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Niche construction and optimal foraging theory in Neotropical agricultural origins: A re-evaluation in consideration of the empirical evidence

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ABSTRACT

The various theoretical approaches advanced over the past 50 years to explain the origins of agriculture have prompted much discussion and debate. Most recently, controversy has arisen concerning the utility of two Darwinian approaches; namely, cultural niche construction (CNC) and human behavioral ecology-derived optimal foraging theory (OFT). Recent papers advocate for the primacy of cultural niche construction, calling for optimal foraging approaches to be all but disregarded in the quest to explain how and why foragers became farmers (Smith, 2015, 2016; Zeder, 2015, 2016). In particular, it is claimed that archaeological, paleo-environmental, and paleontological evidence from the Neotropics of northern South America fail to meet predictions derived from OFT theory, while predictions said to be derived from CNC-based approaches are supported (Smith, 2015, 2016; Zeder, 2015). However, a number of misreadings of the northern South America evidence are made in those discussions, while some pertinent literature is not considered. In this paper we discuss these misreadings and provide a clear re-articulation of the original data and interpretations, finding support for OFT predictions. Our re-evaluations of OFT and CNC further suggest they can, in fact, be complimentary explanatory approaches.

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1. Introduction

The fundamental importance in human history of plant domestication and human economies based on agricultural products has prompted a number of theoretical debates as to how and why human populations around the globe became farmers starting about 11,000 years ago. Current arguments center on the utility of two Darwinian theoretical approaches for explaining agricultural origins; human behavioral ecology (HBE) and its derivative optimal foraging theory (OFT) and cultural niche construction (CNC) (e.g., Gremillion et al., 2014; Codding and Bird, 2015; Freeman et al., 2015; Smith, 2015, 2016; Zeder, 2015, 2016; Bird et al., 2016; Stiner and Kuhn, 2016; Wallach, 2016). In two recent papers Smith (2015, 2016) argues that OFT approaches should generally be rejected and replaced by CNC explanations. In way of assessing empirical data for his arguments, he focuses on a portion of the archaeological and paleo-environmental records from northern South America, thought to be a major independent region of agricultural origins (hereafter termed plant food production [PFP] to incorporate both initial cultivation of plants and appearance of their domesticated products). As investigators who have carried out long-term research there, we find that in Smith's discussions there are several critical misreadings of the evidence, while a number of important sources aren't considered. Given the considerable importance of this region in Neotropical prehistory and its place as an early and likely independent center of agricultural origins, our aim here is two-fold: 1) to provide a more complete and arguably more accurate review of the evidence for the transition from foraging to farming, and 2) on this basis, re-evaluate the different positions taken with regard to OFT and CNC in agricultural origin research.

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2. Background: optimal foraging and niche construction theory

So that empirical evidence from Neotropical records discussed below may be best considered and understood in the light of the two theories, we first briefly review a few pertinent tenets and theoretical predictions of each with particular regard to PFP origins. More extensive discussions are available in Kennett and Winterahlder (2006), Gremillion et al. (2014), and Codding and Bird (2015). In Piperno and Pearsall (1998) and Piperno (2006a, 2011a) the "diet breadth model" (DBM) of OFT was employed in order to posit and test some underlying reasons accounting for resource use, change, and intensification among the first farmers and their forager predecessors. The DBM uses a straightforward currency—energy—to measure the costs and benefits of alternative resource sets, and assumes that humans will have a goal of optimizing the energetic returns of their subsistence labor. One of its strengths is how it underwrites the logic of diet choice and dietary broadening or narrowing, both shown to be integral to PFP origins globally (e.g., Larson et al., 2014). Under the DBM, resource "rankings" are based on their energetic returns to labor, not simply on their actual abundances on landscapes. Those resources with the highest returns are expected to be taken when encountered, and when higher-ranked resources become less frequent or unavailable due to environmental change or human over-exploitation, lowerranked items are taken. A result is that the diet may broaden and becomes less energetically efficient overall. This decrease of highranked resources is in OFT terms called "resource depression".

Piperno and Pearsall (1998) and Piperno (2006a, 2011a) applied the DBM to Neotropical PFP based on the following: 1) demonstrations from ethnographic data that energetic efficiency is a significant influence on food procurement decisions, 2) seeds and underground plant organs are typically shown to be much lowerranked than small to medium-sized fauna, in turn lower-ranked than many large animals, and 3) paleoecological evidence for considerable climate, vegetation, and faunal changes during the Pleistocene-Holocene transition, with loss of open, savanna-type lands and their subsistence resources-including the now-extinct megafauna-in concert with expansion of tropical forests and their lower-ranked plant and animal resources, and 4) the limited but intriguing evidence that initial PFP may have been more energetically-efficient than the preceding tropical full-time foraging, providing an OFT-derived rationale for initial cultivation (see Piperno and Pearsall, 1998; Piperno, 2006a; Piperno, 2011a for complete discussions). Therefore, decreasing foraging efficiency as dietary breadth necessarily expanded to incorporate lower-ranked resources was posited as an important selection pressure acting on human food procurement strategies during the Late Pleistocene and early Holocene.

Turning to CNC theory, archaeologists are increasingly interested in its applications, for good reasons. Human environmental modification has a deep history, as studies dating back to the Paleolithic demonstrate, and humans may be expected to alter their environments with numerous practices that leave both short- and long-term ecological legacies. Moreover, topics such as subsistence intensification and PFP origins are intimately tied to how human actions often times drive environmental change, both intentionally and not. The application of CNC to PFP origin questions is more recent than with HBE and OFT. In two recent papers that explicitly discuss the Neotropics, Smith (2015, 2016) argues that CNC uniquely predicts the circumstances around which initial domestication occurred, and he puts forward a number of "test implications" said to derive from CNC logic for evaluating its efficacy when empirical evidence is considered. These are set against competing test implications said to be derived from OFT formulations.

For example, the following, operating shortly before or concomitant with PFP origins, are argued to support primacy of CNC; the opposite would support OFT: 1) little to no environmental change that would cause biomass reduction of optimum dietary resources, 2) no changes in food processing activities such as appearance of a grinding stone technology, 3) no decrease of high ranking resources. 4) evidence for CNC in way of sustained local ecosystem modification and without prior decrease in highranking resources, and 5) decreases in residential mobility due to a focus on rich resource areas "with abundant, predictably available resources within a relatively circumscribed area" (the OFTsupported implication would be population packing) (Smith, 2015; Zeder, 2016:339 following Smith, 2015). Numbers 1, 3, and 4 relate directly to the issue of resource depression, one of Smith's foci when comparing OFT with CNC. In contrast, therefore, to OFTderived hypotheses that a decreased availability of high-ranked resources (i.e. resource depression) led to subsistence changes with dietary broadening shortly before and at PFP origins, energetic efficiency as a determinant of subsistence choice/change is not considered in these CNC-derived expectations, and initial domestication is predicted to occur "... within a context of stable or enhanced resource availability ..." (Smith, 2015:239). These test implications are evaluated below with regard to the empirical evidence from northern South America and Neotropics more broadly.

3. Paleoenvironments and subsistence changes in northern South America

A zone located in Colombia and labeled D1 in Piperno (2011a. Fig. 1) that is reproduced here as Fig. 1, is an area where a number of archaeological sites with early PFP evidence occur and putative wild ancestors of some crop plants are native, making it a likely center of domestication. Early PFP occupations there, located in the Middle and Upper Cauca Valley and dating from about 11,000 to 7500 BP (all ages are in calendar years BP unless noted), are characterized not only by appearance of crop and other economic plants, but also by the introduction of numerous ground stone tools for plant processing and hoes, all indicating a substantial subsistence focus on plants (Piperno, 2011a; Aceituno and Loaiza, 2014, 2015; Dickau et al., 2015 for recent reviews). Reconstructed vegetation for these occupations is tropical forest of various types depending on elevation and annual precipitation. Smith (2015, 2016), focusing on Zone D1, makes several errors in his presentation of the evidence from it that form part of his basis for his critique of OFT applications, and which need to be addressed.

Smith states that in Piperno (2006a, 2011a) the D1 zone is characterized as being "generally covered by savanna/thorny scrub vegetation" during the Late Pleistocene (hereafter, LP), but then states that this characterization is contradicted in the same publications where Zone D1 is placed in forest during the LP in Fig. 7.4 in Piperno (2006a) and Fig. 1 in Piperno (2011a). He also claims, citing three papers (Gnecco, 2003; Gnecco and Aceituno, 2006; Gnecco and Mora, 1997), that environmental reconstructions of the D1 zone by others place it in "dry seasonal forests" during the LP, supposedly ruling out any open savanna/thorny scrub-dominated landscape to forest cover change during the transition from the LP to early Holocene (hereafter, EH). As discussed above in Section 2, using the DBM in light of the paleoenvironmental data, an openland to forested vegetation change was predicted to have occurred that significantly altered energetic return rates and subsistence choices for foragers during the LP to EH transition, as higher-ranked open-land flora and fauna (including now-extinct megafauna, discussed below) were replaced by those of lower-ranked tropical forest taxa (Piperno and Pearsall, 1998; Piperno, 2006a, 2011a). Smith goes on to argue from the same three papers he cited above

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