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Quantitative paleodietary reconstruction with complex foodwebs: An isotopic case study from the Caribbean

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ABSTRACT

Stable isotope analysis has a long history in Caribbean archaeology. The Caribbean region, however, possesses a highly complex isotopic ecology, including both a large number of isotopically variable food sources, and a high degree of isotopic overlap between different food groups. As such, to date, most regional paleodietary studies have been limited to descriptive and qualitative conclusions concerning the relative contributions of different food sources. In this study we apply an iterative Bayesian multi-source mixing model (FRUITS) to skeletal stable isotope data from the prehistoric population of Tutu, St. Thomas, USVI, to test the feasibility of such models to generate quantitative and probabilistic individual paleodietary reconstructions. The isotope data set includes both bone collagen ($\delta^{13}C_{co}$ and $\delta^{15}N_{co}$) and apatite ($\delta^{13}C_{ap}$) data. The results of two different dietary models using four and five distinct food groupings, respectively, are compared and assessed relative to other relevant archaeological evidence pertaining to past diet at the site. We highlight the potentials and limitations of multi-source mixing models for regional paleodietary studies, and their relevance to ongoing debates within Caribbean archaeology concerning the relative importance of different food sources such as manioc, maize, and seafood.

1. Introduction

Recent years have seen a notable increase in the use of mixture models, many of which employ Bayesian principles, in isotopic studies of paleodiet (Fernandes et al., 2014, 2015; Lubetkin and Simenstad, 2004; Moore and Semmens, 2008; Newsome et al., 2004; Parnell et al., 2010, 2013; Phillips, 2001; Phillips and Gregg, 2003; Stock and Semmens, 2013). Many of these applications have been made in continental settings (e.g. Fernandes et al., 2015; Pestle et al., 2016a, 2016b), however, which tend to possess comparatively simple foodwebs featuring little overlap in the isotopic signatures of source groups. In comparison, few examples of the use of such models are to be found in Caribbean paleodietary literature (the only exceptions being Pestle, 2010a and Chinique de Armas et al., 2015). In large part, the paucity of Caribbean applications can be attributed to the incredible complexity of the region's foodweb (Pestle, 2010b, 2013). Not only do the floral and faunal foodwebs of the region comprise hundreds and hundreds of edible taxa but the isotopic signatures of different food groups (established based on taxon, ecological niche, supposed trophic position) are non-overlapping. This stands in stark opposition to many of the continental regions in which stable isotope analysis was first developed and applied. The huge number of potential sources and the lack of discrete, non-overlapping clusters of ecologically similar organisms tend to produce overly broad and non-definitive solutions in multi-source mixture models.

The lack of such studies is unfortunate, as these Bayesian tools can provide quantitative and probabilistic solutions to individual diet and, "offer a powerful means to interpret data because they can incorporate prior information, integrate across sources of uncertainty and explicitly compare the strength of support for competing models or parameter values" (Moore and Semmens, 2008: 471). The capability to compare models/competing hypotheses could be of particular utility in the Caribbean, where some long-held assumptions about diet (e.g. the primacy of manioc/cassava) are/have been challenged (e.g. Mickleburgh and Pagán-Jiménez, 2012; Pagán-Jiménez, 2013). Moreover, these approaches are inherently stronger in that they are model-bound, and allow testing of possible alternatives fitting the observed data following Bayesian principles, instead of traditional approaches that fit possible explanations of diet only after patterns in the data are defined (See Pestle et al., 2016b). Finally, these models have significant interpretive value in that they move discussions beyond isotopes or macronutrients to actual assessment of food intake, a metric that would

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have been cognizable to the human populations under study.

To address this apparent lacuna, we present here the results of an iterative Bayesian modeling study of a previously analyzed and well-studied Caribbean population from the Tutu site, St. Thomas, USVI. The Tutu site was chosen given: a) the existence of a robust corpus of human isotope data, b) the high degree of preservation of the human bone samples from which the isotopic data were derived, c) that St. Thomas is a relatively small island, without major river systems, thereby eliminating the confounding possibility of freshwater food sources, and d) the existence of independent evidence for paleodiet (in particular, zooarchaeological analysis, Wing et al., 2002) against which the results of modeling might be compared. It was our intent to employ successively more complex dietary models so as to gauge the effects of using more and more "realistic" and complex models, all the while comparing the resulting data with the independent sources of paleodietary data. The hope was that the consilience of modeling and archaeological data could serve to validate the use of such models in future Caribbean studies.

Ultimately, the results of our study show multi-source mixture modeling (in this case, FRUITS, Fernandes et al., 2014) to be useful for characterizing individual level dietary variability, in spite of the notable complexity of the region's foodweb. The limits of such modeling approaches in the region are, however, also evident from the results of this study, and we attempt to present both the pros and cons of this method in as transparent a manner as possible.

2. Background

2.1. Site context

The site of Tutu is located on the island of St. Thomas, US Virgin Islands (USVI), in an inland valley about two km from the coast (Fig. 1). St. Thomas lies in the Virgin Islands at the easternmost end of the Greater Antilles archipelago in the northern Caribbean Sea. The island is situated roughly 55 km east of Puerto Rico and 200 km from the northern end of the Lesser Antilles, at a strategic location in terms of trade between the two major Antillean archipelagos. Geologically, St. Thomas was formed by the uplift of submerged volcanoes capped by marine limestone, and possesses rugged topography with many low-lying hills and sparse flat land. The climate is maritime tropical with little year-round variation in temperature but substantial seasonal fluctuations in rainfall, including pronounced dry periods. The arid conditions and sloping terrain limit permanent freshwater bodies on the island primarily to small fast-moving streams with seasonally variable output. Similar to the insular Caribbean in general, and the smaller islands of the Antilles in particular, the biomass and diversity of terrestrial fauna, especially of mammals, on St. Thomas is quite limited. The island does however provide ready access to a diverse array of marine ecosystems and resources including lagoon, littoral, coral reef, and offshore resources.

Archaeological excavations at Tutu were carried out in the early 1990s prior to development of the land for use as a shopping center (Righter, 2002). The excavations and subsequent investigations of the recovered assemblages from the site represent one of the largest archaeological research projects carried out in the USVI. This research revealed the presence of a large Amerindian village with a central plaza area surrounded by domestic structures and refuse middens (Righter, 2002). Owing to the size and multi-period occupation of the site, the quantity of recovered materials (especially the relatively large number of burials containing well preserved skeletal remains), and the large-scale interdisciplinary research design, the Tutu site has provided unique insights into continuity and change of pre-Columbian Antillean lifeways (Righter, 2002).

The Ceramic Age of the Caribbean is generally divided into an earlier and later phase (Rouse, 1992), which in the Lesser Antilles and eastern Greater Antilles, correspond to approximately 300 BCE to 600 CE (Early Ceramic) and 600 CE to 1500 CE (Late Ceramic), respectively. Ninety-two radiocarbon dates in total have been obtained

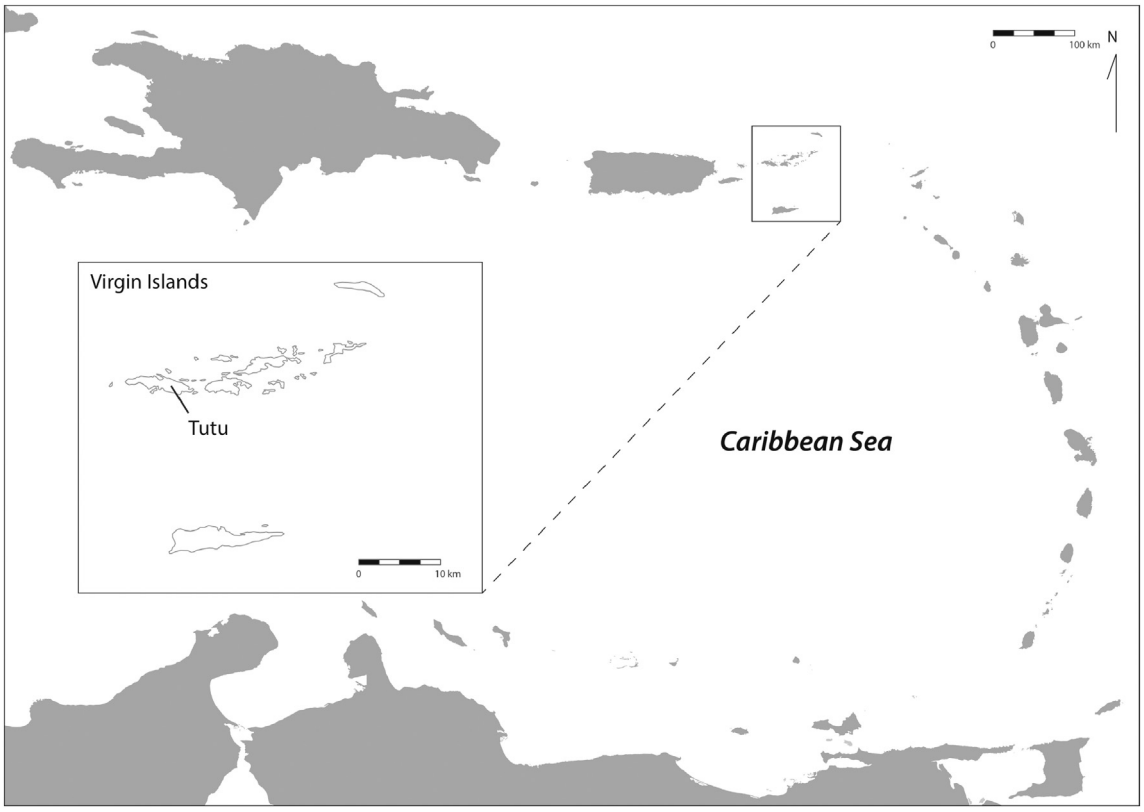

Fig. 1. Map of Caribbean region showing location of St. Thomas, with inset displaying Tutu site's location.