REPRESENTATIVENESS, OCCUPATIONS, AND INFORMATION: CRITICAL CONSIDERATIONS ON THE EVALUATION OF ARCHAEOLOGICAL SIGNIFICANCE IN CRM

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Abstract

The purpose of historic preservation policy is to ensure that data about the past are preserved for future generations of researchers, and—where possible—significant material and places are preserved for the benefit of the general public. Cultural Resource Management (CRM) has developed as an industry to address these requirements. Standard, cookie-cutter practices have become an easy-to-implement, but often inadequate, solution for this primary purpose. We examine the deficiencies in CRM practice in concept and execution. Notably, most recommendations for *insignificance*—and sometimes for significance—are made without justification in terms of the regulations that structure the investment of public monies in historic preservation. A different conceptual approach is needed to ensure that there is a future for archaeological research derived from CRM. Archaeologists must move away from the "National Geographic" principle as a primary justification for "significance." For there to be a science of the past in the future, we must implement a standard of *representativeness* in what types of data are preserved. Further, the concept of "site" should be replaced with evaluations of "occupations" as features in-and-of-themselves. Finally, CRM needs a rigorous definition of "Information" in order to adequately implement justifications of significance under NRHP criterion D. It is impossible to rigorously evaluate "information potential" without a definition of "information." Operationalization of *representativeness*—necessary for a science of the past—may be realized by adoption of Shannon Entropy as a measure of information potential. An occupation that is highly redundant with previously investigated sites may be significant, but it is not significant due to its potential to provide *information* about the past.

Keywords: Section 106; Criterion D; Shannon Entropy; Conditional Entropy; Significance

Every day, archaeologists make significance decisions that lead to permanent alteration of the archaeological record. This is necessary because of the practical impossibility of saving everything. Given the consequences, making significance determinations is the single most important action that any archaeologist can take. Unfortunately, the state of the art remains poorly developed. Most such decision making takes place at the Phase I level, where approximately seventy percent of sites found are written off as non-significant (Peacock and Burnworth 2010). The rationales for such negative assessments often are decidedly weak; small

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site size and/or light artifact density and/or an apparent lack of subsurface features are three reasons commonly invoked for writing a site off. There is no theoretical support for such reasoning; rather, these are common-sense assertions that: a) more stuff is somehow better; and b) features are more important than other kinds of deposits, presumably based on an (usually untested) assumption that features represent primary deposits in sealed context. We have been operating in this rote manner for decades, and the loss of information on the human condition ideally obtainable via archaeology is simply incalculable (Dunnell 1984; Peacock and Rafferty 2007).

The best Phase I, and most Phase II significance assessments are theoretically informed because they refer to concrete research questions. But the sad truth is that our best is far from good enough. Reliance upon even the best research designs suffers from two fatal flaws. The first is that even the best archaeologists cannot possibly be conversant with all contemporary research concerns. A specialist in phytoliths, or residue analysis, or lithic microwear, or land snails might weep at the lost opportunities upon learning that a pertinent site had been written off by a decision-maker understandably unversed in those areas. Even if one had unlimited funding and the best of every kind of specialist on one's team, the second, more insidious problem, still would remain. That is, we also must take into account our impacts on *all future research needs*, as those necessarily are affected by what we choose to preserve. This onus exists despite the fact we cannot, of course, know what will be important in the future, any more than archaeologists prior to Libby could have known that biotic remains would someday be useful for radiocarbon dating. So, if we are honest about our obligations, we face a seemingly impossible dilemma: how to account for all current and future research needs in our significance assessments when such needs are unknown to us?

This fundamental problem has been recognized since the early days of compliance-driven archaeology (e.g., Lipe 1974). Ironically, so has the deceptively simple solution, which is to save some of everything that's out there. Enacting the Principle of Representativeness (POR, Peacock 1996; Peacock and Rafferty 2007; see also Dunnell 1984) as the guiding dictum of CRM theoretically solves the problem because, if enough of everything is saved, then all current and future research needs can be met. In practice, two other questions of paramount importance emerge: a) what "things" are we talking about; and b) how much of each kind of "thing" is enough? Before we explore those questions further, it is important to make two additional points. Firstly, a very great deal of research remains to be done in answering these questions, and there is no reason why such research should not be funded via CRM. Secondly, nothing in the POR approach precludes saving sites (in fact, or in proxy via data recovery) for other reasons, including current research questions, historical or other humanistic concerns, and accommodation of traditional knowledge. These points should allay the discomfort of archaeologists who insist that CRM should be "research" (e.g., Briuer 1996), as well as those who might argue that sites deemed important by contemporary research or cultural patrimony standards would be dismissed from consideration under a POR approach.

There are two kinds of "significance" that we can ascribe from the historical and archaeological records (Dunnell 1984). The first is Humanistic significance (Dunnell 1984:66; Nolan 2015, 2020), best represented by NRHP eligibility Criteria A through C. Sites can be nominated for their representation of significant historical events or themes, significant people, and significant artistic or aesthetic value, evaluation of which may particularly benefit from descendant and interest group input. The second kind of significance is Scientific (Dunnell 1984; Nolan 2015, 2020). It is for this type of significance that the POR—once operationalized in a study region—is crucial. Scientific value is assessable under criterion D, "Information Potential" (see Nolan 2020), as discussed below, but here we repeat the point that properties considered significant for humanistic reasons are not summarily dismissed when a more robust strategy for accommodating scientific value is emplaced.

Where scientific value is concerned, to design a sampling strategy and assess sample representativeness, we must first know what "things" we are talking about. The things that need to be considered for preservation are occupations. An occupation is an artifact at the scale of assemblage: in plain speak, it is all the artifacts that belong together at any particular locale. Just as an arrow is made up of several component artifacts but still coheres as a single artifact at a higher level so too with occupations. The concept of "site" as a phenomenological entity is notoriously nebulous (e.g., Dunnell 1992; Dunnell and Dancey 1983; Kerber 1983), as exemplified by the fact that definitions of this familiar and long-standing term vary dramatically from state to state. A site is simply a place where artifacts are found, the boundaries of which vary depending on field methodology and scale of recovery. A site can have any number of occupations, which may or may not overlap to some degree. Occupations are physical things, artifacts that can be measured in space, time, and form. They are distinct from components, or "manifestations of a phase at a site" (Willey and Phillips 1958), which are nothing more than signifiers that diagnostics of one or more arbitrarily defined cultural periods are present. A "multi-component site" may appear to have two or more phenomenological entities present (e.g., a Late Woodland and a Mississippian component), when in fact only a single occupation may be present, over the span of which artifacts diagnostic of more than one culture period were produced.

These distinctions are not semantic; they are critically important where significance assessments are concerned. If only a single occupation is present, then the number of research questions that may be asked of an assemblage is little diminished by disturbance; the occupation retains considerable scientific integrity *even if the artifacts have been spatially mixed.* The same cannot be said when disturbance has mingled artifacts from different occupations. It also must be recognized that one does not need postholes, pits, or other non-portable artifact types to argue for significance based on the presence of features: *an occupation is itself a feature*, regardless of how many or what kinds of component artifacts contribute to its makeup (Peacock et al. 2008). No one would argue that a refuse pit is not a feature and cannot provide useful information simply by the fact that a rodent burrowed into it and mixed depositional strata. The disturbance reduces the precision of the data recovered (spatially and/or temporally), but that only matters relative to the questions being asked. Sourcing studies, to give one example, would be essentially unaffected by such disturbance. Likewise, plowing of a lithic scatter, a common form of single-occupation site, does not remove that occupation from the category of feature, even if horizontal precision is lost.

Time precludes detailed discussion of how occupations are recognized and recorded; suffice to say that a relevant literature exists (e.g., Alvey 2021; Dunlop 2018; Madden 2017;

Morton 2015; Parrish and Peacock 2006; Peacock 2004; Peacock and Rafferty 2007; Rafferty 2001, 2008; Rafferty et al. 2011; Reith (ed.) 2008, and chapters therein), and that more research on this front would be a most worthy investment of CRM funds. Because of its importance in significance assessments, occupation analysis should be a *required* part of every CRM report, regardless of level.

The next question, how much to save, is a classification and sampling problem. Paradigmatic classifications (*sensu* Dunnell 2002:70-76) of occupations must be constructed and previously recorded occupations identified with their respective classes, so that underrepresentation in particular classes can be identified and corrected via significance determinations. This approach is perfectly in line with the "may be likely to yield important information" of Criterion D; if it can be demonstrated that one or more entire classes of occupations have been neglected, then a potential for significant information return clearly will have been identified.

To accommodate all current and future research needs, the dimensions (*sensu* Dunnell 2002:71) employed in classification must be "value-free," that is, not biased by contemporary research concerns or any one theoretical perspective, and they must reflect actual observable phenomena, not conceptual categories like "base camp," "hunting camp," etc., which are assumptions and interpretations rather than empirically observable characteristics. Because environmental factors such as soil acidity greatly impact what is observable in the record, and thus what dimensions (i.e., "*a set of mutually exclusive alternative features,*" after Dunnell [2002:71]) may be employed, separate classifications must be constructed for different environmental zones. Choosing dimensions that will allow for incorporation of existing site file data is difficult, but there is no reason why the process should not be iterative, such that improvements in class construction and sample adequacy can be fine-tuned as more data become available, especially if projects at all levels include mandated occupation analysis. How many of each class to save is a sampling question, but surely the vast literature on sampling produced by the discipline can provide answers in this regard (e.g., Ammerman 1981; Banning 2002; Kintigh 1988; Lovis 1976; Mueller 1975; Wobst 1983).

The POR approach has moved beyond the theoretical in a few important cases. In a Phase I survey of a proposed coal mine area in south-central Mississippi, Rafferty et al. (2011) classified occupations via a paradigm employing number of occupations (single or multiple), occupational intensity, artifact richness, and artifact evenness as dimensions, with specific criteria for defining attributes under each dimension and accounting for sample size differences produced from shovel-testing or open-ground survey. Richness and evenness were calculated based on the number and spread of artifact categories present; intensity was measured via midden presence/absence and soil phosphate levels. Twenty-four occupation classes resulted when attributes were intersected (Figure 1). The best-preserved examples of each of the 464 occupations so classified were then selected as being potentially eligible for the NRHP. As Rafferty et al. (2011:534) note, "This procedure assured that some occupations in each class will receive further field investigation in the event that adverse impacts are planned to occur."

The POR approach was further theorized in a master's thesis by Madden (2017). Dimensions employed in paradigm construction were artifact density, occupation size, presence/absence of diagnostics, presence/absence of perishable artifacts, and presence/absence of visible features, again with specific definition of attributes; separate paradigms were used for occupations discovered via shovel testing vs. open-ground survey. Seventy-two classes resulted when attributes were intersected (Figure 2). One hundred sixty-six occupations from previously reported sites on the Tombigbee National Forest, Mississippi, were then identified with their respective classes, and statistical analysis was conducted to identify biases in significance assessments between classes.

			MULTIPLE OCCUPATIONS/ Richness					
			ABSENT			PRESENT		
			Low	Medium	High	Low	Medium	High
INTENSITY/ Evenness	LOW	Even	1	2	3	4	5	6
		Uneven	7	8	9	10	11	12
	HIGH	Even	13	14	15	16	17	18
		Uneven	19	20	21	22	23	24

Figure 1. Paradigm for classifying occupations in the North American Coal mine area, Kemper and Lauderdale counties, Mississippi (Rafferty et al. 2011:Figure 345).

While the specifics of these two case studies should be of interest to anyone attempting a POR approach, the larger point for this paper is that the feasibility and utility of the approach have been demonstrated. A final counter-argument against the approach was given by the then-Chief Archaeologist of Mississippi, who had agreed to Rafferty's research design for the coal mine survey but later reneged on the consequent significance determinations, falling back instead on the same, tired criteria that have typified American CRM for so long. Her defense was that a member of the Advisory Council on Historic Preservation had told her that representativeness was not an allowable argument for significance under the Section 106 process. That is patent nonsense; one has only to look at how standing architecture is assessed to demonstrate that "representatives of a type" can be significant, a long-standing practice in the field. One has only to extend it to stuff in the ground in addition to stuff above it. Further, the National Park Service themselves highlight that archaeological sites can be included under Criterion C as "representative of a type" (Andrus and Shrimpton 1995:18). To embrace the POR approach necessitates letting go of our reliance on traditional typologies, current research trends, ethnographically informed ideational constructs, and common-sense assumptions (Peacock and Rafferty 2007). The reward is that we become better stewards of the present and future as well as of the past. This necessary change in approach will not occur without SHPO and agency buy-in and consequent mandates for professional practice.

			Light Artifact Density			Medium Artifact Density			Heavy Artifact Density		
			Small occupa-tion	Medium occupa-tion	Large occupa-tion	Small	Med.	Large	Small	Med.	Large
Presence of visible features	Perishables present	Diagnostic present	1	2	3	4	5	6	7	8	9
		Diagnostic absent	10	11	12	13	14	15	16	17	18
	Perishables absent	Diagnostic present	19	20	21	22	23	24	25	26	27
		Diagnostic absent	28	29	30	31	32	33	34	35	36
Absence of visible features	Perishables present	Diagnostics present	37	38	39	40	41	42	43	44	45
		Diagnostics absent	46	47	48	49	50	51	52	53	54
	Perishables absent	Diagnostic present	55	56	57	58	59	60	61	62	63
		Diagnostic absent	64	65	66	67	68	69	70	71	72

Figure 2. Paradigmatic classification of occupations for the Ackerman Unit of the Tombigbee National Forest devised by Madden (2017:Figure 3.1).

Paradigmatic classification and sampling of occupations is perhaps the most straightforward way to implement a POR approach, as it employs terms and concepts for which most archaeologists should have a basic understanding. However, there is another way in which the POR can be seen as fully encapsulated within existing regulations and theoretically justified. Here we present a summary of Nolan's (2020) argument for using a formal definition of "information" and "information potential" as used in the language of Criterion D. It has been argued that one aim of historic preservation legislation is to preserve *information* for future archaeological research (e.g., Dunnell 1984; Tainter 2006). If that is the purpose, we cannot very well operationalize those marching orders without knowing what it is we are to preserve. "Information" is nowhere defined in the law or implementing regulations. Therefore, the legal framework must be referencing some outside, objective definition. Archaeologists have never come up with a definition of "archaeological information," and there is no reason to suspect that the legislation and regulations imply some special archaeological definition of "information"; information is information, regardless of discipline. It is worth noting that some of the conceptualization of archaeology as "information" was being theorized and explored at the same time that CRM archaeology was developing. Justeson (1973) reviewed many of the same concepts discussed by Nolan (2020) in his attempt to define the limits of archaeological inference. Justeson reviews key concepts in Information Theory (IT) and delineates how these concepts map onto the archaeological record, including: information/entropy function (H), source, code, input message, channel, channel capacity, noise, distortion, output message, etc. (1973:132-136). Justeson's review of IT illustrates that there has long been a realization that archaeological information is not qualitatively different from information in any other field, and thus reasonably associated with the usage of the "information" in the law and regulations implemented initially in the 1970s during the infancy of US CRM. A detailed review of Justeson's work is beyond the scope of this paper; his application was different than ours, and some of his conceptual mapping is different from that of Nolan (2020), and thus of limited relevance to the issue under consideration here. Those differences notwithstanding, Justeson's work offers further support for our contention that archaeological information is not a special case, and interdisciplinary concepts of measuring and analyzing information systems are relevant to the discussion of "Information Potential" in CRM archaeology.

As noted by Nolan (2020:1172), "In practice, Criterion D has a lower threshold, simply noting a likelihood of quantities of archaeological data justifies eligibility under the 'Information Potential' criterion" (sensu National Parks Service (NPS) 1995:21). This results in minimal justifications, and unsystematic sampling of the same kinds of resources." The equation of "more things" with "more information" is a non sequitur (Altschul 2005; Peacock 1996; Tainter 2006). The only necessary corollary of more stuff is more curation.

One major aspect of the false equivalency of volume of material with significance value is what Pecora characterized in a previous Ohio Archaeological Council workshop (2014:1) as "seeking the easy-way-out when evaluating archaeological sites." This in turn leads to a major issue noted by Peacock and Burnworth (2010; Peacock 2012) and Hebler (1996), and summarized in Nolan (2020:Table 1); specifically that most negative assessments occur at the Phase 1 (Identification) level not at the Phase II (Evaluation) level. Most significance assessments do not explicitly refer to the regulations or the criteria in justifying no further evaluation. Apparently, Principal Investigators, and SHPO and Agency reviewers are implicitly relying on the "obvious" relevance of the "archaeology criterion." This means there is limited rigorous assessment of whether we are getting what we are supposed to get out of CRM compliance with preservation law. Reviewers and sponsors must insist on explicit reference to the legal framework that is our warrant for spending public monies on historic preservation. To step away from this intuitive association of volume of stuff with quality of significance, we must use explicit criteria and definitions of the terms in those criteria.

Many have noted that current practice in many jurisdictions leads to between 70 percent and 95 percent of places with artifacts being recommended as insignificant at the Phase 1 (Identification) level (Alvey 2015, 2019; Cain 2012; Morton 2015; Peacock 1994, 1996; Plog et al. 1978), leading Tainter (2006:444) to question "how well we can preserve or write prehistory relying on an unrepresentative sample of 5% of the archaeological record." Our answer to Tainter's question is, "We can't do either particularly well." We must heed this warning if we are to make appropriate use of public support and funding of preservation work. We have already noted how Humanistic value—can and should— be argued and justified on the basis of Criteria A through C, as appropriate for the resource(s) considered. We have further discussed how POR can be associated with Scientific value and Criterion D. We now develop that argument further (see Nolan 2015, 2020 for more extensive review and justification).

Table 1: Terms for a Model of Archaeological Information Potential, copied from Nolan's (2020) Table 3.

Term	Notation	Description
Source 1	X_i	Behavioral/systemic context in the past at time *i*
Source 2	Δ_j	Archaeological record as a source at time *j*
Channel	C	Matrix that holds the archaeological record
Noise	N_j	Noise introduced by formation processes at each successive period *j*
Received signal	Y_s	Sample of the signal Δj produced by investigative technique *s*
Entropy 1	$H(X_i)$	Entropy of the systemic context (X_i) at time *i*
Entropy 2	$H(\Delta_j)$	Entropy of the archaeological (Δ_j) at time *j*
Entropy 3	$H(Y_S)$	Entropy of the received sample for a particular investigative technique *s*
Equivocation 1	$H_{\Delta j}(X_i)$	Conditional entropy of X_i given Δ_j
Equivocation 2	$H_{Ys}(\Delta_j)$	Conditional entropy of Δ_j given Y_s
Equivocation 3	$H_{YE}(\Delta_j)$	The N-gram conditional entropy of Δ_j given a composite set (Y_E) of Y_s

Nolan's (2020) application of Shannon Entropy to the definition of information and "information potential" in Criterion D, plus the paradigmatic classifications of *occupations* (see Madden 2017 and Rafferty et al. 2011), is the key to preservation of Scientific value and operationalizing POR within the language and framework of the current regulations. The language of the regulations and guidance explicitly reference "data gaps" (Andrus and Shrimpton 1995:21) when discussing Criterion D. So, in a common-sense way they are saying, if it is something new or if there is something we don't fully understand in the regional trends, then it has the potential to contribute important information. Now we know what can make "information" important, but what is "information"?

For this discussion, we proceed in a somewhat reversed presentation of the logical structure of the proposed operationalization of Shannon Entropy as measuring "information potential." Nolan (2020; for similar analysis, see Justeson 1973) works through the variables of Shannon's original (1948) formulation of information as entropy, then adapts the structure to the complex signal(s) of high entropy sequences that make up the archaeological record (see Nolan 2020:Table 3; Table 1) as a version of Shannon's (1951) N-gram conditional entropy for the archaeological record as:

$$H_{YE}(\Delta_j) = -\Sigma_{(YbE(1,n-1),Yns)}\, p(Y_{bE}, Y_{ns}) \log_2 p_{bE}(Y_{ns})$$

This formula likely causes some symbol-shock and math-phobia, which is why we are putting it here in the middle of the presentation before discussing how the concepts can be applied in practical terms with some simple illustrative cases. A major addition to the usage N-gram conditional entropy in IT is that for archaeological analysis, there are two different stages of a source which we are attempting to characterize from our archaeological observations related to Schiffer's (1972) systemic and archaeological contexts and Binford's (1981:200) "statics and dynamics." There are multiple potential behavioral contexts (X_i), for multiple possible occupations on the palimpsest of the landscape (see Justeson [1973:133-134] for similar discussion, though the level at which Justeson defines "*Information*" is at a scale distinct from that which Nolan considers). Our ultimate goal in archaeology is understanding the X_i at one or more time(s) *i* (paraphrased from Nolan 2020:1188). We are building this application of conditional entropy upon sound foundational archaeological theory, and in terms entirely consistent with the regulatory language.

To pull back from the symbol shock induced by Nolan's N-gram conditional entropy for the archaeological record, and even that induced by Shannon's (1948) original entropy formula ($H = -\Sigma\, p_i \log p_i$), let's explore what this means in practical terms. In the age of pocket supercomputers, we are all familiar with predictive text and auto-completed forms. These are real applications of a version of conditional entropy. In plain terms, conditional entropy is the likelihood of observing a specific value in the coding system given a partial sequence preceding the next observation. An example with English spelling and syntax may be helpful.

Here, we reuse the same example that Nolan (2020) did in his Table 2 (Table 2), the problem of predicting the next letter given two different frequently encountered starting letter(s): an English sequence beginning with 'th' and another beginning with the letter 'q'. In Table 2, we can see both of these sequences do not leave much to the imagination. That is, there are few valid options for what comes next. There are only 8 of 27 symbol options in the first case (w, y, o, u, a, r, i, e), and only 5 of 27 symbol options in the second (w,o,i,a,u). If you were going to bet on the next letter of the first sequence, you would be advised to start with 'e' or 'i' in your Wordle practice. And we should not have to tell you what you should choose for the second sequence. These are low entropy observations in a sequence with a known conditional probability structure. That is, these are low conditional entropy sequences. What counts as "low" in terms of entropy? Well, with a 27 symbol set, 'q' is about as low as you can get. It's almost certainly going to be 'u', and it is approximately 95% of the time. Now if you are not playing Wordle, but in a situation where you have to invest resources to be able to observe the next sequence, we can still intuitively understand the application of conditional entropy here. If you have to pay a cost to confirm that the next letter in the 'q-' sequence is in fact a 'u', we wager that very few of you would be willing to spend money to learn the identity of an observation you almost certainly already know. That is what low entropy is; you already know (with high probability) the identity of the next observation in a sequence of structured observations.

To translate this into another context, suppose you are reading a PDF copy of an old Xeroxed article and there is a smudge that obscures one letter of a word. If the word starts 'th', we already know there is a greater than even chance that the smudge is 'e' or 'i'. Now if there is another letter after the smudge (e.g., 'th*s'), this changes the conditional probability distributions for the missing letter (this is distinct from the *next* letter conditional entropy). The conditions of the observations you already have further constrain the relevant probabilities. We opt not to reconstruct the quantitative values for that to make the point that you do not need to know the absolute values of the likelihoods, but if you are an expert user of the symbolic system, you already possess a sense of the *relative* likelihoods. One more example for this sequence will hopefully cement the lesson.

Table 2: Frequency of Each of 27 Possible Symbols in English Words Starting with 'th' or 'q' (originally from https://word.tips/ 2019 and reproduced here from Nolan 2020:Table 2).

Next letter	'th-'	p	$p_i \log_2 p_i$	$p_i \log_2 (1/p_i)$	'q-'	p	$p_i \log_2 p_i$	$p_i \log_2 (1/p_i)$
_	0	0.000	0.000	0.000	0	0.000	0.000	0.000
a	139	0.123	-0.372	0.372	30	0.030	-0.152	0.152
b	0	0.000	0.000	0.000	0	0.000	0.000	0.000
c	0	0.000	0.000	0.000	0	0.000	0.000	0.000
d	0	0.000	0.000	0.000	0	0.000	0.000	0.000
e	363	0.322	-0.526	0.526	0	0.000	0.000	0.000
f	0	0.000	0.000	0.000	0	0.000	0.000	0.000
g	0	0.000	0.000	0.000	0	0.000	0.000	0.000
h	0	0.000	0.000	0.000	0	0.000	0.000	0.000
i	209	0.185	-0.451	0.451	15	0.015	-0.091	0.091
j	0	0.000	0.000	0.000	0	0.000	0.000	0.000
k	0	0.000	0.000	0.000	0	0.000	0.000	0.000
l	0	0.000	0.000	0.000	0	0.000	0.000	0.000
m	0	0.000	0.000	0.000	0	0.000	0.000	0.000
n	0	0.000	0.000	0.000	0	0.000	0.000	0.000
o	79	0.070	-0.269	0.269	4	0.004	-0.032	0.032
p	0	0.000	0.000	0.000	0	0.000	0.000	0.000
q	0	0.000	0.000	0.000	0	0.000	0.000	0.000
r	169	0.150	-0.410	0.410	0	0.000	0.000	0.000
s	0	0.000	0.000	0.000	0	0.000	0.000	0.000
t	0	0.000	0.000	0.000	0	0.000	0.000	0.000
u	81	0.072	-0.273	0.273	950	0.949	-0.072	0.072
v	0	0.000	0.000	0.000	0	0.000	0.000	0.000
w	18	0.016	-0.095	0.095	2	0.002	-0.018	0.018
x	0	0.000	0.000	0.000	0	0.000	0.000	0.000
y	70	0.062	-0.249	0.249	0	0.000	0.000	0.000
z	0	0.000	0.000	0.000	0	0.000	0.000	0.000
		Entropy	2.645	2.645			0.364	0.364

Say that now we have this sequence of observations with some disruption during the transfer of the data from one place to another. In our article, we now see:

"th*s s*nte*ce go**me**ed u*"

Our calculation of the most likely letter after the 'th' has changed. Now being constrained by an 's' ending the word, we know that this word is "this." We are going to ignore capitalization here and stick a 27-symbol set (capitalization would introduce 26 more symbols). We suspect most readers can figure out what this phrase is even with 8 of 28 symbols missing, but clearly obeying the structural relationships of the known system of the English language. That means that at least 30 percent of the symbols (letters) are redundant; they carry little or no *information potential*. We would learn nothing more about the message by paying to drive to the library, track down the original in hard copy and re-scan the article. This level of redundancy is in line with other estimates of the information potential per character in written English (see Shannon 1951).

As goes for English, so goes for the archaeological record. If you wouldn't be willing to drive to the library and rescan that article for 30 percent error in copying, then you shouldn't be willing to pay tens of thousands, hundreds of thousands of dollars for the *information potential* of a site type that you have excavated repeatedly and can predict what you will find if you pay for the rest of the phases of investigation.

Now consider a different situation., Your next article contains this error-riddled sequence of symbols: "x*r** δ1** v*lue*." Notice two things. First, our symbol set has grown to include numbers and Greek letters, so each character now has many more possible values which almost guarantees an increase in entropy (i.e., increase in uncertainty). Second, this is likely some sort of scientific notation, so that adds some context and may constrain our conditional entropy estimates. Further, 'x' is the least common letter in English for starting a word. This constrains the possible options (reducing entropy/uncertainty); however, most of us have very little familiarity with these words, so we do not have the innate understanding of possible options (increasing uncertainty/entropy), unless this particular scientific context is well within your wheelhouse. However, even if this is within your specialty, you might be more willing now to drive back to the library to examine the original. Or at least email the Interlibrary Loan Librarian and ask them to get a clearer scan of the original. The context and content, and the knowledge of the structure are missing to different extents, so some more investment in reducing the uncertainty is definitely warranted.

We need to ask some specific types of questions to start to estimate and then reduce entropy in this new signal. Are there more messages from this source that can help us to fully populate the symbol set (alphabet)? What are the conditional relationships (e.g., grammar) within this new context for this new message? We need to build up observations about the contingencies in this new sample set before we can start to predict what the missing symbols are. That is, we need a large and wide enough sample of messages to statistically model the dependencies and to identify the full range (or nearly so) of the symbol set. This new sequence, and the whole alphabet and context carry a large quantity of entropy, and therefore new observations in this unknown context carry significant *information potential*, each very likely to fill gaps in our understanding of the overall system. In other words, we should pay for those additional observations, and much more frequently than additional observations in familiar symbol sets and contexts.

-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	+	-	-	-
-	-	-	-	-	-	-
-	-	*	-	+	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-

Figure 3: Hypothetical artifact distribution for small precontact lithic scatter.
(- = negative STP; + = isolated flake in positive STP; * = two flakes in positive STP)

Taking this last example into an imaginary archaeological contextual analog, let's assume a Phase 1 survey in a county with only 175 previously defined archaeological sites in a physiographic region with few compliance surveys and fewer research studies. The stereotypical "data deficient county." Your field crews find 100 artifacts in 25 clusters in 100 acres. More likely than not, every CRM archaeologist reading this is thinking some version of "Great! Easy report, no significant sites, no additional work for the client. Easy money!" But before you write off 100 percent of the sites encountered without an "evaluation" phase investigation, think about the entropy of this 100 acres.

For any one of those 25 artifact clusters, what would you predict you would find if you excavated a 1 percent or 5 percent sample? This setup has added to the entropy for the reader, so maybe you want more data. Okay, let's look at one site. It's an average site for the survey area, so by definition, there are 4 artifacts. Let's say they were in 3 different shovel tests, so 2 isolated flakes and one STP with 2 flakes in a pattern shown in Figure 3. We all recognize a site like this, and we almost certainly recommended it ineligible for the NRHP and never thought about it again. But let's change that. Let's think about what you would find if you decided to perform a Phase 2 evaluation of this site. What would you find if you excavated a sample of this site with test units? We suspect that one of two scenarios would play out among the audience. Either the readers of this article do not know what would be found, or that there are as many guesses as the quantity 2p, where p = the quantity of qualified Principal Investigators reading this article. Either way, this is a high entropy scenario; or, in other words, this site has substantial *information* *potential*. It is precisely analogous to the "x*r** δ1** v*lue*" example distorted text above, and we would love to see more CRM archaeologists pay to get access to the original, hard-copy article so that we can know what the real message in the record of interest contains.

Summary

Phase I identification survey reports dismiss 70 to 95 percent of sites based on the false equation of volume of artifacts with "information," a theoretically unjustified fixation on features, and a failure to recognize that occupations (themselves a kind of feature) are little affected by disturbance unless multiple occupations are mixed. While the best significance assessments employ justifications reflecting existing regulations and current theoretical questions, these are the exception, and even those best examples are inadequate from a stewardship standpoint. Because no single archaeologist can master all current methods and theories—let alone anticipate all future methods, questions, and theories—if CRM is to accommodate the future of archaeological research, we must preserve a representative sample of *occupations*. We argue that the Principle of Representativeness should become the basis for preservation of Scientific value in the archaeological record. Scientific concerns are not the sole domain of importance for the archaeological record, and Humanistic value can be preserved by well-crafted and justified significance arguments under Criteria A, B, and C. We further argue that the application of a formal definition of *information* and *information potential* is the most robust way to operationalize POR consistent with the language and intent of the regulations, specifically Criterion D. By adapting Shannon Entropy as *information*, we can begin to implement the Section 106 process in a way that compensates for the unrepresentative nature of the sample that we have amassed to date. Focusing the application of Criterion D on the reduction of entropy in the archaeological record, we can begin to fill in gaps in our knowledge about the nature and structure of the archaeological record.

As experts in the observation of the archaeological record, we already possess implicit knowledge of the alphabet and grammar of the archaeological record and can identify signals that we recognize and can predict and those which we cannot predict. Even without formal mathematical modeling, we can apply the concept of entropy-as-information-potential in a relative sense. With paradigmatic classification of occupations in observational, value-free, dimensions—as Rafferty et al. (2011) and Madden (2017) have done—we can formalize this relative conditional entropy. As we develop the dimensions of our classification of occupations, we can begin to build the formal quantitative application of the N-gram conditional entropy of the archaeological record (Nolan 2020). Until we have quantitative measurements of $H_{YE}(\Delta_j)$, we will not realize the potential for stewarding the scientific value of the past.

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