Zooarchaeological Database Preservation, Multiscalar Data Integration, and the Collaboration of the Eastern Archaic Faunal Working Group

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ABSTRACT

Data preservation, reuse, and synthesis are important goals in contemporary archaeological research that have been addressed by the recent collaboration of the Eastern Archaic Faunal Working Group (EAFWG). We used the Digital Archaeological Record (tDAR) to preserve 60 significant legacy faunal databases from 23 Archaic period archaeological sites located in several contiguous subregions of the interior North American Eastern Woodlands. In order to resolve the problem of synthesizing non-standardized databases, we used the ontology and integration tools available in tDAR to explore comparability and combine datasets so that our research questions about aquatic resource use during the Archaic could be addressed at multiple scales. The challenges of making digital databases accessible for reuse, including the addition of metadata, and of linking disparate data in queryable datasets are significant but worth the effort. Our experience provides one example of how collaborative research may productively resolve problems in making legacy data accessible and usable for synthetic archaeological research.

Keywords: database preservation, database management, data reuse, database integration, synthetic research, collaborative research, zooarchaeology

La preservación, reutilización y síntesis de datos son objetivos importantes en la investigación arqueológica contemporánea que se han abordado con la colaboración reciente del Grupo de Trabajo de la Fauna Arcaica del Este (Eastern Archaic Faunal Working Group, EAFWG). Utilizamos el Registro Arqueológico Digital (tDAR) para preservar 60 conjuntos de datos de fauna antiguos significativos de 23 sitios arqueológicos del período Arcaico ubicados en varias subregiones contiguas del interior de los bosques de América del Norte. Para resolver el problema de sintetizar los conjuntos de datos no estandarizados, utilizamos las herramientas de ontología e integración disponibles en el tDAR para explorar la comparabilidad y combinarlos para que nuestras preguntas de investigación sobre el uso de los recursos acuáticos durante el Arcaico se puedan abordar a múltiples escalas. Los retos de hacer accesibles las bases de datos digitales para su reutilización, de incluir la adición de metadatos y de vincular los datos dispares en conjuntos de datos consultables son significativos, pero vale la pena el esfuerzo. Nuestra experiencia proporciona un ejemplo de cómo la investigación en colaboración puede resolver problemas de manera productiva al hacer que los datos antiguos sean accesibles y utilizables para la investigación arqueológica sintética.

Palabras clave: conservación de base de datos, gestión de base de datos, reutilización de datos, integración de base de datos, investigación sintética, investigación colaborativa, zooarquelogia

As archaeology has experienced an "explosion of systematically collected archaeological data" (Kintigh et al. 2014:19), curation—including digital curation—has become a priority for our discipline. Several recent articles (e.g., Altschul et al. 2017, 2018; Kintigh et al. 2017) have identified related concerns about database preservation and management, synthesis and integration of digital data, open access, and collaboration among archaeological scholars. More broadly, profound social transformations regarding information, data, and access affect all subfields of archaeology (Kansa 2015; Kansa and Kansa 2018; Kintigh 2006, 2018; Kintigh et al. 2017; Lake 2012; LeFebvre et al. 2019; McManamon et al. 2017; Snow et al. 2006).

We encountered these issues as zooarchaeologists and archaeologists collaborating on research concerning the use of animals by Archaic period (ca. 10,000–1000 BC) societies in the interior North American Eastern Woodlands. In seeking to bring multiscalar faunal data to bear on theoretical debates concerning the Archaic, we recognized significant obstacles to the access,

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preservation, and integration of data. The Eastern Archaic Faunal Working Group (EAFWG) was formed to preserve and integrate zooarchaeological databases recovered from Archaic period sites located in the interior Eastern Woodlands of North America so that research questions could be addressed more thoroughly at local, subregional, and regional scales using existing zooarchaeological databases. Results from the project, funded by the National Science Foundation (NFS; proposal number BCS-1430754), will be reported in forthcoming publications.

This article describes our project and introduces the collection of databases that we created in the Digital Archaeological Record (tDAR, www.tdar.org). We discuss lessons learned concerning preserving accessible databases, the importance of exploring database comparability when synthesizing legacy datasets, and the integration of nonstandardized datasets by mapping to tDAR ontologies. Finally, we note the importance of collaboration to the success of synthetic research like the EAFWG project.

The Eastern Archaic Faunal Working Group Project

Within the interior North American Eastern Woodlands, key archaeological projects conducted over the last half century and longer have generated significant evidence for cultural variability and change during the Archaic period. In several instances, these studies have included analyses of large faunal datasets (e.g., Ahler and Styles 1998; Brown and Vierra 1983; Hill 1975; Kuehn 2013, 2016; Lovis et al. 2006; Marquardt and Watson 2005; Neusius 1982, 1986; Parmalee 1969; Purdue 1982; Raber et al. 1998; Styles and McMillan 2009; Styles et al. 1983; Walker 1998, 2000). Nevertheless, recovered collections and faunal databases, including electronic databases, have been dispersed across institutions and projects and are not fully accessible for reanalysis. Some data have languished for years in paper records or were recorded in inadequately described coded formats, making them virtually inaccessible to anyone other than the original analyst. Summary data tables contained in publications and research reports are the primary way faunal data have been shared (see Styles 2011; Styles and McMillan 2009). As a result, attempts to synthesize databases, elucidate patterns, and discover nuanced variations within and among the databases have been constrained by the inaccessibility of critical information. Disciplinary practice has tended to relegate zooarchaeological work to ancillary status and has isolated specialists from one another so that current theoretical debates have often failed to include zooarchaeologists. Thus, while zooarchaeologists have contributed to local archaeological records and participated in interpretations at local and subregional levels (e.g., Bergman et al. 2014; Colburn 1985, 1986; Crothers 2005; Neusius 1982, 1986; Peres and Deter-Wolf 2016; Peres et al. 2012, 2016; Smith 1989, 1994, 2002; Smith and Egan 1990; Styles 1986; Styles et al. 1983; Walker 1998, 2000; Walker and Parmalee 2004), faunal findings have not been fully included in panregional theoretical debates even though relevant empirical data have been generated.

To address this problem, we formed the EAFWG. Our project was undertaken between 2014 and 2017 with funding from the NSF (BCS-1430754). The EAFWG brought together scholars from six institutions who had contributed significantly to faunal studies of interior Eastern Woodland sites.[1] Our collaboration allowed us to bring disparate datasets together, discuss archaeological and zooarchaeological theory and method, and utilize each other's familiarity with individual sites, local settings, and subregional archaeological practice when working on syntheses across the interior East. We held three-to-four-day working group meetings that facilitated training, data ingestion, and database integration, but we also liberally used e-mail, Skype, Google Docs and Drive, professional meetings, and conference calls.

The first goal of the EAFWG project was to gather and preserve dispersed faunal datasets so that they would be accessible to us and, eventually, others. There are a number of options for archaeologists wishing to preserve and use digital data (e.g., archaeologydataservice.ac.uk/, www.tdar.org/, www.daacs.org, opencontext.org/, https://zooarchnet.org, ux.opencontext.org/archaeology-site-data/, and www.sead.se/), but we found the infrastructure provided by tDAR particularly useful. As an international digital repository for all types of archaeological data, tDAR also has committed to providing tools for digital integration and spent more than a decade developing its capabilities (Kintigh et al. 2017; McManamon et al. 2017). Although it is a nonprofit repository, there are costs to uploading data into tDAR similar to the costs charged by physical curation facilities.[2] Browsing the publicly accessible resources stored in tDAR and registering as a tDAR user are free. A researcher must register to upload data or to use the built-in integration software (www.tdar.org/about/policies).

Working with tDAR had several advantages for the EAFWG. Besides data preservation and accessibility, tDAR offers database integration tools useful in synthetic analyses. We were attracted to the integration tools that use ontologies to link differently coded databases and allow comparison and synthesis without modifying the original data structure because it meant legacy databases would require minimal recoding. Both our goal of exploring database comparability using the original data rather than summary tables, and our goal of investigating temporal and spatial variation in the use of aquatic animals during the Archaic required synthesizing disparate data. The Digital Archaeological Record's integration software provided the efficiency and flexibility required to examine animal use patterns by synthesizing data at the site and on local, subregional, and regional scales. In addition, tDAR's developers used faunal data as the primary testbed for database integration because standard terminology in biological classification systems simplified linking heterogeneous datasets for many zooarchaeological variables (Spielmann and Kintigh 2011). As members of the North American Faunal Working Group, two of the authors (Neusius and Styles) had consulted with tDAR researchers and had advisory roles in the development of tDAR's initial faunal ontologies. We also benefited from an earlier tDAR-affiliated project focused on synthesis of faunal databases from the northern Southwest (Kintigh et al. 2017).

Database Preservation and the tDAR Eastern Archaic Faunal Working Group Collection

The EAFWG collection preserves an unprecedented number of faunal databases from Archaic sites. It includes 60 databases from 23 sites grouped into 21 projects, and it records detailed information on more than half a million faunal specimens (Table 1). Each project has its own resources and metadata and is linked into a

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TABLE 1. Composition of the EAFWG Collection in tDAR, Showing Datasets and NISP.

Site by Region	Site Type	Number of Databases	Total NISP	Early Archaic	Middle Archaic	Late Archaic	Other
Prairie Peninsula							
Modoc Rock Shelter	rock shelter	13	76,352	23,146	42,388	8,819	1,999
Little Freeman Cave	cave	4	11,535	2,011	5,987	460	3,077
Broglio	open air	3	2,741	0	0	85	2,656
White Bend	open air	3	7,597	0	4,896	2,229	472
Tree Row	open air	3	10,037	0	0	10,037	0
Koster	open air	9	201,351	17,432	180,457	3,462	0
Campbell Hollow	open air	2	1,819	154	1,665	0	0
Napoleon Hollow	open air	2	116,398	0	105,221	11,177	0
Great Lakes and Upper Midwest							
Bear Creek	open air	3	4,952	0	1,161	3,791	0
Weber 1	open air	2	8,120	0	6,611	1,509	0
Marquette Viaduct (20BY28)	open air	1	931	0	0	931	0
Marquette Viaduct (20BY387)	open air	1	411	0	0	411	0
Ohio River Valley							
DeWeese	shell midden	1	6,471	0	761	5,710	0
Haynes	shell midden	2	10,582	0	3,373	7,209	0
Carlston Annis	shell midden	1	10,951	0	707	10,244	0
Kramer Mound	open air	1	23,759	0	23,758	0	1
Riverton	shell midden	3	23,572	0	0	23,572	0
Midsouth							
Dust Cave	cave	1	8,407	3,387	5,020	0	0
Sachsen Cave Shelter	cave	1	737	0	0	737	0
40DV7	shell midden	1	33,261	0	33,261	0	0
40CH171	shell midden	1	918	0	918	0	0
40CH37	shell midden	1	83	0	83	0	0
40RD299	cave	1	9,781	0	9,139	0	642

subcollection representing one of the four broad subregions (Prairie Peninsula, Great Lakes and upper Midwest, Ohio River Valley, and Midsouth) in our study area (Figure 1) to facilitate analysis at the regional, subregional, watershed, and site levels.

Fully accessible to the public beginning in January 2020, the EAFWG collection (https://core.tdar.org/collection/28092/eastern-archaic-faunal-working-group) is an important resource for students and other researchers interested in animal use during the Archaic period. At present, the representation of databases by subregion is numerically uneven (Table 1), and there is a great deal of variability in the types of sites (e.g., open air, shell mound, rock shelter, cave) and in the functions of settlements and seasons of use represented. Although additional data could make the EAFWG collection more representative, the amount of information on both aquatic and nonaquatic animal use that is preserved is unprecedented. As such, it invites synthesis and consideration of macro questions beyond those addressed by our project.

Creating Accessible Database Collections

In the process of creating this resource, we learned important lessons. Three of these involved preparing databases that can be digitally preserved and reused, an important issue for zooarchaeologists (Kansa 2015).

First, preserving data for reuse and actually reusing other people's data isn't given the priority it deserves in our discipline (Sobotkova 2018). In the EAFWG project, it was not possible to locate and incorporate all the relevant faunal data from the interior East within our three-year schedule. In part, this was because our goals were novel to many of our colleagues. We think our discipline needs to more explicitly recognize data preservation as a part of scholarship and to emphasize the importance of open access to data. This ethic requires a fundamental shift in how we think about both data and scholarship.

Second, preserving databases in open-access repositories often involves much more than reentering paper records into digital files or translating data stored on outdated digital media (punch cards, tapes, floppy discs) in a variety of database management programs, some of which are no longer in use. Even if standardized formats are not required, as is the case with the tDAR repository, focusing on variable structure with retrieval and analysis in mind is important. Zooarchaeologists have encoded data in digital form for decades (e.g., Anderson and Boyle 1997; Armitage 1978; Clutton-Brock 1975; Gifford and Crader 1977; Klein and Cruz-Uribe 1984; Shaffer and Baker 1992; Styles 1978). Nevertheless, these digital files have been created primarily to meet the needs

FIGURE 1. The EAFWG project and subregion locations within the interior East (map created by Aaron Deter-Wolf).

of the original analyst and project. Zooarchaeology textbooks and identification aids seldom discuss the creation of databases, although Beisaw (2013) is a welcome exception. As a result, faunal databases have been created without much thought for retrieval by anyone but the individual analyst, and some structures do not lend themselves to synthetic analysis. For example, many zooarchaeologists record rare observations as text comments at the end of a record. Although useful to us individually, this practice means information is too idiosyncratic to be fully usable in digital data integration. Creating new variables with set values for each type of comment—such as for burning, cut marks, or animal tooth marks—even when observations are rare, is more expedient for digital retrieval. We also discovered that while some fields made sense intuitively, they were made up of multiple observations that needed to be disentangled. For example, some of us combined information about portion and completeness, recording them together in one data cell (e.g., proximal one-half). However, creating two fields or columns—one for skeletal element portion and one for skeletal element completeness—worked better when extracting data with tDAR software. Thus, digital retrieval is an important consideration when initially recording data as well as when preparing legacy databases.

A third lesson is that part of data preservation involves including information about how a database was generated and structured. Metadata is essential to making data accessible for reuse (Kansa and Kansa 2018). Some discussion of analytic decisions and procedures is standard in reports and other publications, but digital archaeological databases also need to link to thorough metadata. If we envision integrating our results across projects, regions, and time, as well as making them accessible in perpetuity to other researchers through digital repositories, recording more extensive metadata is obviously necessary.

Standards for metadata have seldom been discussed by zooarchaeologists, although there are some guidelines for archaeology in general (e.g., the Archaeology Data Service/ Digital Antiquity guides to good practice found at http://guides.archaeologydataservice.ac.uk). Coding sheets that explain the numeric system or other codes that have been used to record faunal data are only part of what is needed. Other metadata that should be stored with an electronic database include the following: basic information about the variables recorded, methods for secondary data calculations, formatting language and requirements, information on dating of remains, location of the collection described, analysts, and bibliographic sources.

Figure 2 details the metadata requested by tDAR. Note that metadata is needed for projects, resources or databases, and variables within the data tables. In tDAR, databases can be linked to projects so that separate digital resources containing faunal data, artifact and feature descriptions, photographs or digital images, excavation records, and relevant articles can be grouped together. Besides the obvious organizational advantages of

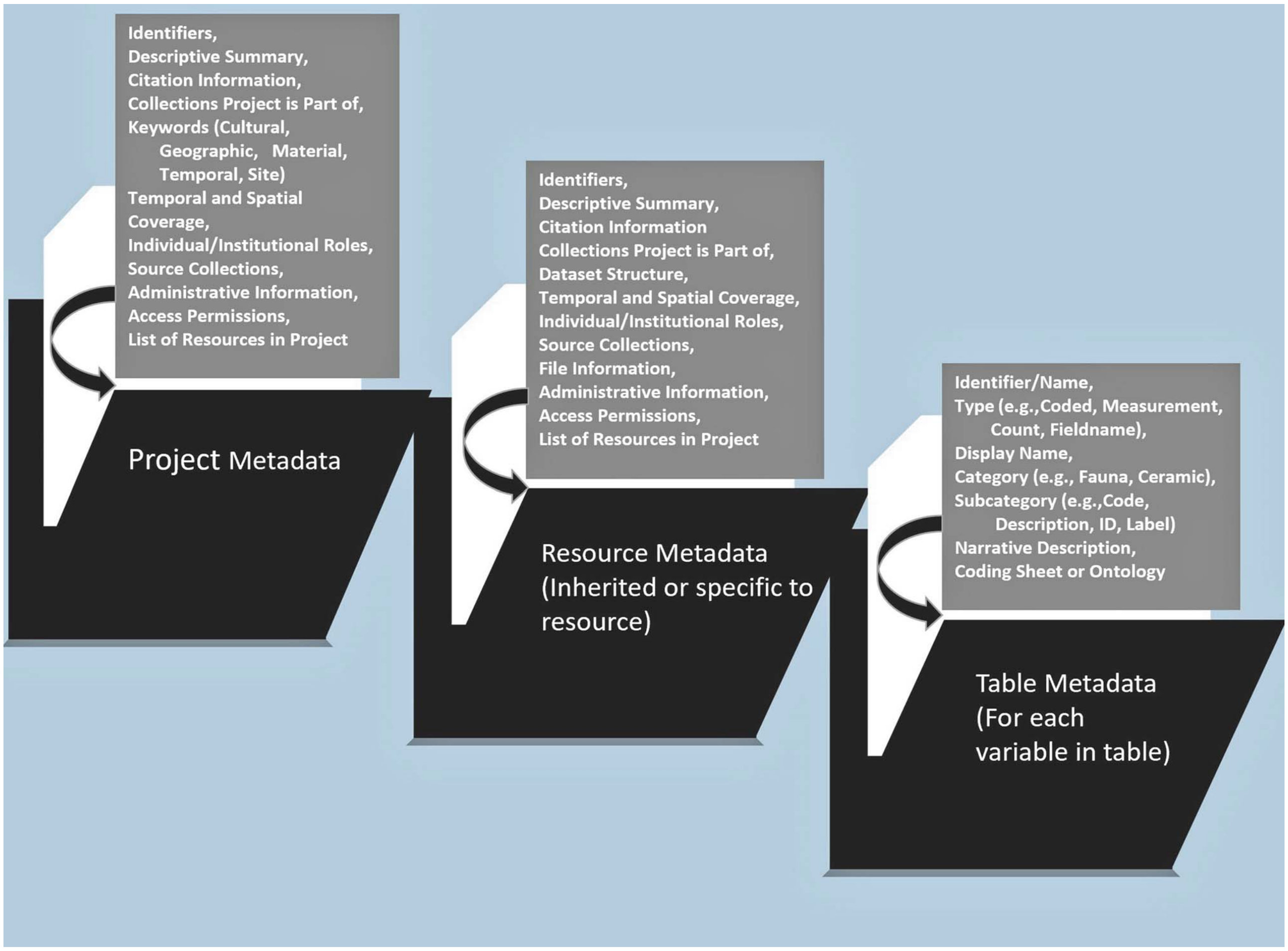

FIGURE 2. Metadata requested by tDAR for projects, resources, and table variables.

having related information linked to projects, all resources in a project may inherit project metadata so that shared information is entered once and then attached to all resources in the project (https://tdar-arch.atlassian.net/wiki/spaces/TDAR/pages/557222/Organizing+Your+Data). Given that many of our sites were stratified, we took special care to provide information on site stratigraphy, radiometric dates for strata, and information on settlement function for strata or cultural components. Although tDAR prompts users to provide these types of information when creating projects or uploading resources, we certainly underestimated the time and effort providing metadata requires. Creating metadata needs to be more integrated into the process of creating faunal databases in the first place. This is a topic to discuss with colleagues and students as we undertake new investigations so that the inclusion of metadata becomes more automatic.

The Importance of Exploring Database Comparability

Concerns about comparability should be addressed in any integrative project, but members of the EAFWG were particularly aware that many factors besides the environmental and cultural influences of interest in our research could be responsible for variability among our faunal assemblages. Thus, much of the first two years of our project was focused on assessing comparability. We took a broad view of taphonomy that is common among zooarchaeologists, not restricting it to bone deposition and diagenesis (e.g., Hesse and Wapnish 1985; Lyman 1994; O'Connor 2000), and that is consistent with archaeology's broader interest in formation processes (e.g., Binford 1981; Schiffer 1987). Many of the taphonomic processes that were likely to have affected our databases are natural processes that act on bones after burial and lead to bone alteration and decay. However, some taphonomic processes also result from past human practices, such as butchering and disposal. For example, the practice of burning bone refuse can affect faunal assemblage composition and condition. Moreover, archaeologists and zooarchaeologists also affect data in assemblages through their sampling and recovery decisions and the observations they choose to record. These kinds of processes were of particular concern in the EAFWG collection because many of our databases were legacy datasets created more than 50 years ago when zooarchaeological techniques were in their infancy.

The EAFWG built on protocols developed by colleagues who were part of the Southwestern Faunal Working Group (Bocinsky

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et al. 2019; Clark 2014a, 2014b; Kintigh et al. 2017). In conjunction with exploring issues of resource depression during the Late Prehistoric in the northern Southwest, Clark identified eight variables relating to bone condition and survivorship that could be used to assess the taphonomic history and comparability of their different databases (Clark 2014b).

The EAFWG identified a series of variables, some of which Clark had identified, that would allow us to assess evidence for element destruction resulting from both human and nonhuman processes in our Eastern Archaic faunal databases. Because our assemblages were much more diverse taxonomically, we targeted a larger series of vertebrates (deer, tree squirrels, rabbits, semi-aquatic mammals, anatids, and fish) as well as invertebrates (bivalves) for these comparability analyses. We were concerned with the evidence for element destruction as a result of either natural or human processes. Thus, we examined weathering of bone specimens from each targeted taxon, evidence of rodent and carnivore gnawing for deer remains, butchering for deer bones, and burning of bones for all our targeted taxa. We assessed fragmentation for the targeted taxa by calculating the proportion of bone or shell that was less than 50% complete. We recognized that fragmentation includes both unintentional breakage through processes such as weathering and trampling, as well as intentional breakage by humans during food processing. Following the Southwestern Faunal Working Group, we explored fragmentation of deer elements that were not likely to have been intentionally fractured by humans for marrow extraction, such as carpals and tarsals. Finally, for deer, rabbits, and turkey, we examined whether density-mediated attrition of skeletal elements could be affecting our assemblages. These analyses allowed us to highlight assemblages that were outliers among our datasets because of taphonomic factors (Styles et al. 2016, 2017). We suggest zooarchaeologists follow a protocol with six steps when working with Eastern Woodlands assemblages:

1. Calculate proportions of weathered bone and shell for targeted taxa;
2. Calculate the proportion of gnawed (all types) and butchered specimens for deer;
3. Calculate proportions of heavily burned (burned black or calcined) specimens for targeted taxa;
4. Calculate proportions of fragmented specimens (less than 50% complete) for targeted taxa;
5. Evaluate deer, rabbit, and turkey elements for potential density-mediated attrition;
6. Analyze and compare the results of Steps 1 through 5 among sites and components.

Styles and Colburn (2019) illustrate use of the taphonomic protocol to assess data comparability for different temporal components and areas of excavation at Modoc Rock Shelter in Illinois.

We found the protocols of Southwestern colleagues less helpful with respect to the effects of comparability in recovery and sampling procedures. They documented little variation in recovery methods or contextual comparability beyond interesting differences between samples from intramural and extramural contexts (Clark 2014a). Within the EAFWG collection, the recovery methods, site types, and contexts sampled varied considerably. Thus, it was imperative to consider these factors.

Comparison of datasets indicated not only a high degree of variability in recovery methods among faunal assemblages in the EAFWG collection (dry screening, wet screening, and flotation using screen meshes varying from finer than 1⁄16 in. to ½ in.) but also a significant contrast in percent identifiable, overall taxonomic composition, and the proportion of each targeted taxon among subassemblages recovered in different ways. The details of our findings will be discussed in other publications, but a sense of how the composition of macro assemblages (recovered by ¼ in. mesh or larger procedures) and micro assemblages (recovered by fine 1⁄16 in. or smaller screening or flotation) may vary can be gained from Figure 3, which shows proportions of our targeted taxa at Modoc Rock Shelter. Within zooarchaeology, it is well known that recovery methods influence taxonomic composition (e.g., Chaplin 1971:24–26, Emery 2004; Lovis et al. 2001; Payne 1972; Reitz and Wing 2008:147–151; Shaffer and Sanchez 1994; Styles 1981). However, when integrating legacy and more recent faunal databases in synthetic analyses, it is important to develop a specific understanding of how recovery has influenced results with respect to percent identifiable, overall taxonomic composition, and the proportions of key taxa. We recommend that comparisons be made between subassemblages whenever multiple recovery methods have been employed and that macro faunal assemblages and micro faunal assemblages be analyzed as separate samples at least with respect to taxonomic assessments.

It is also clear that the faunal assemblages in the EAFWG collection are not contextually comparable. First, the EAFWG collection includes assemblages drawn from open-air habitations and camps, open-air shell mounds, and cave sites and rock shelters. Second, the kinds of contexts represented no doubt vary among these types of sites, although because of small sample sizes, we often could compare only general categories, such as features versus midden. Because most of the sites do not represent year-round habitations, there is contextual variation associated with seasonality as well. Third, comparisons between Archaic subperiods—such as Early Archaic, Middle Archaic, and Late Archaic—clearly indicate that a wider range of context types are represented in our Late Archaic databases. Examination of percent identifiable, taxonomic composition, and the proportion of each targeted taxa in subassemblages drawn from varying contexts confirmed the significance of context to taxonomic composition and bone condition. Much of the variation associated with context is of interest archaeologically, and this variation is important to explore when doing synthetic analyses. As will be discussed in forthcoming publications, we urge zooarchaeologists to include contextual information in their databases either as recorded variables or in metadata to facilitate comparability studies and strengthen the validity of synthetic analyses.

Thus, exploring comparability is a way to highlight potential biases when doing synthetic studies that involve disparate databases. It is an important step in database integration and assists analysts in interpreting results. Our experience may be most relevant to those working with faunal databases, but researchers integrating other types of archaeological databases also need to add this step to ensure reliable interpretations.

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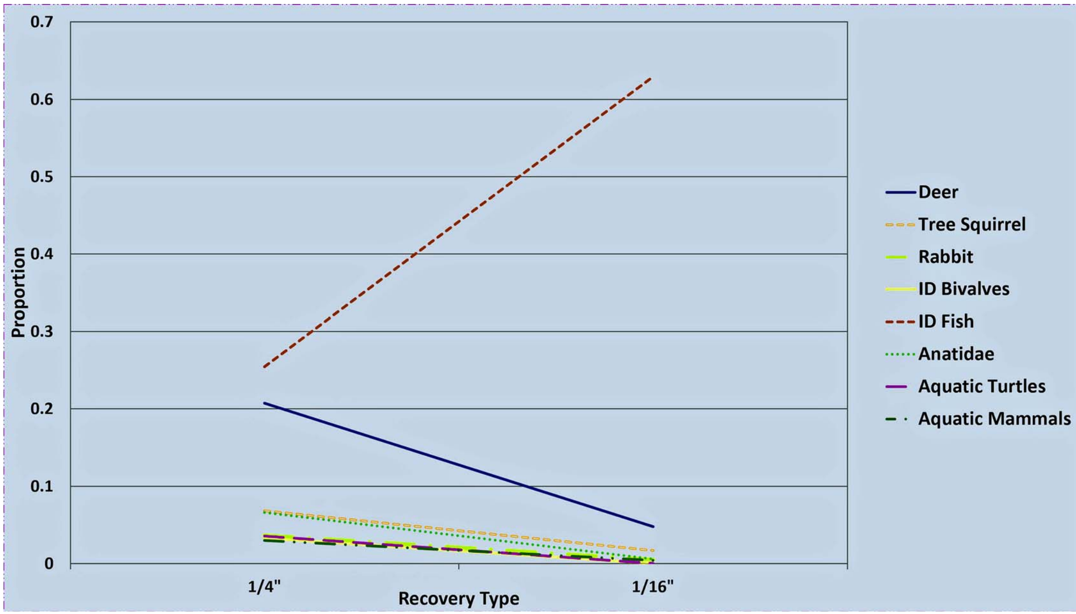

FIGURE 3. Proportions of the key taxa by recovery type for Modoc Rock Shelter (west shelter).

Database Integration and Multiscalar Analyses

Both EAFWG database comparability studies and our synthetic research about the use of aquatic animals during the Archaic were facilitated by the use of tDAR ontologies, which enabled the integration of the databases in the EAFWG collection. Ontologies are tools that structure the associations between related terms and concepts in a hierarchical order. To use the ontologies, researchers must map the variable attributes used in datasets of interest to relevant ontologies by matching codes in the original databases to specific nodes in a tDAR ontology. These assignments must be agreed on by collaborators.

An example helps clarify how mapping to ontologies works for researchers doing synthetic analyses. First, although many of our databases include a "burning" variable, individual codes for burning are not identical. Some databases had many more categories of burning than others. Some researchers left the "burning" field blank when a specimen was unburned, and they only entered a code when a bone was burned black or calcined. We discussed the variability and then agreed on how to map coded terms in our databases before mapping each to tDAR's Fauna Burning Intensity Ontology (https://core.tdar.org/ontology/3443/fauna-burning-intensity-ontology). This facilitated integration of databases with different coding structures for burning without modifying the original coding. We agreed to map blanks and "unburned" to the unburned ontology node (unless the researcher knew a blank meant "not recorded"), "burned black" to the charred node, "calcined" to the calcined node, and the relatively rare instances of "lightly burned" or "reddened" to the singed node. tDAR stored these mappings with the databases, and when we compared the proportions of heavily burned specimens for the various targeted taxa, we simply asked tDAR to integrate burning information based on the ontology nodes for the databases being compared. tDAR created downloadable output in an Excel file that combined data on burning for statistical analysis. Figure 4 shows mapping to the burning ontology of simplified codes used in two databases. It is evident from this figure that both numeric and letter codes, as well as multiple codes for the same attribute, can be accommodated when mapping coding to ontologies. Similarly, other variables could be mapped to common ontologies and utilized in data integrations to produce synthetic information.

Ontologies and "query-driven, on-the-fly data integration" (Kintigh et al. 2017:32–34) within tDAR have real advantages. Traditional synthesis of heterogeneous databases within archaeology is time-consuming, ad hoc, and typically results in a standardized dataset that is constrained by the researcher's decisions in creating the standardization. It is not feasible to undertake multiple syntheses at varying scales in this manner. The ontology approach is much more flexible, as new ontologies can be created and old ontologies can be modified for the specific integrations needed as synthetic research progresses, even while the original databases remain unmodified. In the EAFWG project, working with ontologies and completing database integrations was central to our analyses. We relied on existing faunal ontologies created as part of the development of tDAR, and we modified existing ontologies as well as created some of our own. Table 2 shows the ontologies used by the EAFWG project. All these ontologies are now available to other researchers through tDAR and are publicly accessible using the links listed so that they could be used in coding when creating new faunal databases. These resources can also be modified or superseded with new ontologies for other research purposes.

Even when ontologies are not updated, tDAR's query-driven integrations allow a researcher to assess the same question using different combinations of datasets. Each downloadable integration results in a file that can be analyzed using Excel or a statistical

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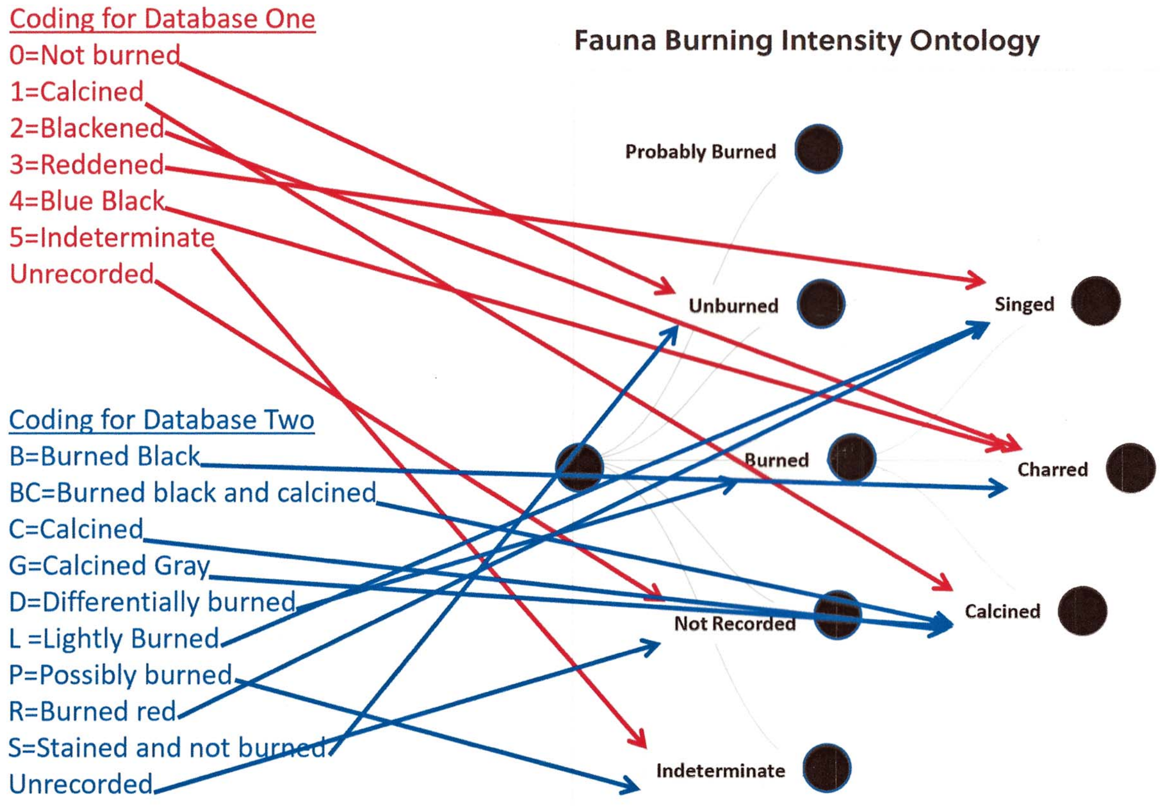

FIGURE 4. Mapping of burning variable attributes for two databases to tDAR Fauna Burning Intensity Ontology.

package. It is this feature that made it possible for the EAFWG to examine its mass of data at multiple scales. In tDAR, a researcher makes a number of choices in setting up an integration: which datasets are to be incorporated, which ontologies are to be used, and which values or attributes are to be selected from each chosen ontology. Researchers also may designate other variables for display only that may be helpful in interpretation, and integrations may be weighted by specimen count when multiple specimens have been encoded on a single line. Given the complexity of these choices, we found tDAR's ability to save a given integration especially helpful because we could efficiently tweak choices to improve clarity or to change the scale of analysis.

The steps in creating an integration are illustrated with a simple query shown in Figure 5. Suppose we want to know what proportion of the mammal specimens are from white-tailed deer in the Koster site faunal assemblage and whether this proportion changes over time. We can explore this through the tDAR integration described by this flow chart. Note that there are four databases that must be incorporated, each of which has a slightly different structure because several faunal analysts were involved. Once these databases are loaded into the integration query, we select two of the ontologies to which each of these databases have been mapped as integration ontologies. The first of these, the Eastern Archaic Resource Type Ontology (https://core.tdar.org/ontology/4634/eastern-archaic-resource-type-ontology), sorts specimens into types based on animal size, general habitat preferences, and taxonomic identification. The second ontology is the EAFWG Chronology Ontology (https://core.tdar.org/ontology/4857/eafwg-chronology-ontology) that assigns specimens to periods and subperiods. Within these ontologies, we need only include the nodes in which we are interested. For the first, we select only two nodes. These nodes are labeled "deer," which is its own category because of its likely importance to Archaic hunter-gatherers, and "mammals," into which all other unchecked, indeterminate, or identified mammalian categories will sort because of the hierarchical structure of the ontology. For the second ontology, we select three nodes: Early Archaic, Middle Archaic, and Late Archaic. Once again, because of the hierarchical nature of the ontology, specimens actually assigned to finer periods (e.g., Early Archaic II, Middle Archaic I, etc.) will simply sort into these general Archaic subperiods. Finally, we must tell tDAR to weigh by the count of specimens (NISP) rather than by database record since each record may describe more than one specimen, and we include the horizon (cultural layer) variable for additional perspective on variation over time.

As shown in Figure 6, the first integration indicates that, proportionately, there are not a lot of deer specimens among the mammal remains in the Koster site assemblages, and the lowest proportion is in the Early Archaic assemblage. As is common with research findings, these data lead us to many other questions, and there are reasons to reframe the integration. Most notably included in the "other mammal" category are both identified mammals that are not assigned to white-tailed deer

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TABLE 2. tDAR Ontologies Mapped to EAFWG Databases.

Ontology Name	Observations Mapped
Fauna Taxon—Eastern U.S. https://core.tdar.org/ontology/394377/fauna-taxon-ontology-eastern-us	the taxonomic identifications, created by the EAFWG project for the eastern United States (follows the Integrated Taxonomic Information System)
Eastern Archaic Resource Type https://core.tdar.org/ontology/4634/eastern-archaic-resource-type-ontology	the broad resource categories (e.g., large mammal, aquatic turtle, fish). Created for the EAFWG project
Fauna Element https://core.tdar.org/ontology/6029/fauna-element-ontology	the skeletal element. Greatly expanded by the EAFWG to accommodate the diverse fauna of the eastern United States
Fauna Side https://core.tdar.org/ontology/3034/fauna-side-ontology	the side of the element
Fauna Confidence in Identification https://core.tdar.org/ontology/377786/fauna-confidence-in-identification-ontology	the certainty of identification (e.g., c.f.)
Fauna Proximal-Distal Portion https://core.tdar.org/ontology/3035/fauna-proximal-distalportion-ontology	the detail on the portion of the element that a fragment represents
Fauna Anterior-Posterior https://core.tdar.org/ontology/3037/fauna-anterior-posterior-ontology	the detail on the portion of the element that a fragment represents
Fauna Dorsal-Ventral Portion https://core.tdar.org/ontology/3036/fauna-dorsal-ventral-ontology	the detail on the portion of the element that a fragment represents
Fauna Completeness https://core.tdar.org/ontology/376370/fauna-completeness-ontology	the proportion of the element represented
Fauna Age https://core.tdar.org/ontology/3030/fauna-age-ontology	the age of the animal represented
Fauna Sex https://core.tdar.org/ontology/3026/fauna-sex-ontology	the sex of the animal represented
Fauna Origin of Fragmentation https://core.tdar.org/ontology/3031/fauna-origin-of-fragmentation-ontology	whether any breakage is ancient or recent
Fauna Butchering https://core.tdar.org/ontology/3989/fauna-butchering-ontology	the presence or absence and type of butchering mark
Fauna Burning Intensity https://core.tdar.org/ontology/3443/fauna-burning-intensity-ontology	the presence or absence and degree of burning (e.g., calcined, charred)
Fauna Worked-Bone https://core.tdar.org/ontology/377789/fauna-worked-bone-ontology	whether humans modified the specimen
Fauna Digestion https://core.tdar.org/ontology/3991/fauna-digestion-ontology	the likelihood of whether the specimen was digested
Fauna Erosion https://core.tdar.org/ontology/3992/fauna-erosion-ontology	whether the edges of a specimen show rounding or erosion
Fauna Gnawing https://core.tdar.org/ontology/3033/fauna-gnawing-ontology	the presence or absence and origin of gnawing or chewing marks (e.g., rodent, carnivore)
Fauna Condition https://core.tdar.org/ontology/3990/fauna-condition-ontology	the physical condition of the specimen (e.g., good, flaking, porous)
Fauna Weathering https://core.tdar.org/ontology/3032/fauna-weathering-ontology	the presence or absence of weathering damage
Eastern Archaic Site Type https://core.tdar.org/ontology/400778/eastern-archaic-site-type	the type of site represented (e.g., rock shelter, cave, or open air). EAFWG created
Eastern Archaic Context Type https://core.tdar.org/ontology/400790/eastern-archaic-context-types	the context within the site (e.g., midden, feature, and type of feature). EAFWG created
Eastern Archaic Excavation Level/Unit Type https://core.tdar.org/ontology/402209/eastern-archaic-excavation-levelunit-type	how the archaeological unit was defined (e.g., natural level, arbitrary level). EAFWG created
EAFWG Recovery Method https://core.tdar.org/ontology/400921/eafwg-recovery-method-ontology	the recovery method and mesh size if screened (e.g., screen-¼ in., flotation-1⁄16 in.). EAFWG created
EAFWG Chronology https://core.tdar.org/ontology/4857/eafwg-chronology-ontology	the periods within the Archaic. EAFWG created

and indeterminate remains assigned only to a size class such as small, medium, or large mammal. A simple modification would be to select the node for indeterminate large mammal in the research type ontology as we did to get the results shown for Integration Two in Figure 6. Since we know from reviewing the taxonomic breakdown for the Koster assemblages that the vast majority of the specimens assigned to the indeterminate large mammal category are likely white-tailed deer remains that are

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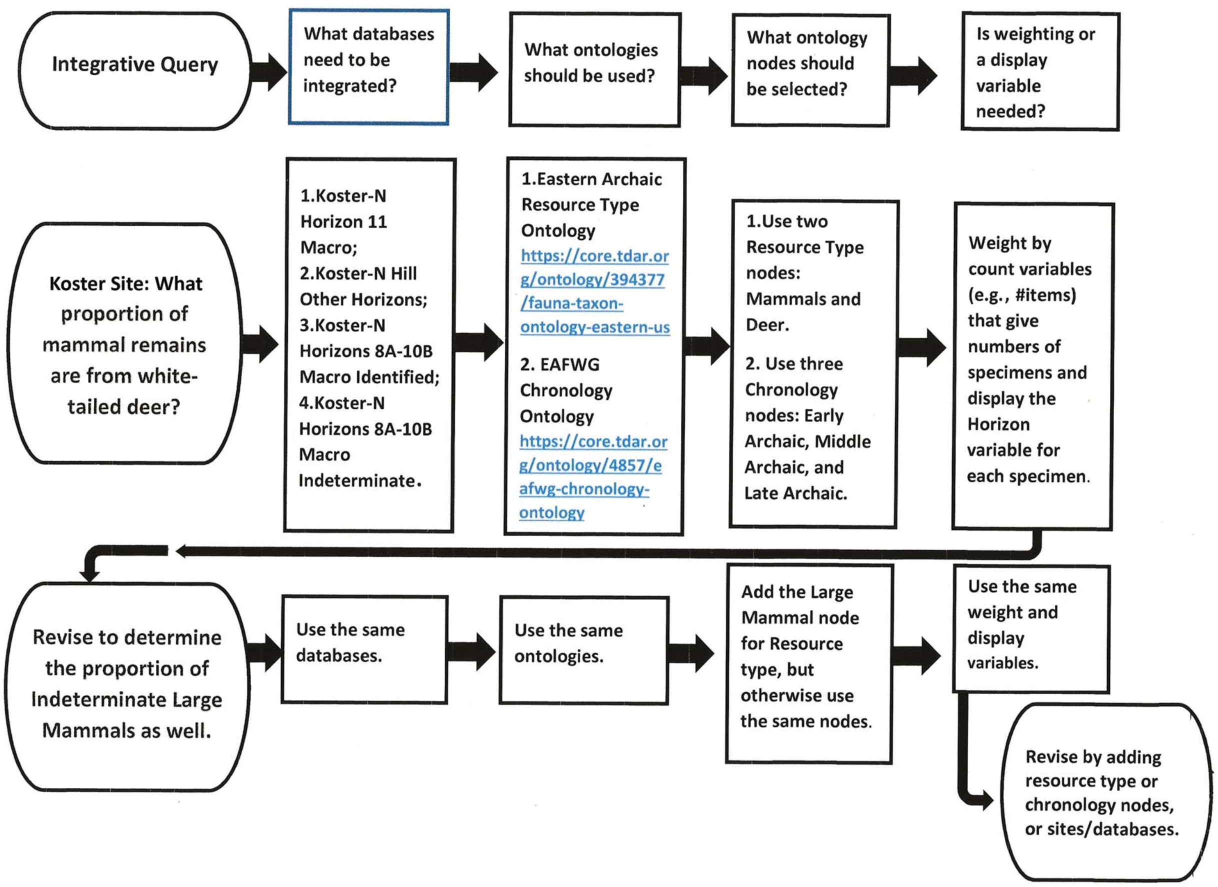

FIGURE 5. The integration process for the query "What proportion of the mammal specimens are white-tailed deer?"

too fragmentary to identify further, Integration Two may actually give us a better sense of the relative importance of deer in the Koster assemblages. It is noteworthy that the Early Archaic assemblage still has the lowest proportion of deer because other findings from Early Archaic faunal assemblages in this region tend to show more diverse use of mammals than later ones (Neusius 1982, 1986; Styles and McMillan 2009). We may want to revise this integration further by adding additional integration variables, other resource type or chronology nodes, or databases from other sites in the EAFWG collection to explore these trends more thoroughly.

This simple example hints at the iterative, exploratory, often multiscalar nature of archaeological analysis, which no doubt is familiar to most researchers. Integration tools, which allow us to query multiple nonstandard datasets repeatedly, are obviously useful. However, there is a significant learning curve for mapping to ontologies and constructing useful integrations in tDAR. More time and attention to this process was required in the EAFWG project than we first envisioned, and achieving group agreement on the structure of ontologies, the mapping of variable attributes, and designing integrations was important but time-consuming. Nonetheless, these tools were tremendously useful, and our solution would be to include more collaborative time to work through this process in project budgets.

Collaboration and the Future of Archaeology

Although synthesis has been done by individual archaeologists, collaborative synthetic research, such as that of the EAFWG, takes advantage of the diverse skills and perspectives of multiple researchers working on the same problem. We agree with Altschul and colleagues (2017, 2018) that a collaborative approach facilitates synthetic, macro-level analysis.

Our experiences convince us of two key advantages to collaborating in working groups. First, having a team of individuals with firsthand knowledge of how data were created as well as direct knowledge of the contexts from which data were drawn was invaluable, and we daresay necessary, to the EAFWG project. This knowledge enriched the investigation of our synthetic research problem. Moreover, it was helpful in creating databases within the EAFWG collection that can be reused by others. Second, the synergistic advantages of collaborating with researchers who have different skills and experiences within archaeology go far beyond a particular project. Our shared enthusiasm for advancing understanding of the Eastern Archaic through faunal analysis certainly contributed to the synergy. Beyond this, we found that we had much in common but also much to learn from each other. We shared other research

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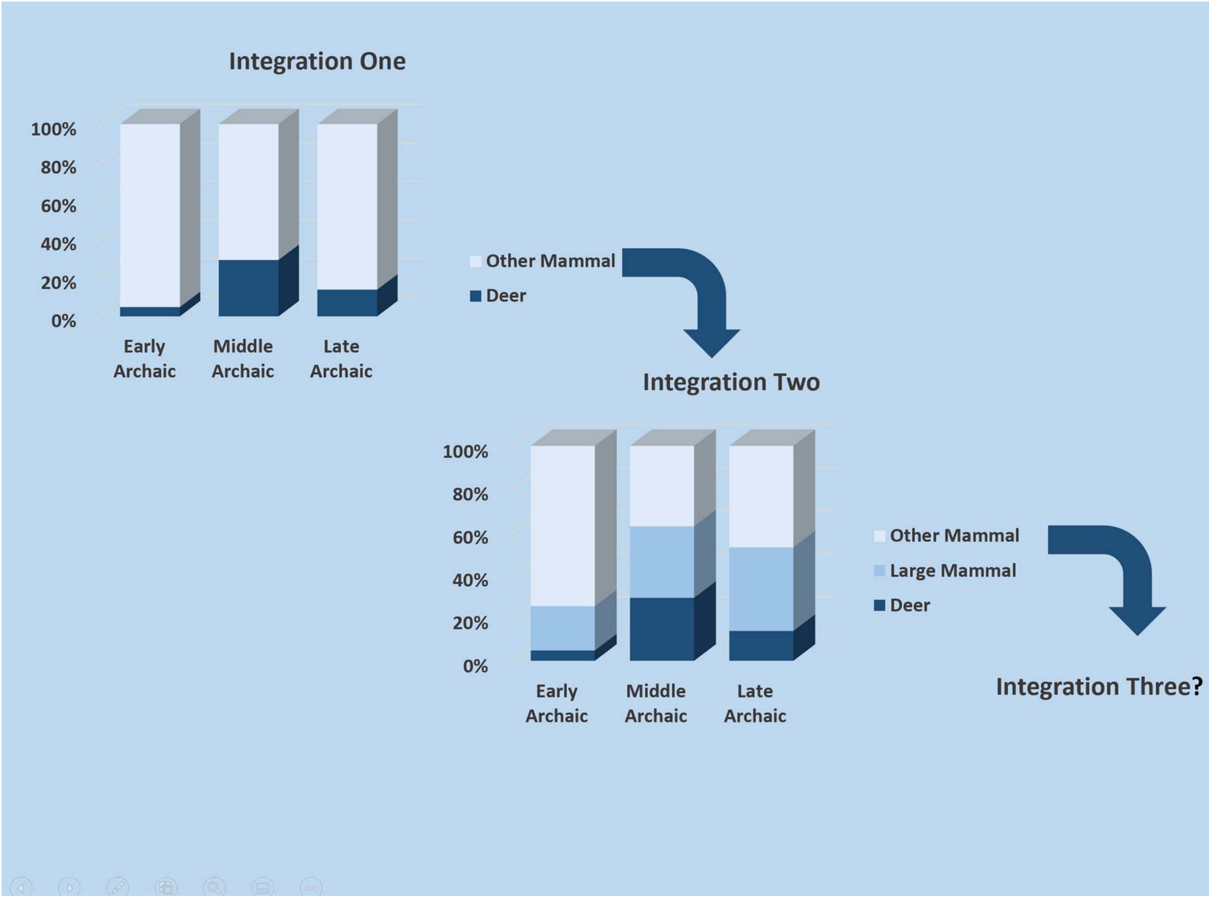

FIGURE 6. Iterative results for the query "What proportion of the mammal specimens are white-tailed deer?"

problems of joint interest and plan to collaborate on other topics in the future.

We strongly support the continued development of synthetic projects within archaeology. In contrast to the traditions within archaeology, a more collaborative approach involving data sharing across research groups and institutions, as well as among disciplines, is needed. The data we generate should no longer be viewed as ours individually or institutionally. We also need to find ways to promote time for collaboration. Researchers must commit to collaboration across traditional scholarly boundaries, and institutions and professional organizations also need to recognize its importance. The significance of collaboration should be recognized in institutional evaluations for tenure and promotion. Structures, such as those proposed by Altschul and colleagues (2017, 2018), and other creative mechanisms that promote collaboration need to be further developed within our discipline.

Conclusion

The EAFWG project was an NSF-funded project that focused on preserving and integrating Archaic period zooarchaeological databases in tDAR. One tangible product of this project is the creation of the EAFWG collection of databases in tDAR. This collection, which will be fully accessible to the public at the beginning of 2020, provides unprecedented information about how Archaic people in the interior eastern United States used animals. A second product of this project is a regionally useful protocol for exploring faunal database comparability with respect to taphonomic processes, as well as insights concerning how recovery methods and contextual variables may affect database comparability (Styles and Colburn 2019; Styles et al. 2017). A third product is our research findings on variation in the use of aquatic animals during the Eastern Archaic, which will be discussed in forthcoming publications (Peres et al. 2017; Smith et al. 2017).

The EAFWG project also taught us about the trials of database preservation, the importance of database comparability, the efficiency of ontologies in database integration and synthetic research, and the importance of collaborative working groups in advancing archaeological research. The specific lessons we have learned from our experience can be summarized as follows:

1. Archives such as tDAR can preserve our data and make it accessible, but successful preservation and accessibility require preparation of digital databases structured with digital retrieval in mind.
2. Providing rich metadata is essential for creating resources that can be reliably reused by other researchers.

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3. Exploring the comparability of disparately structured databases before synthetic analyses is a critical step, especially for faunal data.
4. tDAR ontologies and integration tools are well suited for query-driven synthetic research, but collaborating researchers must agree on ontology structure and use as well as how to map the variable attributes.
5. Archaeology will benefit from exploring creative mechanisms that foster collaboration among working groups of scholars.

These lessons have broad applicability for contemporary archaeology and zooarchaeology students and scholars alike. They contribute to what needs to be a wide-ranging discussion within the discipline of archaeology about data sharing, database reuse and integration, and the importance of synthetic research and greater collaboration as our discipline continues to develop.

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Data Availability Statement

Charts and tables in this article use data from the EAFWG collection of faunal databases that is stored in tDAR. These databases will be made fully available to the public on January 1, 2020. In the meantime, permission for access may be sought from each database creator as indicated in tDAR.

NOTES

1. The authors were EAFWG members, and Scott Rivas was the graduate assistant for this project. Katherine Spielmann, Keith Kintigh, and Tiffany Clark of Arizona State University and Adam Brin of Digital Antiquity served as consultants to the EAFWG project.
2. Fees are charged for digital curation when files are uploaded at the rate of 10 dollars per file (</= 10 MB) for the first 99 files, and five dollars per file for 100 or more files. tDAR also offers services, including file checking, metadata drafting, quality control assessing, consulting, and programming, for additional charges.

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