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Marine resource reliance in the human populations of the Atacama Desert, northern Chile – A view from prehistory

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ABSTRACT

The Atacama Desert is one of the most inhospitable terrestrial environments on Earth, yet the upwelling of the Humboldt Current off the coast has resulted in the presence of a rich marine biota. It is this marine environment which first enabled the human settlement of the northern Atacama Desert, and continues to form the basis of regional economies today. In this paper we explore how the desert has shaped human dietary choices throughout prehistory, using carbon and nitrogen isotope analysis of human bone collagen (n = 80) to reconstruct the diets of the inhabitants of the Arica region of the northern Atacama. This area is one of the driest parts of the desert, but has been generally understudied in terms of dietary adaptation. Statistical analysis using FRUITS has allowed deconvolution of isotopic signals to create dietary reconstructions and highlight the continued importance of marine resources throughout the archaeological sequence. Location also appears to have played a role in dietary choices, with inland sites having 10–20% less calories from marine foods than coastal sites. We also highlight evidence for the increasing importance of maize consumption, coinciding with contact with highland polities. In all periods apart from the earliest Archaic, however, there is significant variability between individuals in terms of dietary resource use. We conclude that marine resource use, and broad-spectrum economies persisted throughout prehistory. We interpret these results as reflecting a deliberate choice to retain dietary diversity as a buffer against resource instability.

1. Introduction

The Atacama Desert is one of the most extreme environments on Earth. As the driest hot desert in the world, life here is extremely marginal. Natural terrestrial resources are few, and freshwater availability is extremely limited (Williams et al., 2008). Human habitation of the desert, even today, is restricted to the valleys of the snowmelt-fed and seasonal rivers which traverse the Andean cordillera, and desert oases (Santoro et al., 2005). Yet, humans have occupied the desert for thousands of years (Arriaza et al., 2008). This is primarily due to the nearby marine environment. The Humboldt Current upwells off the north coast of Chile, bringing with it nutrient-rich waters and sustaining a rich and complex marine ecosystem (Thiel et al., 2007). The presence of plentiful marine resources meant that habitation of the desert was possible even prior to the adoption of agriculture, after which the ability to manipulate the desert environment began (Santoro et al., 2017).

In order to evaluate how different societies and natural environments affected diet in the Atacama Desert, however, there is a need for palaeodietary data from multiple parts of the desert, and different time periods. Palaeodietary work already undertaken in the Atacama Desert suggests, relatively unsurprisingly, that human subsistence choices were constrained by the desert environment (Santana-Sagredo et al., 2015; Torres-Rouff et al., 2012). There is evidence from the incipient agricultural sites (dating from 1700BCE) of coastal valleys of extreme northern Chile, such as Pampa Tamarugal and the Loa River Valley, that during the transition to agriculture, desert populations retained significant

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marine-resource input into their diet (Bonilla et al., 2016; Pestle et al., 2015a; Santana-Sagredo et al., 2015; Torres-Rouff et al., 2012). This has been interpreted as reflecting the presence of trade networks (Pestle et al., 2015a, 2015b) to mitigate the instability of terrestrial crops through use of marine resources (Santana-Sagredo et al., 2015). While trade networks developed during the Formative Period (*ca.* 1700BCE - 450CE), these socio-economic interactions continued during all subsequent periods, allowing some areas to become focused on maize agriculture and camelid pastoralism (e.g. Pestle et al., 2016; Torres-Rouff et al., 2015). Other regions seemed to have retained broad-spectrum based subsistence despite being influenced by polities whose dietary focus was maize (Knudson et al., 2007), such as the Tiwanaku, Wari (*ca.* 450–900CE) and later Inka peoples (1450–1600CE). These polities whose homelands were in the Peruvian highlands, expanded and annexed surrounding areas in the Middle Period (Wari and Tiwanaku) and Late Period (Inka). While there has, in the past, been a strong focus on the impact of these external polities and their reliance on maize in the Atacama Desert, it is becoming increasingly recognised that this crop has played a variable role in the subsistence economies of the desert people (Cuéllar, 2013; Tykot et al., 2006). Similarly, the role of different ecological niches in subsistence decisions is just beginning to be explored in the region (Zaro, 2007).

To date there have been relatively extensive isotopic studies of diet conducted in the San Pedro de Atacama and Tarapacá regions, but there is a dearth of data from the Arica region. These areas, while all located in the Atacama Desert, have quite different local environments, and therefore the potential for different subsistence choices in prehistory. For instance, the desert varies quite considerably in terms of freshwater availability and therefore suitability for human habitation and agriculture. In San Pedro de Atacama, in inland northern Chile, for example, archaeological sites are centred around the natural oases. Agriculture was possible in this area (Llagostera and Costa, 1999; Nuñez, 2007) and it was likely an important stopping point for camelid traders moving from the political centres of the Andean highlands (Hubbe et al., 2012; Kolata, 1991; Llagostera, 1996). In Peru there are fog 'oases' in the desert, providing moisture which increases floral variability (Beresford-Jones et al., 2015) and the potential for agricultural yields (Sandweiss et al., 1999). The desert in the Tarapacá and Arica regions, however is extremely dry, experiencing less than 0.6 mm of rain per year (Williams et al., 2008). Agriculture even today is possible in very restricted areas centering around the river valleys and inland oases.

As well as geographic variation in water availability, there has also been climatic variation in rainfall over time. The El Niño southern oscillation has serious effects on the amount of rainfall in any given year, and El Niño cycles have varied in intensity throughout prehistory (Gayo et al., 2012; Moseley and Keefer, 2008; Sandweiss et al., 2009). Around 500 BCE, for example, palaeoclimatic data suggest a change to El Niño regime, resulting in higher levels of humidity in the Atacama Desert (Gayo et al., 2012), and considerably expanding the agriculture land available. During this time period, archaeological evidence suggests the development of extensive field systems alongside villages such as Ramaditas, Guatacondo and Caserones (Uribe and Vidal, 2012; Vidal et al., 2012), located in harsh environments where today agriculture is not possible. In these sites, remains of *Zea mays*, *Phaseolus lunatus*, *P. vulgaris*, Lagenaria, *Arachis hypogaea*, *Chenopodium quinoa* and Algarrabo (*Prosopis*) pods have been identified (McRostie et al., 2017; Santoro et al., 2017). These plants are not endemic to the northern Atacama and it is likely that they were introduced from the Andes and the eastern lowlands. This research aims to assess both the impact of the arrival of these crops, and the marginality of the desert environment on resource choices.

2. Environmental context: Arica region

The Arica region (Fig. 1) has four snowmelt-fed rivers, the Lluta, San Jose, Chaca and Camarones. Further to the south it is more truly arid, with the Loa River and its tributaries providing some of the only freshwater (Santoro, 2012). Use of the terrestrial environment in the Arica region, however, is further complicated by the presence of high levels of contaminating heavy metals (arsenic, lithium and boron) in the rivers (Apata et al., 2017; Figueroa et al., 2012). This means that, while there is freshwater, its use and consumption can have serious health implications (Arriaza et al., 2010; Swift et al., 2015).

Dietary adaptations in the Arica region have not yet been investigated using isotopic techniques, but instead inferred using archaeological evidence. Archaeological evidence suggests that marine resource consumption was fairly ubiquitous throughout prehistory, with marine faunal remains and material culture associated with fishing found even in interior valley sites (Table 1). From around 7000 BCE the area played host to a large Archaic period population of *Chinchorro* marine hunter-gatherers, who settled the coast and relied heavily on the ocean for all sustenance (Arriaza et al., 2008; Standen et al., 2017). From 1700 BCE, however, there appears to have been a change in the El Niño regime, resulting in depression of the fisheries, relocation of the coastal peoples into inland river valleys, and the beginnings of agriculture in the region (Grosjean et al., 2007; Moreno et al., 2009; Williams et al., 2008). The cultivation of the interior valleys will have provided the people of the region with the ability to produce staple terrestrial crops for the first time. Andean domesticates such as potato (*Solanum*), ullucu (*Ullucus*), and quinoa (*Chenopodium*) become common in the archaeological record (Pearsall, 2008). Later in prehistory the region begins to interact with highland Andean polities such as the Tiwanaku (Muñoz, 1983, 1995), eventually being annexed by the Inka Empire in the Late Period (Santoro et al., 2010). These cultures would have allowed resource trade with other parts of their empires, as well as having specific ideas surrounding diet. In particular, both the Tiwanaku people and the Inka Empire placed ceremonial importance on the consumption of maize (Goldstein, 2003; Staller, 2010). There is ethnographic and archaeological evidence that, despite the marginality of agricultural land, the area became significant for maize production under the Inka Empire (Murra, 1980; Santoro et al., 2010).

In this study we investigate the effect of the desert environment on prehistoric resource-use in the Arica region. We hypothesise that the marginality of the desert means that ancient populations are unlikely to have relied solely upon agricultural resources in any period. Instead a sustained reliance on marine resources is likely. The ocean has always been a plentiful source of food, leading to a maritime tradition which persists even into the present day. We therefore examined diet in coastal and near-coastal valley sites from both agricultural and pre-agricultural periods to examine whether or not dietary diversity, and marine resource use, is maintained throughout prehistory. We then compare the isotopic data to other lines of archaeological evidence relating to resource use to build a fuller picture of subsistence strategies in the region.

3. Archaeological context

The studied samples derive from archaeological sites in the northern Atacama Desert, close to the modern-day city of Arica (Fig. 1). Sites lie both on the coast, and in the near-coastal areas of the Azapa Valley. This region has a long human occupation history, but not all periods and cultures are present both inland and on the coast. For example, the Archaic period is not well-represented in the inland valleys. Conversely there is a lack of evidence for Middle