that consumption of raw fish caused tapeworm infection. Reinhard (1988) showed that the introduction of agriculture caused a significant rise in parasitism in the Southwest USA (Reinhard 1988). Hugot et al. (1999) showed that house style and population aggregation increased the prevalence of pinworm infection. These and other studies as reviewed by Reinhard (1990, 1992a) show that archaeoparasitology is the only way to objectively see the influence of cultural development on the state of human parasitism.

At this point, we have no data regarding the impact of the development of Empire states on parasitism. There are theoretical perspectives on this issues (Boyden 1970, Cockburn 1971, Black 1975). However, recent excavations in the Lluta Valley of Chile provide us with the opportunity to assess the influence of the Inca Empire expansion on the area. Coprolites have been recovered from both Inca (Late Period, LP) and pre-Inca (Late Intermediate Period, LIP) settlements. Presented below is a helminthological analysis of a small number of coprolites from this region.

Archaeological background - The archaeological remains of the Atacama Desert are particularly good for the

assessment of the influence of cultural development on parasitic disease. This is especially true of the region near the modern city of Arica, Chile. Two large rivers, Rios Azapa and Lluta, flow from the high Andes to the Arica region and form an estuary at the coast. The rivers, estuary, and marine areas provide a variety of environments for subsistence. They also provide a corridor for commerce. Because of the availability of food resources, there is a long cultural continuity in the region from early Chinchorro hunter-gatherers to Inca agriculturalists.

Paleoparasitological studies have focused only on the Chinchorro hunter-gatherers. However, many other cultures exist in the valley. Two agricultural occupations are the LIP and LP. During the LIP, each settlement consisted of a small, simple hamlet formed by a group of houses and one or more cemeteries. The residential areas were no larger than 4 ha. The LIP settlements lacked any discernable public architecture (Santoro 1995).

During the LP, the Lluta Valley became part of the Inca Empire. The size of the residential areas increased to 11 ha. Public architecture in the form of platforms are present. Analysis of coprolites shows greater subsistence complexity in the LP (Dorsey Vinton 1997). The foods of the LIP (pre-Inca) were nearly exclusively obtained in the region local to the small settlements. In contrast, in the LP (Inca), there was more trade in food. Tuber crops from higher elevations (potato and oca) supplement the locally grown maize and manioc. Importantly, there was a statistically significant difference in fish consumption between the periods. Fish bone was found in 45% of LP coprolites but only in 15% of LIP coprolites.

MATERIALS AND METHODS

Thirty-nine coprolites were analyzed from the Lluta Valley excavations. Fifteen of these came from LIP contexts. The remainder came from LP contexts. Processing methods follow those previously published (Fry 1977, Reinhard et al 1988, Reinhard 1996). Five grams from each coprolite were rehydrated in 0.5% trisodium phosphate. The coprolites were disaggregated and screened through 300 µm mesh. The material that passed through the screen was concentrated by centrifugation and a subsample was stored in 1 g vials in alcohol for parasitological study.

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Nine microscope preparations were made from each sample. Each preparation was made with one drop of sediment mixed with one drop of glycerine on a microscope slide. A cover slip was placed over the mixture and sealed. The preparations were then scanned at 400 power with a Jenaval microscope.

RESULTS

Four parasite species were found: pinworm (*Enterobius vermicularis*), whipworm (*Trichuris trichiura*), fish tapeworm (*Diphyllobothrium pacificum*), and hymenolepidid tapeworm (*Hymenolepis nana*). Of 15 LIP coprolites, one was positive for whipworm eggs (7%) and one was positive for *H. nana* tapeworm eggs (7%). Of 24 LP coprolites, five are positive for pinworm (21%), two are positive for whipworm (8%), and one is positive for fish tapeworm (4%). See Table I for data.

DISCUSSION

A comparison of the data from the two periods shows an interesting difference between the two cultural periods (Table II). Several points are apparent. First, the Lluta Valley inhabitants hosted multiple species of parasites. Second the infection modes represented by this array of parasites is diverse with air-borne infection, fecal borne infection, and dietary infection. Pinworms were transferred by direct person to person contact or by air-borne contamination of the environment. Whipworm infection occurred as a result of fecal contamination of hands, food, water, eating utensils and/or drinking utensils. Fish tapeworm infection resulted from consumption of poorly cooked fish. *H. nana* had two potential infection modes. Humans could have become infected by eating infected grain beetles. However, *H. nana* has evolved a direct mode infection through fecal contamination.

Three parasite species are present in each of the LIP and LP occupations. Diet-related parasite species are more common in the LIP (tapeworms) and air-borne and fecal transmitted species are predominate in the LP.

Effects of Inca Empire expansion - Pinworms provide the best indications of behavioral changes between the LIP and the LP. When the Inca added the Lluta Valley to their empire, they resettled the indigenous population from small scattered habitations to large towns. As a result, the population became concentrated in a few places. In small populations that are dispersed, pinworm infection remains low (Reinhard 1992b, Reinhard et al. 1997, Hugot et al. 1999). However, when population density increases, the combined aspects of retroinfection and air-borne contamination result in especially high rates of infection. The LP coprolites exemplify this point. In the case of the LP coprolites, five of 24 (21%) contained eggs. Therefore, it is safe to conclude that the LP population suffered from pinworm hyperinfection. The behavioral cause of this was population aggregation. LIP settlements were small, apparently family units that were dispersed in the valley. LP settlements were large villages covering many hectares and housing several hundred or more people. Population crowding was then the cause of sanitation and hygiene breakdown. In North America, the prevalence of pinworm eggs in coprolites is correlated statistically with the skeletal lesions of porotic hyperostosis (Reinhard 1992b). It would be worthwhile to compare the lesions of porotic hyperostosis between the Late Intermediate and LP skeletons in the Lluta Valley.

It is noteworthy that fish tapeworm is present in the LP coprolites. Since dietary analysis of the coprolites showed an increased consumption of fish in the LP, it is likely that fish tapeworm infection became more prevalent due to the consumption of fish.

TABLE I

Coprolites positive for parasite eggs by laboratory analysis numbers with calculations of the number of eggs per gram of coprolite

Sample	Parasite species	No. of eggs/g	Time period
7	<i>Enterobius vermicularis</i>	1,700	LP Inca
10	<i>E. vermicularis</i>	1,800	LP Inca
11	<i>Diphyllobothrium pacificum</i>	5,400	LP Inca
16	<i>E. vermicularis</i>	2,100	LP Inca
28	<i>E. vermicularis</i>	700	LP Inca
	<i>Trichuris trichiura</i>	700	
29	<i>E. vermicularis</i>	900	LP Inca
31	<i>T. trichiura</i>	1,200	LP Inca
59	<i>Hymenolepis nana</i>	6,200	LIP pre-Inca
61	<i>T. trichiura</i>	1,800	LIP pre-Inca

LP: Late Period; LIP: Late Intermediate Period

TABLE II

Comparison of percentages of coprolites positive form parasites from the two cultural periods

Culture	<i>Trichuris trichiura</i>	<i>Hymenolepis nana</i>	<i>Diphyllobothrium pacificum</i>	<i>Enterobius vermicularis</i>
Inca (Late Period) n = 24	8%	0%	4%	21%
Pre-Inca (Late Intermediate Period) n = 15	7%	7%	0%	0%

Comparison with other areas - No other area or time has been documented with higher parasite prevalence in the New World than the LP of the Lluta Valley. This includes all studies in Peru (Patrucco et al. 1983, Horne 1985, Reinhard, current research), Chile (Arriaza 1998), Brazil (Ferreira et al. 1988), and the Great Basin, Mexico, and Southwest of North America (Reinhard et al. 1987, Reinhard 1990). Several Anasazi sites have high prevalence of pinworm, most notably Antelope House, Arizona (Reinhard 1992b, 1996). However, whipworm and fish tapeworm are not present at this site. Early Chinchorro mummies exhibit a high prevalence of fish tapeworm, but do not show the same species richness as the Lluta Valley coprolites. Therefore, in comparison with other regions, parasitism seems to have been an especially serious problem for the LP inhabitants.

This is a preliminary study of the influence of the Inca Empire on indigenous disease patterns in Chile. This first analysis shows that the Lluta Valley has the greatest promise for showing how Empires influence disease. Since completing this analysis, many more remains have been excavated in the Lluta Valley. In the near future, we plan to do more extensive analysis of coprolites and mummies from this region. In addition to applying the basic methods of investigation discussed here, we will also complete molecular studies for protozoa parasites. Ultimately, the first glimpse of Inca parasitism on a population level will come from this work.

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