Introduction

On the Challenges of Measuring Diversity in Archaeology

Briggs Buchanan and Metin I. Eren

Calculating the diversity of biological or cultural classes is a fundamental way of describing, analyzing, and understanding the world around us. Diversity can be understood simply in terms of richness, the number of classes in an assemblage, and evenness, the relative proportion of those classes, or some combination of those measures. And as archaeology inevitably continues to mature as an evolutionary science, the regular integration of diversity measures and concepts into archaeological practice—along with hypothesis testing; quantitative methods, morphometrics, and inferential statistics; experimentation; cultural transmission theory; and population thinking (Lycett 2011; Lycett and Chauhan 2010 [cf. Shott 2020]; Lycett and von Cramon-Taubadel 2015; Lycett, von Cramon-Taubadel, and Foley 2006; Lycett et al. 2016; Mesoudi 2011)—will become increasingly important.

The idea for this volume stemmed from a symposium we organized at the 2019 annual meeting of the Society for American Archaeology (SAA) in Albuquerque, New Mexico. That year marked the 30th anniversary of the landmark volume on archaeological diversity, *Quantifying Diversity in Archaeology* (Leonard and Jones 1989) (see O'Brien and Thomas Foreword, this volume). The Leonard and Jones volume included several theoretical and methodological contributions, as well as case studies using diversity measures to analyze an array of different artifact types and datasets from the archaeological record. Despite the success of that book, and several other important studies involving diversity that preceded and succeeded

Defining and Measuring Diversity in Archaeology
Another Step Toward an Evolutionary Synthesis of Culture
Edited by Metin I. Eren and Briggs Buchanan
https://www.berghahnbooks.com/title/ErenDefining

it (e.g., Cruz-Uribe 1988; Kaufman 1998; Meltzer, Leonard, and Stratton 1992; Nagaoka 2001; Rhode 1988; Shott 1989, 1997, 2010), 1989 seems to mark a high point in the archaeological use of diversity concepts and measures (Figure 0.1). Our intent in organizing the symposium, and subsequently this volume, was to try to reverse the declining trend by illustrating both the range of datasets to which diversity measures can be applied, and the new methods now available to examine archaeological diversity.

As so often happens in science, we each began to work with concepts of diversity independently of each other. Buchanan started his work on archaeological diversity in his dissertation comparing the proportions of stone tools in Clovis-aged tool assemblages recovered in different regions of the United States (Buchanan 2005). To account for varying sample sizes of tool assemblages, he made use of rarefaction techniques, although very small and homogenous Clovis toolkits in the Western United States made comparisons across regions difficult. Later, working with Collard and colleagues, Buchanan applied measures of diversity to toolkits recorded among more recent hunter-gatherer (Collard et al. 2011a, 2011b, 2013a) and food-producing (Collard et al. 2011b, 2012, 2013b) populations across the world. In these studies, Buchanan and colleagues counted the number of tools and tool parts recorded by ethnographers to investigate hypotheses concerning the drivers of technological diversity.

Eren also began his work with diversity concepts in his dissertation, which focused entirely on Clovis unifacial tool diversity in the North

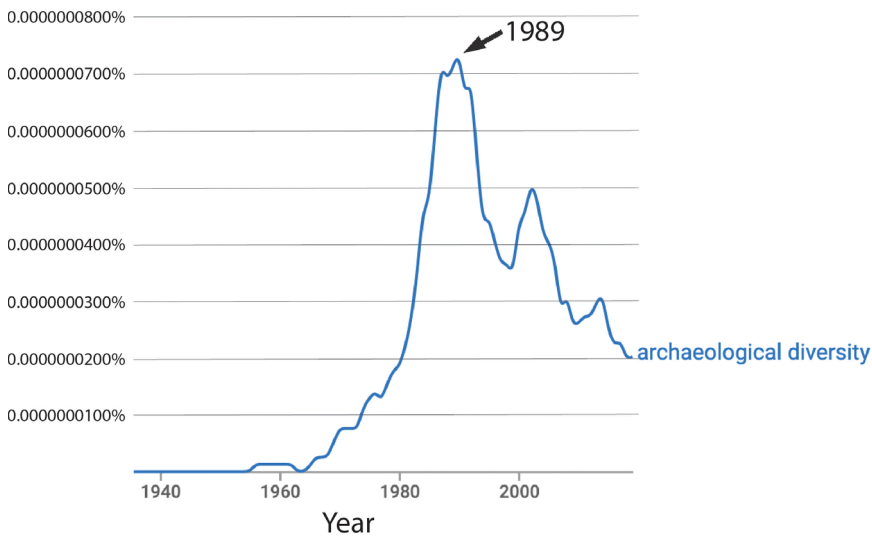

Figure 0.1. Google NGram of the term "archaeological diversity" shows that it peaked in 1989. © The authors.

Defining and Measuring Diversity in Archaeology
Another Step Toward an Evolutionary Synthesis of Culture
Edited by Metin I. Eren and Briggs Buchanan
https://www.berghahnbooks.com/title/ErenDefining

American Lower Great Lakes region (Eren 2011; see also Eren 2012, Eren et al. 2012). It was during his attempts to apply the Chao1 Richness Estimator (Chao 1984) to his paradigmatic artifact classes that he found an anomaly using paradigmatic classification (for description see below). Paradigmatic classification produces a fixed number of classes, which is different than the typical situation in ecology or biogeography, where established upper limits for the number of species that can be found in a particular region are rarely, if ever, known. When the Chao1 estimator was used to estimate paradigmatic class richness, an impossible estimate emerged: the upper 95 percent confidence interval of unifacial tool class richness sometimes exceeded the maximum number of possible classes. Eren contacted Robert Colwell and Anne Chao, shared his results, and all agreed that a new method was needed to address richness estimation when both upper and lower bounds are known. This collaboration resulted in a new method, doubly-bounded confidence intervals (both lower and upper bounds fixed), for class richness (Eren et al. 2012).

We (Buchanan and Eren) began to formally collaborate a few years later, and, having taken a short break from archaeological diversity, returned to the subject, along with Colwell, Chao, and others, in order to explore Clovis stone point diversity across North America (Buchanan et al. 2017; Eren et al. 2016). It was after these latter studies had been published that we felt, given the 30th anniversary of the 1989 Leonard and Jones volume was upon us, that archaeological diversity should once again be brought to the fore.

Challenges in the Study of Archaeological Diversity

This volume features studies of archaeological diversity ranging from the data-driven to the theoretical, from the Paleolithic to the Historic periods. Most importantly, however, is the application of diversity concepts and measures to a broad range of *kinds* of archaeology data. Chapters in this volume focus on the diversity of parfleche (Lycett), metal artifacts (Bebber and Chao), architecture (Andrews, Macdonald, and Morgan), faunal remains (Faith and Du; Otárola-Castillo, Torquato, and Hill), ethnobotanical remains (Farahani and Sinensky), and flaked stone on macroscopic (Boulanger, Breslawski, and Jorgeson) and microscopic (Stemp and Macdonald) scales. A Forward by Mike O'Brien and David Hurst Thomas, and discussion chapters by Steve Kuhn, by Robert Colwell and Anne Chao, and by Lee Lyman reflect on important issues remaining in the methodological and theoretical treatment of diversity.

Rather than summarize the findings of the chapters above, as is typical for an introductory chapter, we instead outline three challenges that we

Defining and Measuring Diversity in Archaeology
Another Step Toward an Evolutionary Synthesis of Culture
Edited by Metin I. Eren and Briggs Buchanan
https://www.berghahnbooks.com/title/ErenDefining

have already encountered in our study of archaeological diversity, but that are also addressed in various ways, either fully or partly, within the chapters of this volume.

Challenge #1: Creation of Units

The analysis of diversity requires classes of phenomena. In some subfields of archaeology, such as zooarchaeology, the data translate easily into explicit, discrete classes. In other subfields, such as flaked stone artifact analysis, data are less readily translatable into explicit, discrete classes. In these latter subfields the use of paradigmatic classification is a very robust solution (Dunnell 1971). Paradigmatic classification is a procedure specifically intended to document and monitor artifact variation in a manner that is explicit, and unbiased by the experience of the analyst. Specimen classes arise from the unique combinations of character states, scoring each specimen with one character state for each character, to classify it. This procedure makes paradigmatic classes explicit, equivalent, and comparable. Thus, we are not saying the paradigmatic classification is always necessary for analyses of archaeological diversity, but in many cases it will substantially facilitate and strengthen such analyses. It is important to note that "classes" are theoretical/ideational/conceptual units, just like inches and grams. In other words, paradigmatic classes are not empirical; instead, they are measurement units, where "measurement" means "description."

In his landmark, although arguably still underappreciated, work *Systematics in Prehistory*, Dunnell explored "the lowest order of theory in any discipline, that of the definition and conception of data, the creation of meaningful units for the purposes of a particular field of inquiry" (Dunnell 1971: 6). His reasons for discussing archaeological systematics and introducing paradigmatic classification are varied and complex, but they broadly involve the maturity of archaeology (prehistory) as a scientific discipline. Paradigmatic classification is a dimensional classification procedure in which the units (i.e., classes) are defined by intersection, with each dimension (henceforth "character") being a set of mutually exclusive alternate features (henceforth "character states"). All character states belonging to a single character share the ability to combine with character states of each other character. Dunnell specified: "In paradigmatic classification, all of the class definitions are drawn from the same set of dimensions [characters] of features [character states]. Individual classes are distinguished from one another by the unique product obtained in the combination, permutation, or intersection of features [character states] from the set of dimensions [characters]" (ibid.: 71).

Defining and Measuring Diversity in Archaeology
Another Step Toward an Evolutionary Synthesis of Culture
Edited by Metin I. Eren and Briggs Buchanan
https://www.berghahnbooks.com/title/ErenDefining

Dunnell (1971: 73–76) noted that paradigmatic classes possess three important properties given their creation via intersection of character states. First, all of the characters and character states are equivalent; none is or can be weighted more or less than any other. Second, paradigmatic classes are unambiguous, given that character states within a single character are mutually exclusive, and the intersection of character states from different characters prevent internal contradiction. Third, paradigmatic classes are comparable; that is, one class is comparable with all other classes in the same classification. In other words, "the structure of paradigmatic classification always specifies that all classes within it differ from one another in the same manner" (ibid.: 74). O'Brien and Lyman (2002: 47) note a fourth property of the procedure, namely that any paradigmatic classification is infinitely expandable, meaning that attribute states can be added as needed. Similarly, deletion of a dimension or of an attribute found to be analytically useless or ambiguous does not require another examination of specimens (Beck and Jones 1989).

Of course, as Dunnell clearly spelled out, the field of a particular classification must be established *prior* to the creation of the classification. This field, what Dunnell (1971: 74) termed the "root of the paradigm", is a statement of what the classes are classes of, and it is usually expressed as a trait or set of traits common to all the classes within the paradigm. That said, Dunnell emphasized that the root or common trait(s) is not a product of the paradigmatic classification, but is instead a symbolic record of one of the decisions made prior to the construction of the classification.

The fact that paradigmatic classification is not more frequently used in formal artifact analyses in archaeology is not altogether surprising, although it is disappointing. This is probably mostly attributable to the difficulty in giving up traditional extensionally defined classifications (see O'Brien and Lyman 2000), and the associated type names that are in common use within archaeology. There have been several implicit or explicit criticisms of paradigmatic classification and its use in archaeological or cultural evolutionary studies (e.g., Araujo 2015; Read 2015; Shott 2011; Thulman 2006; Whallon 1972). Such assertions can arise from the identification of true shortcomings of paradigmatic classification in particular instances, but can also arise from a misunderstanding of Dunnell's (1971) jargon-laden prose, from confusion as to how paradigmatic classification works, from a misunderstanding of pattern versus noise, from a lack of experience with hypothesis-driven archaeology, or simply from unfounded skepticism that paradigmatic classes—given their inherent properties—are useful. One can easily contrast criticisms of paradigmatic classification with the substantive ones about typology. Indeed, Thomas (1989) pointed out in his contribution to *Quantifying Diversity in Archaeology* (Leonard

Defining and Measuring Diversity in Archaeology
Another Step Toward an Evolutionary Synthesis of Culture
Edited by Metin I. Eren and Briggs Buchanan
https://www.berghahnbooks.com/title/ErenDefining

and Jones 1989) that typology and its extensionally defined taxonomic units can be subjective, often defined by overlapping and inconsistent criteria (see also Bisson 2000; Dunnell 1971; Eren et al. 2012; Fish 1978; O'Brien, Darwent, and Lyman 2001; O'Brien et al. 2014; Whittaker, Caulkins, and Kamp 1998). Yet, none of the above should be taken to mean that paradigmatic classes are perfect or that types are useless (e.g., see Lyman 2021). Instead, our point is that both classes and types (and, for that matter, "modes," Clark 1969; Shea 2013) are tools that should be judiciously used or designed when the question asked or analysis performed requires, or at least benefits from, the employment of one or more of these tools to arrive at a robust conclusion.

Paradigmatic classification can be applied to *any* kind of archaeological data, as illustrated by Table 0.1, and has been used outside of archaeology as well (Adriano and Ricarte 2012; Deetz 1965; Shaw 1969; Strong 1935). Distinct paradigmatic classifications can also be applied to the same artifactual datasets, depending on the question being asked. For example, Eren (2011, 2012; Eren et al. 2012) applied two distinct paradigmatic classifications to the same set of Clovis unifacial tools. The first classification was designed to categorize overall unifacial tool morphology, while the second classification was designed to categorize unifacial tool edge morphology. Although each of these classifications and subsequent diversity analyses explored specific questions, the subsequent side-by-side comparison of the diversity results from each classification is also productive. For example, Eren (2011) found an inverse relationship between sample size and tool class evenness, but a positive relationship between sample size and edge class evenness. This means that as sample size increases, every additional discarded *tool* specimen is increasingly likely to be a class that is already abundantly represented in the sample. It also means that every additional discarded *edge* specimen is increasingly likely to be a rare class minimally represented in the sample or a class not yet represented. He reasoned that this difference lies in the distinction between the *potential of a tool* and the *function of an edge*. The potential of a tool involves whether or not its edges can be modified. This is largely determined by the tool's shape. Relatively thick, spherical tools are more difficult to modify and resharpen than other shapes. If a person is going to discard a tool, it is more likely to be thick and spherical than any other shape. Thus the "bins" of spherical, thick tools will continually be filled as sample size increases. However, this pattern does not appear to be the case for edge classes. As sample size increases, rarer edge classes are more likely to be discarded because their function is presumably more limited than that of more common edge classes. When it comes time to decide which tools to discard and which tools to keep, the tools with edges that are not functionally limited are more likely to be kept.

Defining and Measuring Diversity in Archaeology
Another Step Toward an Evolutionary Synthesis of Culture
Edited by Metin I. Eren and Briggs Buchanan
https://www.berghahnbooks.com/title/ErenDefining

Table 0.1. Studies that have used paradigmatic classification to classify archaeological or other types of data.

Year	Authors	Material Classified	Time Period	Geographic Location
1969	Shaw	Conodonts	Devonian	n/a
1971	Dunnell	Pottery (Hypothetical)	n/a	n/a
1973	Dancey	Use Wear	Prehistoric	Washington, USA
1974	Dunnell and Lewarch	Use Wear	Prehistoric	Washington, USA
1975	Dancey	Use Wear	Prehistoric	Washington, USA
1975	Dunnell and Fuller	Use Wear	Prehistoric	Washington, USA
1976	Dunnell et al.	Flaked Stone Tools (Core Tools)	Prehistoric	Washington, USA
1976	Dunnell et al.	Flaked Stone Tools	Prehistoric	Washington, USA
1976	Dunnell et al.	Use Wear	Prehistoric	Washington, USA
1977	Aikens and Minor	Use Wear	Prehistoric	Oregon, USA
1977	Dunnell and Campbell	Use Wear	Prehistoric	Washington, USA
1977	Croes	Woven textiles (Basketry, hats, mats)	1050 BC – AD 1300	Pacific Northwest
1978	Thompson	Use Wear	Prehistoric	Pacific Northwest
1979	Duncan	Use Wear	Prehistoric	Washington, USA
1979	Dunnell and Beck	Use Wear	Prehistoric	Washington, USA
1980	Hanford Arundale	Flaked Stone Tools	2000 BC – AD 1600	Baffin Island, Canada
1980	O'Brien et al.	Architecture (Houses)	AD 1800 – 1900	Missouri, USA
1981	Campbell	Bone Technology	Prehistoric	Washington, USA
1981	Campbell	Clay Concretions	Prehistoric	Washington, USA
1981	Campbell	Subsurface Features	Prehistoric	Washington, USA
1981	Campbell	Flaked Stone Tools	Prehistoric	Washington, USA
1981	Campbell	Use Wear	Prehistoric	Washington, USA
1981	Meltzer	Flaked Stone Tools (Endscrapers)	Various	Various
1982	Johnson et al.	Groundstone Tools	3000 BC – AD 1000	Kansas, USA
1982	Mason et al.	USDA Soil Series	n/a	Missouri, USA
1982	Lewarch	Use Wear	n/a	Missouri, USA
1982	Zeier	Cultural-Historic Integration Systems	Misc.	North American Plains
1983	Futato	Projectile Points	Prehistoric	Southeastern USA
1983	Lyman et al.	Use Wear	Prehistoric	Oregon, USA

(continued)

Defining and Measuring Diversity in Archaeology
Another Step Toward an Evolutionary Synthesis of Culture
Edited by Metin I. Eren and Briggs Buchanan
https://www.berghahnbooks.com/title/ErenDefining

Table 0.1. *Continued*

Year	Authors	Material Classified	Time Period	Geographic Location
1984	Chatters	Use Wear	Prehistoric	Washington, USA
1984	Goodwin et al.	Ceramics	AD 19th/20th centuries	Louisiana, USA
1984	Meltzer	Flaked Stone Tools (Projectile Points)	Paleoindian	Eastern North America
1984	Jones	Flaked Stone Tools	Prehistoric	Oregon, USA
1984	Beck	Flaked Stone Tools	Prehistoric	Oregon, USA
1984	Campbell et al.	Flaked Stone Tools	Prehistoric	Washington, USA
1984	Beck	Use Wear	Prehistoric	Oregon, USA
1984	Campbell et al.	Use Wear	Prehistoric	Washington, USA
1984	Jones	Use Wear	Prehistoric	Oregon, USA
1984	O'Brien and Lewarch	Architecture (Houses)	AD 1800 – 1900	Missouri, USA
1985	O'Brien and Warren	Flaked Stone Tools (Projectile Points)	7500 – 5000 BC (Early-Middle Archaic)	Missouri, USA
1985	Currey et al.	Flaked Stone Tools (Projectile Points)	Prehistoric	Missouri, USA
1986	Winterhalder	Behavioral Responses	n/a	n/a
1987	Chatters	Use Wear	Prehistoric	Columbia Plateau, USA
1987	Lyman	Faunal Processing (butchery) marks	n/a	n/a
1987	Leonard and Jones	Societies	n/a	Various
1987	Miss	Use Wear	Prehistoric	Washington, USA
1988	Clark	Flaked Stone Tools	AD 1575 – 1790	Oregon, USA
1988	Clark	Lithic Raw Materials	AD 1575 – 1790	Oregon, USA
1991	Dockall	Flaked Stone Tools	AD 200 – 1150	New Mexico, USA
1993	Thorpe and Brown	Lithic Raw Materials (Volcanic)	n/a	Pacific Northwest
1994	Rafferty	Flaked Stone Tools (Projectile Points)	Archaic and Woodland Periods	Mississippi, USA
1995	Gunn and Graves	Ceramics	Prehistoric	Philippines
1995	Lewarch and Bangs	Use Wear	Prehistoric	Washington, USA
1996	Allen	Fishhooks (heads only)	AD 1250 – 1650	Cook Islands
1996	Allen	Fishhooks	AD 1250 – 1650	Cook Islands
1996	Jones	Flaked Stone Tools (Projectile Points)	Paleoindian	Montana, USA
1996	Loughran-Delahunt	Spindle whorls	AD 750 – 1800	Pacific Northwest

Defining and Measuring Diversity in Archaeology
Another Step Toward an Evolutionary Synthesis of Culture
Edited by Metin I. Eren and Briggs Buchanan
https://www.berghahnbooks.com/title/ErenDefining

Year	Authors	Material Classified	Time Period	Geographic Location
1997	McCutheon	Lithic Raw Materials (Volcanic)	n/a	Pacific Northwest
1998	Blackham	Ceramics	Various	Southern Levant
1998	Cogswell and O'Brien	Ceramics	Early Mississippian Period	Missouri, USA
1998	Lohse	Use wear and Flaked Stone Tools	n/a	n/a
1998	Seong	Flakes Stone Tools (Microblades)	Paleolithic	Korea / Northeast Asia
1998	Weitzel	Hair	n/a	n/a
1999	Lohse and Sammons	Flaked Stone Tools	n/a	n/a
1999	Pierce	Ceramics (Coil Dimensions)	AD 650 – 1450	Southwestern USA
2000	Carr and Bradbury	Flaked Stone Tools (Bifaces)	n/a	n/a
2000	Weisler	Shell Rings	AD 1st – 11th centuries	Marshall Islands
2001	Cagle	Sediment deposits	2500 – 2290 BC (Old Kingdom)	Egypt
2001	Cochrane	Architecture	ca. AD 1250	Society Islands
2001	Pfeffer	Fishhooks	AD 1400 – 1750	Hawai'i, USA
2001	Lipo	Ceramics (Pottery Decorations)	AD 1400 – 1600	Central Mississippi River Valley, USA
2001	Sterling	Ceramics (Pottery Rims)	3500 – 2100 BC	Egypt
2001	Wilhelmsen	Flaked Stone Tools (Projectile Points)	Pleistocene & Holocene	Central Mississippi River Valley, USA
2003	Gjesfjeld	Architecture	Historic	Great Plains, USA
2003	VanPool	Flaked Stone Tools (Projectile Points)	8050 BC – AD 1900	Arizona, USA
2003	McElroy	Groundstone Tools (poi pounders)	Prehistoric	Hawai'i, USA
2003	McElroy	Groundstone Tools (poi pounders)	Prehistoric	Hawai'i, USA
2004	Emery	Ceramics	A.D. 1700 – 1970	Louisiana, USA
2004	Cochrane	Ceramics	Prehistoric	Fiji
2005	Commendador	Archaeological Structures	Prehistoric	Rapa Nui, Chile
2005	Darwent	Flaked Stone Tools (Projectile Points)	8950 – 6000 BC (Late Paleoindian-Early Archaic)	Missouri, USA

(continued)

Defining and Measuring Diversity in Archaeology
Another Step Toward an Evolutionary Synthesis of Culture
Edited by Metin I. Eren and Briggs Buchanan
https://www.berghahnbooks.com/title/ErenDefining

Table 0.1. *Continued*

Year	Authors	Material Classified	Time Period	Geographic Location
2006	Burris	Flaked Stone Tools (Projectile Points)	Early Holocene	Mississippi, USA
2006	Harmon et al.	Ceramics (Pottery Decorations)	100 BC – AD 1450	Mexico
2006	Darwent and O'Brien	Flaked Stone Tools (Projectile Points)	8950 – 6000 BC (Late Paleoindian-Early Archaic)	Missouri, USA
2007	Beck and Jones	Flaked Stone Tools (Projectile Points)	Paleoindian	Great Basin, USA
2008	Egerer	Ceramics	Mayan	Belize–Guatemala Border
2008	VanPool et al.	Horned Serpent Motifs (pottery, murals, rock art)	AD 1000 – 1500	Southwestern USA
2009	Allen	Architecture (Foundations)	AD 17th Century and later	Marquesas Islands
2009	Edmonds	Flaked Stone Tools (Projectile Points)	Pleistocene & Holocene	Mississippi, USA
2009	Miksic et al.	Ceramics	AD 11th Century	Cambodia
2009	Ramenofsky et al.	Ceramics (glaze-paint types)	AD 1200 – 1700	New Mexico, USA
2009	Rorabaugh	Bone/Antler Barbed Tools	ca. 650 BC	Pacific Northwest
2009	Riede	Table Cutlery (forks)	AD 1500 – 1600	Northern Europe
2009	Riede	Table Cutlery (knives)	AD 1500 – 1600	Northern Europe
2009	Tehrani and Collard	Woven textiles	Modern/ Ethnographic	Iran
2009	Zedeño	Hunting Objects	n/a	North America
2010	Brown	Adzes and Fishhooks	Prehistoric	New Zealand
2010	García Rivero	Decorated slate plaques/ gorgets	3800 – 1800 BC (Neolithic)	Southwestern Iberian Peninsula
2010	Nolan	Subsurface Features	Late Prehistoric Period	Ohio, USA
2011	Bradbury et al.	Flaked Stone Tools (Projectile Points)	AD 1000 – 1500	Kentucky, USA
2011	Eren	Flaked Stone Tools (Unifacial tools)	Paleoindian	North American Lower Great Lakes
2011	Nolan and Cook	Time Periods	Late Prehistoric Period	Middle Ohio River Valley, USA
2012	Adriano and Ricarte	Digital Annotation Systems	n/a	n/a

Defining and Measuring Diversity in Archaeology
Another Step Toward an Evolutionary Synthesis of Culture
Edited by Metin I. Eren and Briggs Buchanan
https://www.berghahnbooks.com/title/ErenDefining

Year	Authors	Material Classified	Time Period	Geographic Location
2012	Bradbury et al.	Flaked Stone Tools (Projectile Points)	AD 1000 – 1500	Kentucky, USA
2012	Eren	Flaked Stone Tool (Unifacial tool edges)	Paleoindian	North American Lower Great Lakes
2012	Eren et al.	Flaked Stone Tools (Unifacial tools)	Paleoindian	North American Lower Great Lakes
2013	Darwent et al.	Architecture (Houses)	AD 1150 – 1850	Alaska, USA
2014	Crema et al.	Flaked Stone Tools (Projectile Points)	Neolithic	Western Europe
2014	Gjesfjeld	Ceramics (Pottery Decorations)	6000 BC – AD 1850	Kuril Archipelago, Northeast Asia
2014	García Rivero and O'Brien	Decorated slate plaques/ gorgets	3800 – 1800 BC (Neolithic)	Southwestern Iberian Peninsula
2014	Letham	Archaeological Sites	Prehistoric and Historic	British Columbia, Canada
2014	O'Brien et al.	Flaked Stone Tools (Projectile Points)	Paleoindian	Eastern North America
2014	Okumura and Araujo	Flaked Stone Tools (Projectile Points)	11600 – 7540 cal. BP	Brazil
2015	Cardillo and Alberti	Flaked Stone Tools (Projectile Points)	Middle-Late and Final-Late Holocene	Argentina
2015	Lipo et al.	Flaked Stone Tools (Stemmed obsidian tools [mata'a])	Prehistoric	Rapa Nui, Chile
2015	Nolan et al.	Flaked Stone Tools (Bifaces)	1520 – 1370 BP	Ohio, USA
2015	O'Brien et al.	Flaked Stone Tools (Projectile Points)	Paleoindian	Eastern North America
2015	Sheldon	Subsurface Features, Lithic Technology	3500 – 2400 BP	Washington, USA
2015	VanPool et al.	Flaked Stone Tools (Projectile Points)	Paleoindian	Southwestern USA
2016	O'Brien et al.	Flaked Stone Tools (Projectile Points)	Paleoindian (Clovis)	Ohio, Indiana, Kentucky, USA
2016	O'Brien et al.	Flaked Stone Tools (Projectile Points)	Paleoindian	Eastern North America
2016	Eren et al.	Flaked Stone Tools (Projectile Points)	Paleoindian	Eastern North America
2017	Buchanan et al.	Flaked Stone Tools (Projectile Points)	Paleoindian (Clovis)	North America

Defining and Measuring Diversity in Archaeology
Another Step Toward an Evolutionary Synthesis of Culture
Edited by Metin I. Eren and Briggs Buchanan
https://www.berghahnbooks.com/title/ErenDefining

Challenge #2: Scale of Analysis

As described above, the use of paradigmatic classification requires the use of mutually exclusive characters and character states in each dimension. This is one area in which a researcher can potentially exercise subjectivity—specifically in terms of character state breadth and character presence—thereby influencing an archaeological assemblage's relative observed richness of paradigmatic classes.

There is reason to suspect that character state breadth can potentially, in individual cases, influence the relative difference of observed class richness. For a simple example, consider hypothetical assemblages A and B, each classified via a paradigmatic classification consisting of three characters, each character in turn initially possessing two "character states." In this initial iteration, assemblage A is richer than assemblage B. However, what if the data necessary for the first character are more evenly distributed in assemblage B, but more clustered overall in assemblage A (Figure 0.2)? In this circumstance, as character state breadth becomes narrower in character 1, say expanding from two character states to four, observed richness

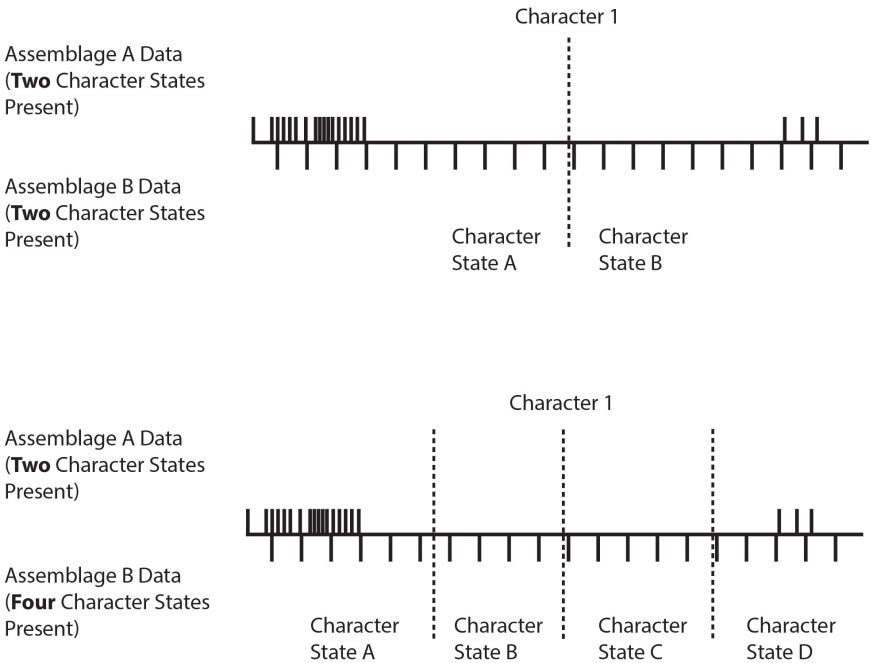

Figure 0.2. An illustration of two hypothetical assemblages' data with respect to a single character. The distribution of data can potentially influence the number of character states present in an assemblage, which in turn can potentially influence relative richness. © The authors.

Defining and Measuring Diversity in Archaeology
Another Step Toward an Evolutionary Synthesis of Culture
Edited by Metin I. Eren and Briggs Buchanan
https://www.berghahnbooks.com/title/ErenDefining

in assemblage B increases at a faster rate than in assemblage A. All other things being equal, this faster rate of increasing richness could potentially erode substantially or even erase the relative difference of observed richness between the two assemblages.

A similar situation could potentially arise with respect to character presence. Again, consider hypothetical assemblages A and B, each classified via a paradigmatic classification consisting of five characters, but this time each character in turn initially possesses ten character states. In this initial iteration, assemblage A is again richer than assemblage B. However, it is soon discovered that the first character is found to be ambiguous, biased, or problematic, and must be discarded. If this first character was a principal driver of richness because of the way its character states combined with other characters' states, then when removed we may again see the relative difference of observed richness between the two assemblages be affected.

Due to these concerns, we incorporated a sensitivity analysis of characters and character states into our study of Clovis point diversity. This study, carried out by the authors and several colleagues (Buchanan et al. 2017), investigated differences in the diversity of Clovis point forms made in the western and eastern halves (split at the Mississippi River) of North America. This study used paradigmatic classification of seven characters that were defined to capture the shape and technological attributes of Clovis points (ibid.: Fig. 5). Because the samples from the west and east were different in sample size and completeness, we compared our three measures of class diversity—richness (the number of classes), Shannon diversity (the effective number of common classes), and Simpson diversity (the effective number of dominant classes)—using sample-size-based rarefaction and extrapolation, and coverage-based rarefaction and extrapolation. The results indicated that Clovis points in the east are more diverse relative to Clovis points in the west.

To assess the impact that our choice of characters and character states had on the outcome of this analysis, we iteratively removed from the analysis each of the seven characters that we had originally defined to measure the Clovis points. After each iteration we compared the three measures of class diversity between the west and east, and found that the removal of any of the seven characters from the analysis did not change its outcome. Next, we modified the breadth of the four characters in our paradigmatic classification that measured continuous variables by reducing the number of character states from three to two. The results of these analyses also showed them to be qualitatively similar to our initial results with the full range of characters and character states.

Lastly, in the study by Buchanan et al. (2017) we also modified the scale of our analysis by investigating the impact of excluding the largest

Defining and Measuring Diversity in Archaeology
Another Step Toward an Evolutionary Synthesis of Culture
Edited by Metin I. Eren and Briggs Buchanan
https://www.berghahnbooks.com/title/ErenDefining

assemblages in our dataset from each region and rerunning the analyses, and comparing the results to the original findings in order to evaluate the influence of these large assemblages on the results. As with the sensitivity analyses described above, the removal of large and potentially influential assemblages from both the east and west regions did not change the results of the study. Taken together, the results of our sensitivity analyses which altered the number of characters, character states, and assemblages in our study demonstrated that our results were robust to these perturbations.

Challenge #3: The Meaning of Diversity

After measuring diversity, and comparing measures of diversity between archaeological assemblages, it was not always immediately clear how to explain patterns or differences. Of course, the better defined the research questions and the implications of each set of predictions are at the outset of a study—that is, a well-developed and deductively derived set of hypotheses—the more compelling the explanations will be. In practice, however, archaeological hypotheses associated with diversity analyses are not always derived in a rigorous deductive manner, and many studies might start as exploratory endeavors or re-evaluations of older hypotheses that were not well justified at the outset. The latter issue is something that we have contended with in our study of Paleoindian point technology in the Eastern United States (Eren et al. 2016). In brief, our study re-examined the long-standing hypothesis put forth by Ronald Mason in the 1960s (Mason 1962) that the Southeastern United States possesses greater Paleoindian point diversity than other regions. We used paradigmatic classification and rarefaction techniques to compare the point-class richness of 1,056 Paleoindian points in different regions of the east. In our first set of analyses, we compared the Southeast region to the Northeast and found that the Southeast did indeed have more point-class richness than the Northeast. Next, we split Eastern North America into three regions—the Lower Southeast, the Upper Southeast, and the Northeast—and made similar comparisons among the three regions as we did with the two regions. We found that the Upper Southeast had greater point class richness than the other two regions. Thus, our first set of results supported Mason's initial claim, and our second set of results provided more specific details on the regional differences in the Eastern United States.

Our support for Mason's (1962) original claim does not however immediately imply that his explanation for this pattern should also be accepted. Mason assumed that greater diversity of Paleoindian point types was a consequence of greater time depth in the region. This explanation was based on a once-held belief that greater time depth was necessarily linked

to greater diversity. However, Eren et al. (2016) pointed out other explanations for the greater point-class richness in the Southeast (and more specifically the Upper Southeast), including demographic processes that led to the isolation of specific populations. Founder effects and cultural drift can be associated with population isolation that might lead to reduced cultural richness and diversity. Eren et al. did not propose a specific explanation for the pattern of point-class richness in the Eastern United States, but rather emphasized that the goal of their study had been to use more rigorous quantitative methods to document diversity. Attributing meaning to the observed pattern of diversity requires the evaluation of multiple competing hypotheses for why there are differences in diversity.

Faced with a similar situation, the study by Buchanan et al. (2017), as described above, evaluated several competing hypotheses to narrow down an appropriate explanation for the patterns they found. To reiterate, the study by Buchanan et al. compared Clovis point-class richness between the broad eastern and western regions of North America. Using interpolation and extrapolation rarefaction techniques, they concluded that the eastern region had a richer and more uneven set of Clovis points compared to the west. Although this study was exploratory in its evaluation of the point-class richness and diversity pattern across the continent, Buchanan et al. attempted to assess the likelihood of several competing hypotheses. The first hypothesis was related to Mason's original proposal that diversity is a function of age. Buchanan et al. evaluated the current radiocarbon and genetic evidence that clearly indicates a west-to-east dispersal of Paleoindians rather than an east-to-west dispersal, thus rejecting this hypothesis. Next, they evaluated the population fissioning and isolation hypothesis, which, as described above, suggests that population budding and subsequent isolation during dispersal from west-to-east would result in more isolated populations in the east. These populations would then be subject to founder effects and drift. Buchanan et al. constructed a network of Clovis point-classes to evaluate this hypothesis and to determine if eastern Clovis assemblages appeared less connected than western assemblages. The results indicated that the east was well connected internally and connected with assemblages in the west, thus rejecting the isolation hypothesis. Lastly, Buchanan et al. assessed differential learning within the different environments of the east and west. They argued that the environment of the east was more heterogenous than the environment of the west, and consequently that learning in the east was more trial-and-error or experimental relative to the west. This difference in learning translated to more point class diversity in the east. To be sure, the hypothesis favored by Buchanan et al. (2017) requires further testing, but their evaluation of multiple hypotheses in this case was able to reject two hypotheses.

Defining and Measuring Diversity in Archaeology
Another Step Toward an Evolutionary Synthesis of Culture
Edited by Metin I. Eren and Briggs Buchanan
https://www.berghahnbooks.com/title/ErenDefining

The Future

In conclusion, as archaeologists we commonly compare artifacts and assemblages, and the future is bright for such comparisons to occur via assessments of diversity. Indeed, the diverse approaches to archaeology—culture-history, processual archaeology, aspects of post-processual archaeology (e.g., agency)—are in many ways melding, as the social sciences in general undergo a culture evolutionary revolution (e.g., Boyd and Richerson 1988; Lycett 2015; Lyman and O'Brien 1998, 2001, 2006; Mesoudi 2007a, 2007b, 2011, 2017, 2020; Mesoudi, Whiten, and Laland 2004, 2006; O'Brien and Lyman 2000, 2002, 2003; O'Brien et al. 2001, 2003; Prentiss 2021; Richerson and Boyd 2008). Understanding archaeological diversity is but one small step in this more general, positive trend in understanding human culture.

Acknowledgments

We would like to thank all of the volume's contributors for their hard work, ingenuity, and patience. These sorts of volumes are truly a team effort, and we are extremely grateful to our colleagues who fulfilled their commitments. We would also like to thank Caryn Berg for her help, interest, patience, and guidance during the production of this book. We are appreciative of the contributions from Matt Boulanger and Lee Lyman in the assembly of Table 0.1, and from P. J. C.-E., who helped to put everything in proper perspective for M. I. E.

Briggs Buchanan is an Associate Professor at the University of Tulsa, Oklahoma, USA.

Metin I. Eren is an Associate Professor at Kent State University, Ohio, and a Research Associate at the Cleveland Museum of Natural History, Ohio, USA.

References

Adriano, C. M., and I. L. M. Ricarte. 2012. "Essential Requirements for Digital Annotation Systems." *Revista de Sistemas de Informação da FSMA* 9: 24–44.

Aikens, C. M., and R. Minor. 1977. *The Archaeology of Coffeepot Flat, South Central Oregon*. Portland: University of Oregon Anthropological Papers No. 11.

Defining and Measuring Diversity in Archaeology
Another Step Toward an Evolutionary Synthesis of Culture
Edited by Metin I. Eren and Briggs Buchanan
https://www.berghahnbooks.com/title/ErenDefining

Allen, M. S. 1996. "Style and Function in East Polynesian Fish-Hooks." *Antiquity* 70(267): 97–116.

———. 2009. "Morphological Variability and Temporal Patterning in Marquesan Domestic Architecture: Anaho Valley in Regional Context." *Asian Perspectives* 48(2): 342–82.

Araujo, A. G. 2015. "On Vastness and Variability: Cultural Transmission, Historicity, and the Paleoindian Record in Eastern South America." *Anais da Academia Brasileira de Ciências* 87(2): 1239–58.

Beck, C. 1984. "Steens Mountain Surface Archaeology: The Sites." PhD dissertation. University of Washington, Seattle.

Beck, C., and G. T. Jones. 1989. "Bias and Archaeological Classification." *American Antiquity* 54: 244–62.

———. 2007. "Early Paleoarchaic Point Morphology and Chronology." In *Paleoindian or Paleoarchaic? Great Basin Human Ecology at the Pleistocene–Holocene Transition*, ed. K. E. Graf and D. N. Schmitt, 23–41. Salt Lake City: University of Utah Press.

Bisson, M. S. 2000. "Nineteenth-Century Tools for Twenty-First-Century Archaeology? Why the Middle Paleolithic Typology of François Bordes Must Be Replaced." *Journal of Archaeological Method and Theory* 7(1): 1–48.

Blackham, M. 1998. "The Unitary Association Method of Relative Dating and its Application to Archaeological Data." *Journal of Archaeological Method and Theory* 5(2): 165–207.

Bordes, F. 1961. *Typologie du Paléolithique Ancien et Moyen*. Bordeaux: Publications de l'Institut de Préhistoire de l'Université de Bordeaux, Mémoire 1.

Boyd, R., and P. J. Richerson. 1988. *Culture and the Evolutionary Process*. Chicago: University of Chicago Press.

Bradbury, A. P., D. R. Cooper, and R. L. Herndon. 2011. "Kentucky's Small Triangular Subtypes: Old Theories and New Data." *Journal of Kentucky Archaeology* 1(1): 2–24.

———. 2012. "Points on Points: A Reply to Pollack et al." *Journal of Kentucky Archaeology* 1(2): 65–88.

Brown, A. 2011. "Material Culture Traditions of Prehistoric Murihiku." Master's thesis. University of Otago, Dunedin, NZ.

Buchanan, B. 2005. "Cultural Transmission and Stone Tools: A Study of Early Paleoindian Technology in North America." PhD dissertation. University of New Mexico, Albuquerque, USA.

Buchanan, B., A. Chao, C. H. Chiu, R. K. Colwell, M. J. O'Brien, A. Werner, and M. I. Eren. 2017. "Environment-Induced Changes in Selective Constraints on Social Learning during the Peopling of the Americas." *Scientific Reports* 7: 44431.

Burris, A. 2006. "Defining an Alternative Typology for Early Holocene Projectile Points from the Hester Site (22MO569), Northeast Mississippi: A Systematic Approach." Master's thesis. Mississippi State University, Starkville, USA.

Cagle, A. J. 2001. "The Spatial Structure of Kom el-Hisn: An Old Kingdom Town in the Western Nile Delta, Egypt." PhD dissertation. University of Washington, Seattle.

Campbell, S. K. 1981. "The Duwamish No. 1 Site: A Lower Puget Sound Shell Midden." Office of Public Archaeology Research Report 1. Seattle: University of Washington Office of Public Archaeology.

Campbell, S. K., R. C. Dunnell, D. K. Grayson, M. E. Jaehnig, and J. V. Jermann. 1984. *Research Design for the Chief Joseph Dam Cultural Resources Project*. Seattle: University of Washington Office of Public Archaeology.

Cardillo, M., and J. Alberti. 2014. "The Evolution of Projectile Points and Technical Systems: A Case from the North Patagonian Coast (Argentina)." *Journal of Archaeological Science: Reports* 2: 612–23.

Defining and Measuring Diversity in Archaeology
Another Step Toward an Evolutionary Synthesis of Culture
Edited by Metin I. Eren and Briggs Buchanan
https://www.berghahnbooks.com/title/ErenDefining

Carr, P. J., and A. P. Bradbury. 2000. "Contemporary Lithic Analysis and Southeastern Archaeology." *Southeastern Archaeology* 19(2): 120–34.

Chao, A. 1984. "Nonparametric Estimation of the Number of Classes in a Population." *Scandinavian Journal of Statistics* 11(4): 265–70.

Chatters, J. C. 1984. "Dimensions of Site Structure: The Archaeological Record from Two Sites in Okanogan County Washington." Central Washington University, Ellensburg: Report to the Seattle District, US Army Corps of Engineers. Central Washington Archaeological Survey.

———. 1987. "Hunter-Gatherer Adaptations and Assemblage Structure." *Journal of Anthropological Archaeology* 6: 336–75.

Clark, G. 1969. *World Prehistory: A New Synthesis*. Cambridge: Cambridge University Press.

Clark, L. A. 1988. "Archaeological Investigations at the Seal Rock Site, 35LNC14: A Late Prehistoric Shell Midden Located on the Central Oregon Coast." Master's thesis. Oregon State University, Corvallis, USA.

Cochrane, E. E. 2001. "Style, Function, and Systematic Empiricism: The Conflation of Process and Pattern." In *Style and Function: Conceptual Issues in Evolutionary Archaeology*, ed. T. D. Hurt and G. F. M. Rakita, 183–202. Westport, CT: Bergin & Garvey.

———. 2004. "Explaining Cultural Diversity in Ancient Fiji: The Transmission of Ceramic Variability." PhD dissertation. University of Hawaii, Manoa, USA.

Cogswell, J. W., and M. J. O'Brien. 1998. "Analysis of Early Mississippian Period Pottery from Kersey, Pemiscot County, Missouri." *Southeastern Archaeology* 17(1): 39–52.

Collard, M., B. Buchanan, J. Morin, and A. Costopoulos. 2011a. "What Drives the Evolution of Hunter-Gatherer Subsistence Technology? A Reanalysis of the Risk Hypothesis with Data from the Pacific Northwest." *Philosophical Transactions of the Royal Society B* 366:1129–1138.

Collard, M., B. Buchanan, M. J. O'Brien, and J. Scholnick. 2013a. "Risk, Mobility, or Population Size? Drivers of Technological Richness among Contact-Period Western North American Hunter-Gatherers." *Philosophical Transactions of the Royal Society B* 368: 20120412.

Collard, M., B. Buchanan, A. Ruttle, and M. J. O'Brien. 2011b. "Niche Construction and the Toolkits of Hunter-Gatherers and Food Producers." *Biological Theory* 6: 251–59.

Collard, M., A. Ruttle, B. Buchanan, and M. J. O'Brien. 2012. "Risk of Resource Failure and Toolkit Variation in Small-Scale Farmers and Herders." *PLoS ONE* 7: e40975.

———. 2013b. "Population Size and Cultural Evolution in Nonindustrial Food-Producing Societies." *PLoS ONE* 8: e72628.

Commendador, A. S. 2005. "Measuring Variability in Prehistoric Stone Construction on Rapa Nui, Chile." PhD dissertation. University of Hawaii, Manoa, USA.

Crema, E. R., K. Edinborough, T. Kerig, and S. J. Shennan. 2014. "An Approximate Bayesian Computation Approach for Inferring Patterns of Cultural Evolutionary Change." *Journal of Archaeological Science* 50: 160–70.

Croes, D. R. 1977. "Basketry from the Ozette Village Archaeological Site: A Technological, Functional, and Comparative Study." PhD dissertation. Washington State University, Pullman, USA.

Cruz-Uribe, K. 1988. "The Use and Meaning of Species Diversity and Richness in Archaeological Faunas." *Journal of Archaeological Science* 15(2): 179–96.

Currey, M., M. J. O'Brien, and M. K. Trimble. 1985. "The Classification of Pointed, Hafted Bifaces." In *Archaeology of the Central Salt River Valley: An Overview of the Prehistoric Occupation*, ed. M. J. O'Brien, 77–189. Missouri Archaeologist 46.

Defining and Measuring Diversity in Archaeology
Another Step Toward an Evolutionary Synthesis of Culture
Edited by Metin I. Eren and Briggs Buchanan
https://www.berghahnbooks.com/title/ErenDefining

Dancey, W. S. 1973. "Prehistoric Land Use and Settlement Patterns in the Priest Rapids Area, Washington." PhD dissertation. University of Washington, Seattle.

———. 1975. "The Wood Box Spring Site (45-KT-209): A Preliminary Report." Reports in Highway Archaeology no. 1. Office of Public Archaeology, University of Washington, Seattle.

Darwent, J. 2005. "Late Paleoindian Period and Early Archaic Period Projectile-Point Phylogeny in the Salt River Valley, Northeastern Missouri." PhD dissertation. University of Missouri, Columbia, USA.

Darwent, J., O. K. Mason, J. F. Hoffecker, and C. M. Darwent. 2013. "1,000 Years of House Change at Cape Espenberg, Alaska: A Case Study in Horizontal Stratigraphy." *American Antiquity* 78(3): 433–55.

Darwent, J., and M. J. O'Brien. 2006. "Using Cladistics to Construct Lineages of Projectile Points from Northeastern Missouri." In *Mapping Our Ancestors: Phylogenetic Approaches in Anthropology and Prehistory*, ed. C. P. Lipo, M. J. O'Brien, M. Collard, and S. J. Shennan, 185–208. New Brunswick, NJ: Transaction.

Deetz, J. 1965. *The Dynamics of Stylistic Change in Arikara Ceramics*. Champaign: University of Illinois Press.

Dockall, J. 1991. "Chipped Stone Technology at the Nan Ruin, Grant County, New Mexico." Master's thesis. Texas A&M University, College Station, USA.

Duncan, M. A. 1979. *Archaeological Assessment of the Proposed Horsethief Lake Interpretive Facility*. Reconnaissance Report no. 25. Office of Public Archaeology, University of Washington, Seattle.

Dunnell, R. C. 1971. *Systematics in Prehistory*. New York: Free Press.

Dunnell, R. C., and C. Beck. 1979. "The Caples Site, 45-SA-5, Skamania County, Washington." Reports in Archaeology no. 6. Department of Anthropology, University of Washington, Seattle.

Dunnell, R. C., and S. K. Campbell. 1977. "Aboriginal Occupation of Hamilton Island, Washington." Reports in Archaeology no. 4. Department of Anthropology, University of Washington, Seattle.

Dunnell, R. C., S. K. Campbell, M. A. Duncan, D. E. Lewarch, and J. Rafferty. 1976. *Archaeological Test Investigations at the Caples Site, 45-SA-5, Skamaia County, Washington*. San Francisco: National Park Service.

Dunnell, R. C., and J. W. Fuller. 1975. *An Archaeological Survey of Everett Harbor and the Lower Snohomish Estuary-Delta*. San Francisco, CA: National Park Service.

Dunnell, R. C., and D. Lewarch. 1974. *Archaeological Remains in Home Valley Park, Skamania County, Washington*. Portland, OR: US Army Corps of Engineers.

Dunnell, R. C., D. E. Lewarch, and S. K. Campbell. 1976. *Test Excavations at the Hamilton Island Site, 45-A-12*. San Francisco: National Park Service.

Edmonds, J. L. 2009. "Mobility and Population Change in Northeast Mississippi: An Object-based Seriation of Projectile Points as a Relative Paleodemographic Indicator." Master's thesis. Mississippi State University, Starkville, USA.

Egerer, C. T. 2008. "The Ancient Maya Ceramics of El Pilar–Characteristics and Comparison." Master's thesis. University of Bonn, Germany.

Emery, J. A. 2004. "What Do Tin-Enameled Ceramics Tell Us? Explorations of Socioeconomic Status through the Archaeological Record in Eighteenth-Century Louisiana: 1700–1790." PhD dissertation. Louisiana State University, Baton Rouge, USA.

Eren, M. I. 2011. "Behavioral Adaptations of Human Colonizers in the North American Lower Great Lakes Region." PhD dissertation. Southern Methodist University, Dallas, Texas.

Defining and Measuring Diversity in Archaeology
Another Step Toward an Evolutionary Synthesis of Culture
Edited by Metin I. Eren and Briggs Buchanan
https://www.berghahnbooks.com/title/ErenDefining

———. 2012. "Were Unifacial Tools Regularly Hafted by Clovis Foragers in the North American Lower Great Lakes Region? An Empirical Test of Edge Class Richness and Attribute Frequency among Distal, Proximal, and Lateral Tool-sections." *Journal of Ohio Archaeology* 2: 1–15.

Eren, M. I., A. Chao, C. H. Chiu, R. K. Colwell, B. Buchanan, M. T. Boulanger, J. Darwent, and M. J. O'Brien. 2016. "Statistical Analysis of Paradigmatic Class Richness Supports Greater Paleoindian Projectile-Point Diversity in the Southeast." *American Antiquity* 81: 174–92.

Eren, M. I., A. Chao, W. H. Hwang, and R. K. Colwell. 2012. "Estimating the Richness of a Population When the Maximum Number of Classes is Fixed: A Nonparametric Solution to an Archaeological Problem." *PLoS ONE* 7(5): e34179.

Fish, P. 1978. "Consistency in Archaeological Measurement and Classification: A Pilot Study." *American Antiquity* 43: 86–89.

Futato, E. M. 1983. "Projectile Point Morphology: Steps Toward a Formal Account." *Southeastern Archaeological Conference Bulletin* 21: 38–55.

García Rivero, D. 2010. "Evolución Cultural y Filogenias en Arqueología: El Caso de los Denominados Ídolos Placa Prehistóricos del Suroeste de la Península Ibérica." PhD dissertation. Universidad de Sevillas, Seville.

García Rivero, D., and M. J. O'Brien. 2014. "Phylogenetic Analysis Shows that Neolithic Slate Plaques from the Southwestern Iberian Peninsula Are Not Genealogical Recording Systems." *PLoS ONE* 9(2): e88296.

Gjesfjeld, E. W. 2003. "New Approaches to Understanding Cultural Continuity in the Great Plains." Master's thesis. University College London.

———. 2014. "Of Pots and People: Investigating Hunter-Gatherer Pottery Production and Social Networks in the Kuril Islands." PhD dissertation. University of Washington, Seattle.

Goodwin, R. C., J. K. Yakubik, and P. A. Gendel. 1984. *Archeological Data Recovery at Algiers Point*. New Orleans: Goodwin and Associates.

Gunn, M. M., and M. W. Graves. 1995. "Constructing Seriations from the Guthe Collection, the Central Philippines: Implications for Southeast Asian Ceramic Chronologies." *Asian Perspectives* 34: 257–82.

Hanford Arundale, W. 1980. "Functional Analysis of Three Unusual Assemblages from the Cape Dorset Area, Baffin Island." *Arctic* 33(3): 464–86.

Harmon, M. J., T. L. VanPool, R. L. Leonard, C. S. VanPool, and L. A. Salter. 2006. "Reconstructing the Flow of Information across Time and Space: A Phylogenetic Analysis of Ceramic Traditions from Prehispanic Western and Northern Mexico and the American Southwest." In *Mapping Our Ancestors: Phylogenetic Approaches in Anthropology and Prehistory*, ed. C. P. Lipo, M. J. O'Brien, M. Collard, and S. J. Shennan, 209–29. New Brunswick, NJ: Transaction.

Johnson, A. E., P. E. Brockington Jr., M. Adair, E. Anderson, and J. A. Artz. 1982. "Archaeological Investigation at El Dorado Lake, Butler County, Kansas. Phase III." Museum of Anthropology, Lawrence, Kansas.

Jones, G. T. 1984. "Prehistoric Land Use in the Steens Mountain Area, Southeastern Oregon." PhD dissertation. University of Washington, Seattle.

Jones, J. S. 1996. "The Anzick Site: Analysis of a Clovis Burial Assemblage." Master's thesis. Oregon State University, Corvallis, USA.

Kaufman, D. 1998. "Measuring Archaeological Diversity: An Application of the Jackknife Technique." *American Antiquity* 63: 73–85.

Leonard, R. D., and G. T. Jones. 1987. "Elements of an Inclusive Evolutionary Model for Archaeology." *Journal of Anthropological Archaeology* 6: 199–219.

Defining and Measuring Diversity in Archaeology
Another Step Toward an Evolutionary Synthesis of Culture
Edited by Metin I. Eren and Briggs Buchanan
https://www.berghahnbooks.com/title/ErenDefining

———, eds. 1989. *Quantifying Diversity in Archaeology*. Cambridge: Cambridge University Press.

Letham, B. 2014. "Settlement and Shell-Bearing Site Diversity in the Sechelt Inlet System, British Columbia." *Canadian Journal of Archaeology* 38(1): 280–328.

Lewarch, D. E. 1982. "Analysis of Lithic Artifacts." In *The Cannon Reservoir Human Ecology Project: An Archaeological Study of Cultural Adaptations in the Southern Prairie Peninsula*, ed. M. J. O'Brien, R. E. Warren, and D. E. Lewarch, 145–70. New York: Academic Press.

Lewarch, D. E., and E. W. Bangs. 1995. "Lithic Artifacts." In *The Archaeology of West Point, Seattle, Washington: 4000 Years of Hunter-Fisher-Gatherer Land Use in Southern Puget Sound*, ed. Lynn L. Larson and Dennis E. Lewarch, pp. 7.1–7.181. Seattle, WA: Larson Anthropological/Archaeological Services, report to CH2M Hill, Bellevue, Washington, and King County Department of Metropolitan Services.

Lipo, C. P. 2001. "Community Structures among Late Mississippian Populations of the Central Mississippi River Valley." In *Posing Questions for a Scientific Archaeology*, ed. T. L. Hunt, C. P. Lipo, and S. L. Sterling, 175–216. Westport, CT: Berlin & Garvey.

Lipo, C. P., T. L. Hunt, and B. Hundtoft. 2015. "An Analysis of Stylistic Variability of Stemmed Obsidian Tools (Mata'a) on Rapa Nui (Easter Island)." In *Lithic Technological Systems and Evolutionary Theory*, ed. N. Goodale and W. Andrefsky, 225–38. Cambridge: Cambridge University Press.

Lohse, E. S. 1998. "Manual for Archaeological Analysis: Field and Laboratory Analysis Procedures." *Archaeological Survey Miscellaneous Paper* 98-1.

Lohse, E. S., and D. Sammons. 1999. "A Computerized Data Base for Lithic Use-Wear Analysis." In *Archaeology in the Age of the Internet*, ed. L. Dingwall, S. Exon, V. Gaffney, S. Laflin, and M. van Leusen, 280-5 to 280-14. Computer Applications and Quantitative Methods in Archaeology. Proceedings of the 25th Anniversary Conference, University of Birmingham, April 1997. Oxford: Archaeopress.

Loughran-Delahunt, I. 1996. "A Functional Analysis of Northwest Coast Spindle Whorls." Master's thesis. Western Washington University, Bellingham, USA.

Lycett, S. J. 2011. "'Most Beautiful and Most Wonderful': Those Endless Stone Tool Forms." *Journal of Evolutionary Psychology* 9(2): 143–71.

———. 2015. "Cultural Evolutionary Approaches to Artifact Variation over Time and Space: Basis, Progress, and Prospects." *Journal of Archaeological Science* 56: 21–31.

Lycett, S. J., and P. R. Chauhan. 2010. "Analytical Approaches to Palaeolithic Technologies: An Introduction." In *New Perspectives on Old Stones*, ed. S. J. Lycett and P. R. Chauhan, 1–22. New York: Springer.

Lycett, S. J., and N. von Cramon-Taubadel. 2015. "Toward a 'Quantitative Genetic' Approach to Lithic Variation." *Journal of Archaeological Method and Theory* 22(2): 646–75.

Lycett, S. J., N. von Cramon-Taubadel, and R. A. Foley. 2006. "A Crossbeam Co-ordinate Caliper for the Morphometric Analysis of Lithic Nuclei: A Description, Test, and Empirical Examples of Application." *Journal of Archaeological Science* 33(6): 847–61.

Lycett, S. J., K. Schillinger, M. I. Eren, N. von Cramon-Taubadel, and A. Mesoudi. 2016. "Factors Affecting Acheulean Handaxe Variation: Experimental Insights, Microevolutionary Processes, and Macroevolutionary Outcomes." *Quaternary International* 411: 386–401.

Lyman, R. L. 1987. "Archaeofaunas and Butchery Studies: A Taphonomic Perspective." In *Advances in Archaeological Method and Theory*, ed. M. B. Schiffer, 249–338. San Diego: Academic Press.

———. 2021. "On the Importance of Systematics to Archaeological Research: The Covariation of Typological Diversity and Morphological Disparity." *Journal of Paleolithic Archaeology* 4: 3.

Defining and Measuring Diversity in Archaeology
Another Step Toward an Evolutionary Synthesis of Culture
Edited by Metin I. Eren and Briggs Buchanan
https://www.berghahnbooks.com/title/ErenDefining

Lyman, R. L., M. A. Gallagher, C. G. Lebow, and M. K. Weber. 1983. *Reconnaissance in the Redmond Training Area, Central Oregon*. Salem: Oregon Military Department.
Lyman, R. L., and M. J. O'Brien. 1998. "The Goals of Evolutionary Archaeology: History and Explanation." *Current Anthropology* 39: 615–52.
———. 2001. "The Direct Historical Approach, Analogical Reasoning, and Theory in Americanist Archaeology." *Journal of Archaeological Method and Theory* 8: 303–42.
———. 2006. "Evolutionary Archaeology Is Unlikely to go Extinct: Response to Gabora." *World Archaeology* 38: 697–703.
Mason, R. J. 1962. "The Paleo-Indian Tradition in Eastern North America." *Current Anthropology* 3: 227–78.
Mason, R. E., R. E. Warren, and M. J. O'Brien. 1982. "Historic Settlement Patterns." In *The Cannon Reservoir Human Ecology Project: An Archaeological Study of Cultural Adaptations in the Southern Prairie Peninsula*, eds. M. J. O'Brien, R. E. Warren, and D. E. Lewarch, 369–88. New York: Academic Press.
McCutheon, P. T. 1997. "Archaeological Investigations of Stone Tool Heat Treatment in Southeast Missouri: An Experimental Approach." PhD dissertation. University of Washington, Seattle.
McElroy, W. K. 2003a. "Rethinking the Traditional Classification of Hawaiian Poi Pounders." *Rapa Nui Journal* 17(2): 85–93.
———. 2003b. "Variability in Poi Pounders from Kaua'i Island, Hawai'i." PhD dissertation. University of Hawaii, Manoa, USA.
Meltzer, D. J. 1981. "A Study of Style and Function in a Class of Tools." *Journal of Field Archaeology* 8(3): 313–26.
———. 1984. "Late Pleistocene Human Adaptations in Eastern North America." PhD dissertation. University of Washington, Seattle.
Meltzer, D. J., R. D. Leonard, and S. K. Stratton. 1992. "The Relationship between Sample Size and Diversity in Archaeological Assemblages." *Journal of Archaeological Science* 19(4): 375–87.
Mesoudi, A. 2007a. "Biological and Cultural Evolution: Similar but Different." *Biological Theory* 2(2): 119–23.
———. 2007b. "A Darwinian Theory of Cultural Evolution Can Promote an Evolutionary Synthesis for the Social Sciences." *Biological Theory* 2(3): 263–75.
———. 2011. *Cultural Evolution*. Chicago: University of Chicago Press.
———. 2017. "Pursuing Darwin's Curious Parallel: Prospects for a Science of Cultural Evolution." *Proceedings of the National Academy of Sciences* 114(30): 7853–60.
———. 2020. "The Study of Culture and Evolution across Disciplines." In *Cambridge Handbook of Evolutionary Perspectives on Human Behavior*, ed. L. Workman, W. Reader, and J. Barkow, 61–74. Cambridge: Cambridge University Press.
Mesoudi, A., A. Whiten, and K. N. Laland. 2004. "Is Human Cultural Evolution Darwinian? Evidence Reviewed from the Perspective of The Origin of Species." *Evolution* 58(1): 1–11.
———. 2006. "Towards a Unified Science of Cultural Evolution." *Behavioral and Brain Sciences* 29(4): 329–47.
Miksic, J., C. Rachna, H. Piphal, and C. Visoth. 2009. "Archaeological Report on the Thnal Mrech Kiln Site, TMK 02, Anlong Thom, Phnom Kulen, Cambodia." *Asia Research Institute Working Paper* 16: 1–43.
Miss, C. J. 1987. "Lithic Artifact Analysis." In *The Duwamish No. 1 Site, 1986 Data Recovery*, by URS Corporation and BOAS, Incorporated, pp. 6.1–6.65. Report to the Municipality of Metropolitan Seattle (METRO). Seattle, WA.

Defining and Measuring Diversity in Archaeology
Another Step Toward an Evolutionary Synthesis of Culture
Edited by Metin I. Eren and Briggs Buchanan
https://www.berghahnbooks.com/title/ErenDefining

Nagaoka, L. 2001. "Using Diversity Indices to Measure Changes in Prey Choice at the Shag River Mouth site, Southern New Zealand." *International Journal of Osteoarchaeology* 11(1–2): 101–11.

Nolan, K. C. 2010. "Multi-staged Analysis of the Reinhardt Village Community: A Fourteenth-Century Central Ohio Community in Context." PhD dissertation. The Ohio State University, Columbus, USA.

Nolan, K. C., and R. A. Cook. 2010. "An Evolutionary Model of Social Change in the Middle Ohio Valley: Was Social Complexity Impossible during the Late Woodland but Mandatory during the Late Prehistoric?" *Journal of Anthropological Archaeology* 29(1): 62–79.

———. 2011. "A Critique of Late Prehistoric Systematics in the Middle Ohio River Valley." *North American Archaeologist* 32(4): 293–325.

Nolan, K. C., P. Sciulli, S. Blatt, and C. K. Thompson. 2015. "A Late Woodland Red Ocher Burial Cache from Madison County, Ohio." *North American Archaeologist* 36(3): 197–236.

O'Brien, M. J., M. T. Boulanger, B. Buchanan, R. A. Bentley, R. L. Lyman, C. P. Lipo, M. E. Madsen, and M. I. Eren. 2016. "Design Space and Cultural Transmission: Case Studies from Paleoindian Eastern North America." *Journal of Archaeological Method and Theory* 23: 692–740.

O'Brien, M. J., M. T. Boulanger, B. Buchanan, M. Collard, R. L. Lyman, and J. Darwent. 2014. "Innovation and Cultural Transmission in the American Paleolithic: Phylogenetic Analysis of Eastern Paleoindian Projectile-Point Classes." *Journal of Anthropological Archaeology* 34: 100–119.

O'Brien, M. J., M. T. Boulanger, R. L. Lyman, and B. Buchanan. 2015. "Phylogenetic Systematics". In *Mathematics in Archaeology*, ed. J. Barcelo and I. Bogdanovic, 232–46. Boca Raton, FL: CRC Press.

O'Brien, M. J., B. Buchanan, and M. I. Eren. 2016. "Clovis Colonization of Eastern North America: A Phylogenetic Approach." *STAR: Science & Technology of Archaeological Research* 2(1): 67–89.

O'Brien, M. J., J. Darwent, and R. L. Lyman. 2001. "Cladistics is Useful for Reconstructing Archaeological Phylogenies: Palaeoindian Points from the Southeastern United States." *Journal of Archaeological Science* 28(10): 1115–36.

O'Brien, M. J., and D. E. Lewarch. 1984. "The Built Environment." In *Grassland, Forest, and Historical Settlement: An Analysis of Dynamics in Northeast Missouri*, ed. M. J. O'Brien, 231–65. Lincoln: University of Nebraska Press.

O'Brien, M. J., D. E. Lewarch, J. E. Saunders, and C. B. Fraser. 1980. "An Analysis of Historic Structures in the Cannon Reservoir Area, Northeast Missouri." Technical Report 80-17. Department of Anthropology, University of Nebraska, Lincoln, USA.

O'Brien, M.J., and R. L. Lyman. 2000. *Applying Evolutionary Archaeology: A Systematic Approach*. New York: Springer.

———. 2002. "The Epistemological Nature of Archaeological Units." *Anthropological Theory* 2(1): 37–56.

———, eds. 2003. *Style, Function, Transmission: Evolutionary Archaeological Perspectives*. Salt Lake City: University of Utah Press.

O'Brien, M. J., R. L. Lyman, and R. D. Leonard. 2003. "What Is Evolution? A Response to Bamforth." *American Antiquity* 68: 573–80.

O'Brien, M. J., and R. E. Warren. 1985. "Archaeology of the Central Salt River Valley: An Overview of the Prehistoric Occupation; Stratigraphy and Chronology at Pigeon Roost Creek." *The Missouri Archaeologist* 46: 203–25.

Defining and Measuring Diversity in Archaeology
Another Step Toward an Evolutionary Synthesis of Culture
Edited by Metin I. Eren and Briggs Buchanan
https://www.berghahnbooks.com/title/ErenDefining

Okumura, M., and A. G. Araujo. 2014. "Long-Term Cultural Stability in Hunter-Gatherers: A Case Study Using Traditional and Geometric Morphometric Analysis of Lithic Stemmed Bifacial Points from Southern Brazil." *Journal of Archaeological Science* 45: 59–71.

Pfeffer, M. T. 2001. "The Engineering and Evolution of Hawaiian Fishhooks." In *Posing Questions for a Scientific Archaeology*, ed. T. L. Hunt, C. P. Lipo, and S. L. Sterling, 73–96. Westport, CT: Berlin & Garvey.

Pierce, C. 1999. "Explaining Corrugated Pottery in the American Southwest: An Evolutionary Approach." PhD dissertation. University of Washington, Seattle.

Prentiss, A. M. 2021. "Theoretical Plurality, the Extended Evolutionary Synthesis, and Archaeology." *Proceedings of the National Academy of Sciences* 118(2): e2006564118.

Rafferty, J. 1994. "Gradual or Step-Wise Change: The Development of Sedentary Settlement Patterns in Northeast Mississippi." *American Antiquity* 59: 405–25.

Ramenofsky, A. F., F. D. Neiman, and C. D. Pierce. 2009. "Measuring Time, Population, and Residential Mobility from the Surface at San Marcos Pueblo, North Central New Mexico." *American Antiquity* 74: 505–30.

Read, D. 2015. "Statistical Reasoning and Archaeological Theorizing: The Double-Bind Problem." *Mathematics in Archaeology*, ed. J. Barcelo and I. Bogdanovic, 100–122. Boca Raton, FL: CRC Press.

Rhode, D. 1988. "Measurement of Archaeological Diversity and the Sample-Size Effect." *American Antiquity* 53: 708–16.

Richerson, P. J., and R. Boyd. 2008. *Not by Genes Alone: How Culture Transformed Human Evolution*. Chicago: University of Chicago Press.

Riede, F. 2009. "Tangled Trees: Modeling Material Culture Evolution as Host–Associate Cospeciation." In *Pattern and Process in Cultural Evolution*, ed. S. Shennan, 85–98. Berkeley: University of California Press.

Rorabaugh, A. N. 2009. "Barbed Bone and Antler Technologies: Cultural Transmission and Variation in the Gulf of Georgia, Northwest North America." Master's thesis. Western Washington University, Bellingham, USA.

Seong, C. 1998. "Microblade Technology in Korea and Adjacent Northeast Asia." *Asian Perspectives* 37: 245–78.

Shaw, A. B. 1969. "Adam and Eve, Paleontology, and the Non-Objective Arts." *Journal of Paleontology* 43: 1085–98.

Shea, J. J. 2013. "Lithic Modes A–I: A New Framework for Describing Global-Scale Variation in Stone Tool Technology Illustrated with Evidence from the East Mediterranean Levant." *Journal of Archaeological Method and Theory* 20(1): 151–86.

Sheldon, D. J. 2015. "Determination of Site Functionality and Subsistence Patterns at the Bray Archaeological Site (45PI1276) in Edgewood, Washington." Master's thesis. Central Washington University, Ellensburg, USA.

Shott, M. J. 1989. "Diversity, Organization, and Behavior in the Material Record: Ethnographic and Archaeological Examples." *Current Anthropology* 30(3): 283–315.

———. 1997. "Activity and Formation as Sources of Variation in Great Lakes Paleoindian Assemblages." *Midcontinental Journal of Archaeology* 22: 197–236.

———. 2010. "Size Dependence in Assemblage Measures: Essentialism, Materialism, and 'SHE' Analysis in Archaeology." *American Antiquity* 75: 886–906.

———. 2011. "History Written in Stone: Evolutionary Analysis of Stone Tools in Archeology." *Evolution: Education and Outreach* 4(3): 435–45.

———. 2020. "Toward a Theory of the Point." In *Culture History and Convergent Evolution*, ed. H. Groucutt, 245–59. Cham, Switzerland: Springer.

Defining and Measuring Diversity in Archaeology
Another Step Toward an Evolutionary Synthesis of Culture
Edited by Metin I. Eren and Briggs Buchanan
https://www.berghahnbooks.com/title/ErenDefining

Sterling, S. L. 2001. "Social Complexity in Ancient Egypt: Functional Differentiation as Reflected in the Distribution of Standardized Ceramics." In *Posing Questions for a Scientific Archaeology*, ed. T. L. Hunt, C. P. Lipo, and S. L. Sterling, 145–75. Westport, CT: Bergin & Garvey.

Strong, W. D. 1935. "An Introduction to Nebraska Archeology." *Smithsonian Miscellaneous Collections* 93(10).

Tehrani, J., and M. Collard. 2009. "The Evolution of Material Culture Diversity among Iranian Tribal Populations." In *Pattern and Process in Cultural Evolution*, ed. S. Shennan, 99–112. Berkeley: University of California Press.

Thomas, D. H. 1989. "Diversity in Hunter-Gatherer Cultural Geography." In *Quantifying Diversity in Archaeology*, ed. R. D. Leonard and G. T. Jones, 85–91. Cambridge: Cambridge University Press.

Thompson, G. 1978. *Prehistoric Settlement Changes in the Southern Northwest Coast: A Functional Approach*. Reports in Archaeology 5. Department of Anthropology, University of Washington, Seattle.

Thorpe, R. S., and G. C. Brown. 1993. *The Field Description of Igneous Rocks*. Chichester, UK: John Wiley & Sons.

Thulman, D. K. 2006. "A Reconstruction of Paleoindian Social Organization in North Central Flordia." PhD dissertation. Florida State University, Tallahassee.

VanPool, C. S., T. L. VanPool, and M. Harmon. 2008. "Plumed and Horned Serpents of the American Southwest." In *Touching the Past: Ritual, Religion, and Trade of Casas Grandes*, ed. G. Nielsen-Grimm and P. Stavast, 47–58. Brigham Young University, Provo, Utah: Museum of Peoples and Cultures.

VanPool, T. L. 2003. "Explaining Changes in Projectile Point Morphology: A Case Study from Ventana Cave, Arizona." PhD dissertation. University of New Mexico, Albuquerque.

VanPool, T. L., M. J. O'Brien, and R. L. Lyman. 2015. "Innovation and Natural Selection in Paleoindian Projectile Points from the American Southwest." In *Lithic Technological Systems and Evolutionary Theory*, ed. N. Goodale and W. Andrefsky, 61–82. Cambridge: Cambridge University Press.

Weisler, M. I. 2000. "Burial Artifacts from the Marshall Islands: Description, Dating and Evidence for Extra-Archipelago Contacts." *Micronesia Agana* 33(1/2): 111–36.

Weitzel, M. A. 1998. "A New Method for the Analysis of Human Hair: A Morphological Case Study of Five Sample Populations." Master's thesis. Oregon State University, Corvallis, USA.

Whallon Jr., R. 1972. "A New Approach to Pottery Typology." *American Antiquity* 37: 13–33.

Whittaker, J., D. Caulkins, and K. Kamp. 1998. "Evaluating Consistency in Typology and Classification." *Journal of Archaeological Method and Theory* 5: 129–64.

Wilhelmsen, K. H. 2001. "Building the Framework for an Evolutionary Explanation of Projectile Point Variation: An Example from the Central Mississippi River Valley." In *Posing Questions for a Scientific Archaeology*, ed. T. L. Hunt, C. P. Lipo, and S. L. Sterling, 97–144. Westport, CT: Bergin & Garvey.

Winterhalder, B. 1986. "Diet Choice, Risk, and Food Sharing in a Stochastic Environment." *Journal of Anthropological Archaeology* 5(4): 369–92.

Zedeno, M. N. 2009. "Animating by Association: Index Objects and Relational Taxonomies." *Cambridge Archaeological Journal* 19(3): 407–17.

Zeier, C. D. 1982. "The Willey and Phillips System Revisited: A Proposed Expansion of the Paradigm." *Plains Anthropologist* 27: 29–36.

Defining and Measuring Diversity in Archaeology
Another Step Toward an Evolutionary Synthesis of Culture
Edited by Metin I. Eren and Briggs Buchanan
https://www.berghahnbooks.com/title/ErenDefining