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Testing osteometric and morphological methods for turkey species determination in Maya faunal assemblages

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ABSTRACT

Identification of turkey (*Meleagris* spp.) remains in Maya archaeological deposits is problematic because the two species that co-existed during ancient Maya occupations are extremely difficult to separate osteologically. One species, *M. gallopavo*, was introduced from northern Mexico possibly multiple times. The other species, *M. ocellata*, is indigenous and was possibly husbanded though never domesticated. The two species are morphologically very similar, their size distributions overlap, and their responses to environmental conditions and human manipulation may have led to non-species delimited skeletal changes. Limited information has, so far, been available to distinguish the two species, and most analysts prefer to identify this group to the genus level only. However, the turkey is the only domesticated fowl of the New World, and is one of only two domesticated vertebrates in North/Central America. It was a source of food, medicines, feathers, and artifacts, an emblem of status and an actor in pivotal ceremonial events. Thus distinguishing among the two species, and recognizing markers of husbandry and domestication, are essential to our understanding of Maya animal use. In this study we review the key morphological and metric diagnostic features of the species and the methods that we have used to develop and test effective morphological and metric characters for distinguishing the two Maya turkeys. This study is based on our ongoing analysis of 55 modern individuals and over 2000 archaeological specimens from Preclassic through Colonial Maya assemblages.

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1. Introduction

The basis of all zooarchaeological analysis is the biologically-linked phenotypic variation between different animal species. But recent studies have revealed that the quality of our zooarchaeological assessments can be compromised by insufficient attention to the characters used in our comparative evaluation. Further, the quality of regional studies that draw on published datasets can suffer as a result of the use of ineffective characters or metrics in basic identification (see, especially, Atici et al., 2012; Driver, 2011; Wolverton, 2013). Archaeological remains are compared to the skeletal elements of modern exemplars of various species and are identified by similarity to these comparative specimens. Variation among individuals of a species is recognized and used in zooarchaeological research (Bochenski, 2008). However, despite our recognition of these individual variations and particularly variations between individuals from different regions or with different life-histories, our comparative collections typically include only a few individuals of most species. This is entirely reasonable given the financial and space costs of collection and curation and is balanced by our need to also include at least one example of each possible species within the geographic and temporal range of our lab's specialization. Many species can be identified by diagnostic features that are reported by taxonomist specialists in the biological literature and are known not to repeat among closely related species (either homologous or taxonomically related). Unfortunately, many other species cannot be as easily separated zooarchaeologically because osteological characters are more conservative than external features like hide or feather coloration which are often the basis for taxonomic differentiations by neontologists. Furthermore, the potential for interspecies hybridization, an occurrence observed among many extant vertebrates, is rarely recognized in the archaeological and fossil record (Bochenski and Tomek, 2000). In these cases, it is vital that analysts take particular care to compare archaeological specimens with many modern exemplars, or to diagnostic metric and morphological trait lists. These trait lists, however, are hard to come by and generally are not the subject of biological studies since neontologists have a wider range of characters to use when species are skeletally similar.

In Maya zooarchaeology, several species groups are especially problematic for identification because they are osteologically very similar and simultaneously very different in cultural or ecological terms. Thus our research is often stymied by an inability to distinguish among

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these problematic species groups. Primary among these in Maya research are the two species of turkey (*Meleagris*) found in the region, one indigenous only to the Maya area (*M. ocellata* or Ocellated Turkey) and one introduced by trade from its natural range in central/northern Mexico (*M. gallopavo gallopavo* or Southern Mexican Wild Turkey). Several ornithological studies have shown that the two birds are virtually identical osteologically, and unfortunately also very similar metrically (Bochenski and Campbell, 2005, 2006; Steadman, 1980). Bochenski and Campbell's (2006) morphological analysis finds that while 25 of the 55 traits they used are characteristic of *M. ocellata*, only five were exclusive of *M. gallopavo*. Sample size may also hinder morphological comparisons because the reference collection may not cover the entire range of intraspecific morphological variation. Steadman (1980:132) noted that his sample of 16 *M. gallopavo* and seven *M. ocellata* provided more effective characters for separation than did smaller samples analyzed by earlier researchers (for example, Brodkorb, 1964a, 1964b; Howard, 1927; Rea, 1980; Shufeldt, 1914), and Bochenski and Campbell's (2006) sample of 20 Ocellated Turkeys and 51 Wild Turkeys is by far the largest so far used.

Despite their osteological similarity, the two birds could not be more different in terms of their habits and habitats, and the cultural implications of their recovery in archaeological deposits. The Ocellated Turkey is a wild game bird native to the Maya region that is found primarily in forested and edge-zone habitats, and occasionally in agricultural fields. *M. gallopavo*, on the other hand, is a non-local domestic bird introduced to the Maya region during prehistoric times (Valadez Azúa, 2003; Thornton et al., 2012). As such it is assumed to have been a household commensal, feeding on human-provided maize and insect pests around the residential zone (Hale and Schein, 1962; Schorger, 1966; Steadman et al., 1979; Williams et al., 2010). Regardless of species, wherever the turkey is found, past or present, it is associated with ceremony, elite status-enhancing activities, and politically important settlements. It is common in both preHispanic iconography and codices, and in ethnohistoric documents from early in the contact period. Both birds were clearly valued for their meat, plumage, and symbolic meanings (Camacho-Escobar et al., 2011; Corona, 2008, 2013; Kockelman, 2011; Nimis, 1982; Pohl, 1983; Pohl and Feldman, 1982; Sharpe, 2014; Thornton et al., 2012; Tozzer, 1941; Tozzer and Allen, 1910). Their zooarchaeological separation therefore is imperative in the Maya area in order to understand the process of husbandry and domestication and whether it was a single or duplicated process, the diffusion of the bird as well as the "idea" of animal husbandry, and the stages of incorporation of wild and domesticated birds into the social system.

Many new methods have been developed for distinguishing problematic species, chief among them aDNA, protein peptides, isotopic variations based on feeding differences, and detailed three-dimensional modeling of osteometric trait complexes (for example, Morey, 2014; Owen et al., 2014). Unfortunately, most zooarchaeologists are not able to fund such methods, and in many cases where meleagrid specimens are rare, do not wish to conduct destructive analysis on these valuable specimens. Thus an important goal for our interdisciplinary study of Maya turkeys has been to create a standardized, clear, and replicable set of diagnostic and metric traits that can be used for discriminating osteological specimens of these species across the Maya area. This paper describes the methods we are using to evaluate our metric and morphological diagnostic trait list to ensure that the methods we recommend are low-cost, accurate, and effective.

2. Methods

To compile a dataset of known metric and morphological parameters for identification of meleagrid species and sex, we reviewed measurements and descriptors from the literature (Bochenski and Campbell, 2006; Olsen, 1968; Steadman, 1980; von den Driesch, 1976). We first tested these parameters on a small sample of modern galliform individuals from the Environmental Archaeology and Ornithology collections of the Florida Museum of Natural History (FLMNH) (Table 1). Closely related galliform birds belonging to the family Cracidae (*Crax rubra* – Great Curassow, and *Penelope purpurascens* – Crested Guan) were also included in our morphological and metric analyses due to their potential confusion with turkeys in Maya zooarchaeological assemblages. Lead authors Emery and Thornton assessed the utility of the previously reported morphological characters distinguishing Ocellated and Wild Turkeys by visual comparison and semi-blind testing of modern skeletal specimens. We rejected any morphological characters that were either not viable from the outset (unclear or indistinguishable characters) or were so variable among the specimens as to have resulted from individual variation rather than taxonomic or sex-derived traits. The final morphological trait list was then described and illustrated by drawings and photographs to ensure accurate interpretation of the written character trait descriptions. Skeletal measurements described for generalized turkeys (Olsen, 1968) and specific to Ocellated or Wild Turkeys (Bochenski and Campbell, 2006; Steadman, 1980) were combined to produce a comprehensive list of osteometrics. Illustrated guides were also produced to clarify the osteometric procedures.

All team members were instructed on recognizing the morphological characters and collecting osteometric data using standardized techniques. We defined single analysts or analyst pairs for each of the two types of studies to mitigate multiple analyst bias. Morphological analysis was done by teams of two or more researchers led by either Erin Thornton or Kitty Emery, with Thornton making all final determinations. Osteometric data was collected by Lisa Duffy and Petra Cunningham-Smith working as a team with Duffy always measuring and Cunningham-Smith always doing data entry. This work was supervised by Emery. Measurements were made using metric digital calipers equipped with an RS-232 interface to enter data directly into Microsoft Excel spreadsheet forms.

Our protocol for morphological assessment of the meleagrids included a character state scoring system wherein two character states were defined for each trait on the element, one representing *M. gallopavo*, and the other *M. ocellata*. We also applied a "confidence value" when scoring for each character. This value ranged from 1 (highest) to 4 (lowest), and is useful for understanding the effectiveness of the character list, and for weighting the results of our archaeological assessment. For example, an identification of several characters as *M. gallopavo* but with poor confidence rankings may be trumped by a single score as *M. ocellata* with a high confidence rank. After assessing each trait individually, the analyst then assigned a species identification to the element as a whole using any combination of the traits assessed, also ranking this identification by confidence. This overall assessment might or might not agree with the preponderance of the scored traits. This method allowed an assessment of the effectiveness of each trait in identifying the specimens as well as allowing a comparison between an identification based on single traits and an identification based on whole-element analysis. Traits were always accompanied by character descriptions to ensure we were describing the correct variation in that trait. All morphological assessments of modern birds were done with reference to the compiled illustrations and photographs, while archaeological specimens were identified in comparison to both the reference manual and modern specimens.

To test the extent to which our metric character set replicated known taxonomy and sex, we first applied it to the large pool of modern birds curated at FLMNH (Environmental Archaeology and Ornithology collections) and then to comparative specimens stored in the Universidad Autónoma de Yucatán (UADY) Zooarchaeology lab in Mérida, Mexico (Table 1). A few representative modern specimens were used to test the accuracy of the morphological characters, but to further test the value of these characters, we also conducted a blind test of our morphological trait list by providing 10 volunteers with trays of unlabeled modern bones representing both *M. ocellata* and *M. gallopavo*. The bones included at least three specimens per element

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Table 1
FLMNH specimens used in the morphometric assessments. OR designates holdings of the FLMNH-Ornithology, EA of the FLMNH-Environmental Archaeology.

Catalog number	Stats code	Taxa	Sex	Age	Where collected	Captive/wild	Specimen type
FLMNH-EA-11057[1,3,4]	40	*Crax rubra*	F	Adult	Alta Verapaz, Guatemala	Wild	Complete skeleton
FLMNH-OR-44827[1,3]	42	*Crax rubra*	F	Adult	Petén, Guatemala	Wild	Incomplete skeleton
FLMNH-OR-44831[3]	44	*Crax rubra*	F	Adult	Petén, Guatemala	Wild	Complete skeleton
FLMNH-OR-44853[3]	48	*Crax rubra*	F	Adult	Petén, Guatemala	Wild	Complete skeleton
FLMNH-OR-44860[3]	49	*Crax rubra*	F	Adult	Petén, Guatemala	Wild	Complete skeleton
FLMNH-EA-11049[1,3]	39	*Crax rubra*	M	Adult	Alta Verapaz, Guatemala	Wild	Complete skeleton
FLMNH-OR-44826[1,3]	41	*Crax rubra*	M	Adult	Petén, Guatemala	Wild	Complete skeleton
FLMNH-OR-44829[1,3]	43	*Crax rubra*	M	Adult	Petén, Guatemala	Wild	Complete skeleton
FLMNH-OR-44834[3]	45	*Crax rubra*	M	Adult	Petén, Guatemala	Wild	Complete skeleton
FLMNH-OR-44837[3]	46	*Crax rubra*	M	Adult	Petén, Guatemala	Wild	Complete skeleton
FLMNH-OR-44838[3]	47	*Crax rubra*	M	Adult	Petén, Guatemala	Wild	Complete skeleton
FLMNH-OR-11674/PB21450[1,2,3]	11	*Meleagris gallopavo osceola*	M	Adult	Glades County, FL	?	Complete skeleton
FLMNH-EA-1810b[3]	2	*Meleagris gallopavo*	F	Adult	Glades County, FL	Wild	Incomplete skeleton
FLMNH-EA-1810c[3,4]	3	*Meleagris gallopavo*	U	Adult	Glades County, FL	Wild	Incomplete skeleton
FLMNH-OR-12812/PB22477[1,3,4]	12	*Meleagris gallopavo osceola*	M	Adult	Highlands County, FL	?	Incomplete skeleton
FLMNH-EA-4546[3]	7	*Meleagris gallopavo*	F	Adult	Brevard County, FL	?	Incomplete skeleton
FLMNH-EA-5710[3,4]	8	*Meleagris gallopavo*	F	Older subadult (less than a year old)	Clay County, FL	Wild	Complete skeleton
FLMNH-EA-5711[3]	9	*Meleagris gallopavo*	F	Adult	Clay County, FL	Wild	Complete skeleton
FLMNH-EA-1811c	–	*Meleagris gallopavo*	F	Sub/juvenile (3 months)	Glades County, FL	Wild	Incomplete skeleton
FLMNH-EA-8896[3]	10	*Meleagris gallopavo*	F	Adult	Petén, Guatemala	Domestic	Incomplete skeleton
FLMNH-EA-1811b	–	*Meleagris gallopavo*	F	Young subadult (3 months)	Glades County, FL	Wild	Complete skeleton
FLMNH-EA-1811d	–	*Meleagris gallopavo*	F	Young subadult (3 months)	Glades County, FL	Wild	Complete skeleton
FLMNH-EA-1487[1,3,4]	1	*Meleagris gallopavo*	M	Adult	Glades County, FL	?	Complete skeleton
FLMNH-EA-1811a[1,2,3,4]	4	*Meleagris gallopavo*	F	Adult	Glades County, FL	Wild	Complete skeleton
FLMNH-EA-3252[3]	5	*Meleagris gallopavo*	M	Adult	Levy County, FL	?	Incomplete skeleton
UADY-124[3]	13	*Meleagris gallopavo*	M	Adult	Yucatan, Mexico	Domestic	Incomplete skeleton
UADY-220[2,3]	–	*Meleagris gallopavo*	U	Adult	Yucatan, Mexico	Domestic	Complete skeleton
FLMNH-EA-4063[3]	6	*Meleagris gallopavo*	M	Adult	Union County, FL	?Wild	Complete skeleton
FLMNH-OR-41665[3]	18	*Meleagris ocellata*	F	Adult	Petén, Guatemala	Wild	Tarsometatarsus only
FLMNH-EA-11048[1,3]	14	*Meleagris ocellata*	F	Adult	Alta Verapaz, Guatemala	Wild	Incomplete skeleton
FLMNH-OR-24104/PB30884/H425[1,2,3,4]	15	*Meleagris ocellata*	F	Adult	Roer Bird Farm, Phoenix, AZ	Captive	Complete skeleton
FLMNH-OR-38861/PB23543[1,3]	17	*Meleagris ocellata*	U	Adult	Busch Gardens, Tampa, FL	Captive	Complete skeleton
UADY-141[3]	37	*Meleagris ocellata*	F	Adult	Yucatan, Mexico	Captive	Incomplete skeleton
UADY-246[3]	38	*Meleagris ocellata*	F	Adult	Yucatan, Mexico	Wild	Incomplete skeleton
UADY-5[2,3]	36	*Meleagris ocellata*	F	Subadult	Yucatan, Mexico	Wild	Incomplete skeleton
FLMNH-OR-41676[3]	24	*Meleagris ocellata*	F	Adult	Petén, Guatemala	Wild	Tarsometatarsus only
FLMNH-OR-41688[3]	26	*Meleagris ocellata*	F	Adult	Petén, Guatemala	Wild	Tarsometatarsus

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Table 1 (*continued*)

Catalog number	Stats code	Taxa	Sex	Age	Where collected	Captive/wild	Specimen type
							only
FLMNH-OR-41696[3]	27	*Meleagris ocellata*	F	Adult	Petén, Guatemala	Wild	Tarsometatarsus only
FLMNH-OR-41702[3]	28	*Meleagris ocellata*	F	Adult	Petén, Guatemala	Wild	Tarsometatarsus only
FLMNH-OR-41713[3]	30	*Meleagris ocellata*	F	Adult	Petén, Guatemala	Wild	Tarsometatarsus only
FLMNH-OR-41719[3]	32	*Meleagris ocellata*	F	Adult	Petén, Guatemala	Wild	Tarsometatarsus only
FLMNH-OR-24105/PB23542[1,2,3,4]	16	*Meleagris ocellata*	M	Adult	Busch Gardens, Tampa, FL	Captive	Complete skeleton
FLMNH-OR-41667[3]	19	*Meleagris ocellata*	M	Adult	Petén, Guatemala	Wild	Tarsometatarsus only
FLMNH-OR-41668[3]	20	*Meleagris ocellata*	M	Adult	Petén, Guatemala	Wild	Tarsometatarsus only
FLMNH-OR-41670[3]	21	*Meleagris ocellata*	M	Adult	Petén, Guatemala	Wild	Tarsometatarsus only
FLMNH-OR-41673[3]	22	*Meleagris ocellata*	M	Adult	Petén, Guatemala	Wild	Tarsometatarsus only
FLMNH-OR-41674[3]	23	*Meleagris ocellata*	M	Adult	Petén, Guatemala	Wild	Tarsometatarsus only
FLMNH-OR-41686[3]	25	*Meleagris ocellata*	M	Adult	Petén, Guatemala	Wild	Tarsometatarsus only
FLMNH-OR-41712[3]	29	*Meleagris ocellata*	M	Adult	Petén, Guatemala	Wild	Tarsometatarsus only
FLMNH-OR-41717[3]	31	*Meleagris ocellata*	M	Adult	Petén, Guatemala	Wild	Tarsometatarsus only
FLMNH-OR-44891[1,3,4]	35	*Meleagris ocellata*	M	Adult	Petén, Guatemala	Wild	Complete skeleton
FLMNH-OR-44889[1,3,4]	34	*Meleagris ocellata*	M	Adult	Petén, Guatemala	Wild	Complete skeleton
FLMNH-OR-44857[1,3]	33	*Meleagris ocellata*	M	Adult	Petén, Guatemala	Wild	Complete skeleton
FLMNH-EA-11044[3]	50	*Penelope purpurascens*	?	Adult	Alta Verapaz, Guatemala	Wild	Complete skeleton
FLMNH-EA-11047[3]	51	*Penelope purpurascens*	?	Adult	Alta Verapaz, Guatemala	Wild	Complete skeleton
FLMNH-OR-44854[1]	–	*Penelope purpurascens*	F	Adult	Petén, Guatemala	Wild	Complete skeleton
FLMNH-OR-44825[1]	–	*Penelope purpurascens*	M	Adult	Petén, Guatemala	Wild	Complete skeleton

Notes: Individuals used in [1]morphological character selection, [2]morphology blind testing, [3]metric statistical analysis, [4]remeasure test of analytic consistency. Since some of Steadman's research was conducted at the FLMNH-OR, it is possible that his individual samples overlap with ours. We do not have a list of the modern type specimens that Steadman used in his analysis, but the following are listed in his figures: PB 23542, PB 30884, PB 27938, PB 33819, PB 23117, and PB 23114. The PB numbering system was used prior to the modern system but these catalogs are included in our table for back-reference. We do not distinguish between the subspecific variants for the Florida galliforms because both morphometric and genetic research has confirmed that the Florida and Eastern subspecies are primarily indistinguishable. Bochenski and Campbell (2006:3) found no consistent morphological character difference between any of the various subspecies.

selected from several modern comparative specimens. Our volunteers were PhD graduate student zooarchaeologists who were not affiliated with our project, and who had limited experience identifying turkey skeletal remains. They assigned a species character state (*M. ocellata* or *M. gallopavo*) and confidence value for each trait, as well as a final overall assessment of which taxon the element as a whole likely belonged to, following the same methods we used for our morphological assessments. We used the blind tests to evaluate the effectiveness of each individual trait, and the overall complex of traits, in identifying the osteological specimens to the species level. In the next phase, we applied the same morphological and metric tests to a large sample of archaeological birds from sites across the Maya world (Fig. 1). This research was primarily conducted in the FLMNH-EA lab where specimens from other institutions were transferred for temporary curation. Shorter term research was conducted at the UADY lab in Mérida, Mexico. Our methods were largely the same for both modern and archaeological samples, but analysis of the archaeological elements also included recording of skeletal element completeness using the diagnostic zones proposed by Serjeantson (2009:79)

Statistical analyses were conducted using the open access software PAST v3.08 (Hammer et al., 2001). We used single-tailed *t*-tests to compare metrics between elements, one- and two-way PERMANOVAs (permutational multivariate analysis of variance) and pairwise tests to evaluate between-group significance, and principal component analysis (PCA) to interpret the factors influencing metric distributions. For all statistical tests on modern birds, only individuals of known taxonomy and age were included, and osteologically defined juveniles were excluded. In tests evaluating sex, only individuals of known sex were included. Further details about the methods used in each test are found below. PERMANOVA and PCA tests require that all individuals with missing metrics be excluded, therefore specimen numbers vary between the tests.

Researcher contributions were as follows: Emery and Thornton designed the project and oversaw all research aspects together. Thornton was responsible for all morphological character evaluations on the modern specimens and was the lead in creating project protocols. Thornton and Emery, with assistance from Cunningham-Smith, Duffy, and McIntosh, conducted all morphological and metric assessments in

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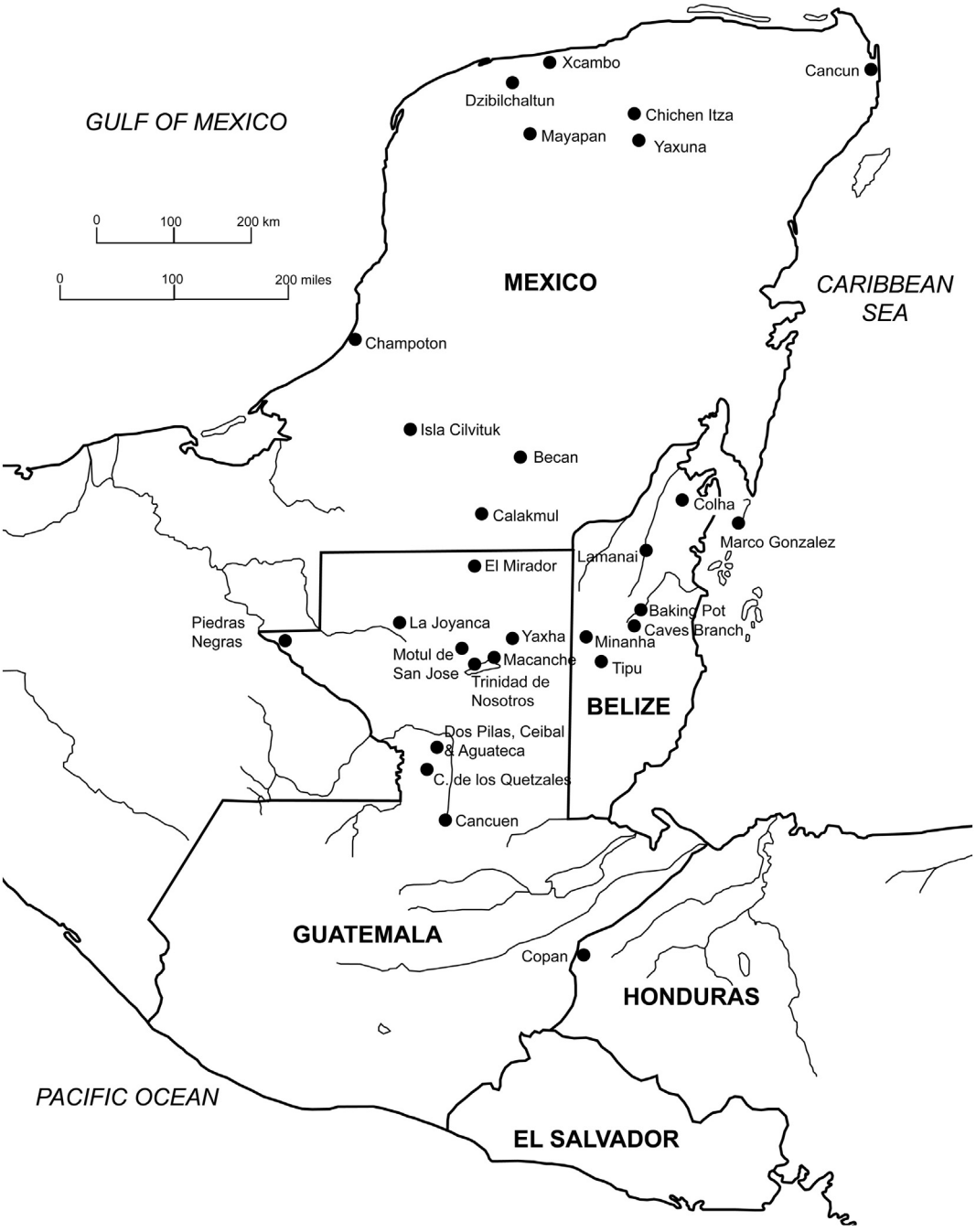

Fig. 1. Map of archaeological sites included in the study.
Map by Thornton and Emery.

Mérida, Mexico. Emery oversaw Duffy and Cunningham-Smith in metric assessments and 3d digitization at the FLMNH. Emery and Sharpe were responsible for all statistical analyses and interpretations.

3. Characters of the study assemblages

3.1. Characters of the modern assemblage

Our modern comparative sample includes the four large galliform taxa that are most commonly confused in the zooarchaeological record of the Maya area because of their size overlap and morphological similarity. The focus, however, is on the two turkey species within the genus *Meleagris*. The sample includes 55 galliform individuals, including 42 *Meleagris* (17 *M. gallopavo* and 25 *M. ocellata*) in the family Phasianidae and subfamily Meleagridinae, and 13 belonging to the family Cracidae (11 *Crax rubra*, 2 *Penelope purpurascens*). Table 1 lists the specimens by catalog number and includes information on specimen sex, age, completeness, and wild/captive reared status. Several of the *M. ocellata* individuals (15) were only represented by tarsometatarsi collected as part of a wildlife study, so our total count of complete *Meleagris* specimens is 27. We did not include smaller-bodied galliforms found in the Maya area including chachalacas (*Ortalis* sp.) and quails (Odontophoridae) since these are quite distinguishable based on size, even from juveniles of the larger birds.

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Table 2
List of diagnostic characters used in the morphological assessment. Note that these characters are fully described and illustrated by the reference authors listed, S = Steadman, 1980, S(H) = Howard as described in Steadman, 1980, B = Bochenski and Campbell, 2006, O = Olsen, 1968.

Element	Code	Reference	Description	Rank
Coracoid	SF	S character 1	Sternal facet shape	Good
	DM-1	B character 1	continuity of the dorsal intermuscular line	Good
	DM-2	B character 2; S(H) character 3	Curvature of the dorsal intermuscular line	Good
	CL	B character 6	Shape of the clavicular articular facet	Good
	VM	B character 8	Curvature of the ventral intermuscular line	Fair
Scapula	AC	S character 1; O	Shape of the acromion	Good
	FU	S(H) character 2	Depth of the furcular articulation	Fair (can be atypical in *M. ocellata*)
	VM	B character 1	Curvature of the ventro-medial muscle line	Good
Humerus	PF	S character 5; O	Definition of the medial rim of the pneumatic foramen	Fair
	DC	S character 6; O	Shape of the deltoid crest	Fair
	PR	S(H) character 10; B character 3	Location of the pronator attachment	Good
	EC	S(H) character 13	Shape of the proximal end of external condyle	Subtle/Inconsistent
	CG	S character 4	Shape of the capital groove and mesial crest	Subtle/Inconsistent
Ulna	SC	S character 1	Shaft curvature	Fair (can be size linked with greater curvature in smaller specimens)
	BR	B character 1; O	Shape of brachial muscle attachment	Fair (can be atypical in *M. ocellata*)
Radius	UL	B character 1a	Rotation of the proximal ulnar articular facet	Fair
	CH	B character 1b	Slant of the cotyla humerus	Fair (but difficult to observe on fragmented specimens)
	RC	B character 2	Transition of distal shaft above radiocarpal articular facet	Fair (but difficult to observe on fragmented specimens)
	LR	S character 1	Pronunciation of the lateral ridge of the distal shaft	Subtle/Inconsistent
	LP	S character 2	Protuberance of the distal ligamental prominence	Subtle/Inconsistent
Carpometacarpus	IT	S character 1; B character 1	Notching of the inner trochlea	Good
Manus proximal phalanx (1) of digit 2	FV	B character 1; O	Definition of the fossa ventralis	Fair
	PE	B character 2	Curvature of the proximal part of posterior edge	Good
Femur	SC	S character 4	Shaft curvature	Fair
	GT	S character 3; O	Proximal extension of the greater trochanter	Fair (but domesticated turkeys may exhibit atypical form)
	LT	S character 1; B character 1	Depth of the transverse groove of lesser trochanter	Subtle/Inconsistent
Tibiotarsus	IN	S character 1; B character 1	Protruberance of inner cnemial crest	Subtle/Inconsistent
Tarsometatarsus	OCR	S character 1	Plantar protrusion of the outer calcaneal ridge	Subtle/Inconsistent
	IC	S character 4	Protrusion of the inner cotyla on proximal articular surface	Subtle/Inconsistent
	GR	S character 7	Depth of the acrotarsial groove of the metatarsal	Subtle/Inconsistent
	DF	S character 16	Size of the lateral distal foramen	Fair, but inconsistent, many intermediate
	IT	S character 18; B character 3	Rotation of the inner trochlea	Good
	TN	S character 25	Width of the intertrochlear notches	Good
	SL		Slope of the outer trochlea	Good
	SP	S character 10; O	Curvature of the spur core	Inconsistent

The modern specimens currently curated in the FLMNH Ornithology and Environmental Archaeology collections include both captive-reared and wild Ocellated Turkeys, and primarily wild *M. gallopavo* (with one exception, a domestic bird from Petén, Guatemala). The wild *M. ocellata* are all from either highland (Alta Verapaz) or lowland (Petén) Guatemala, while the three captive birds were raised in Arizona and Tampa, Florida. The wild *M. gallopavo* specimens are from the southeastern United States. Two are specifically identified as *M.g. osceola* and 13 identified only as *M. gallopavo* providing some subspecific variation to our sample. An additional four comparative specimens (two *M. ocellata* and two *M. gallopavo*) were studied from the UADY Zooarchaeology Lab. These were not included in the original determination of character trait lists and instead formed part of a small secondary study of population differences reported below and to be continued in our later research. They were included in the metric analysis.

The modern birds include 24 male and 25 female, with sex in all cases defined by the original collectors and/or curators of the collections in which they are housed. An additional four birds of unknown sex were included. We have removed all osteologically-defined juveniles from the assemblage we use for metric comparison, but have retained birds that were classified as subadult by the original collector but which do not show any osteological traits of immaturity. This was an intentional choice because as zooarchaeologists, we are not able to recognize immaturity by any other means and thus our archaeological collections might well include these subadult birds. We have excluded birds of unknown sex for evaluations of sex differentiations in the metric analysis but otherwise have included them.

Our morphometric data compilation includes morphological characters and measurements for the 14 elements most commonly measured for fauna, including cranium, mandible, coracoid, scapula, sternum, humerus, radius, ulna, carpometacarpus, first phalanx, pelvis, femur,

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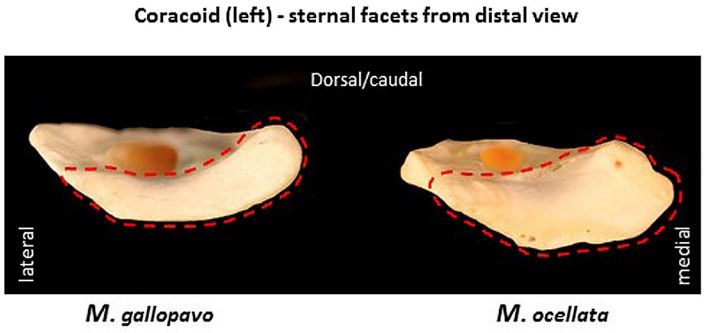

Trait	*M. gallopavo*	*M. ocellata*
Shape of sternal facet (distal view)	Thinner (dorsal/ventral). Note: Morphology of modern domesticated *M. gallopavo* varies.	Medial side is thicker (dosal/ventral); Tapers more towards lateral side (i.e., medial side thicker).

Fig. 2. Sternal facet of coracoid.
Image and descriptors by Thornton.

tibiotarsus, and tarsometatarsus. In this article we focus on the elements most commonly preserved in archaeological collections, so we exclude cranium, mandible, sternum, and pelvis. Our modern comparative assemblage therefore includes 773 element specimens representing individuals in four galliform taxa.

3.2. Characters of the archaeological assemblage

The archaeological collection is still under study and thus continues to grow, but to date, nearly 5000 large galliform remains have been examined and 2380 archaeological specimens from 39 archaeological sites (Fig. 1)

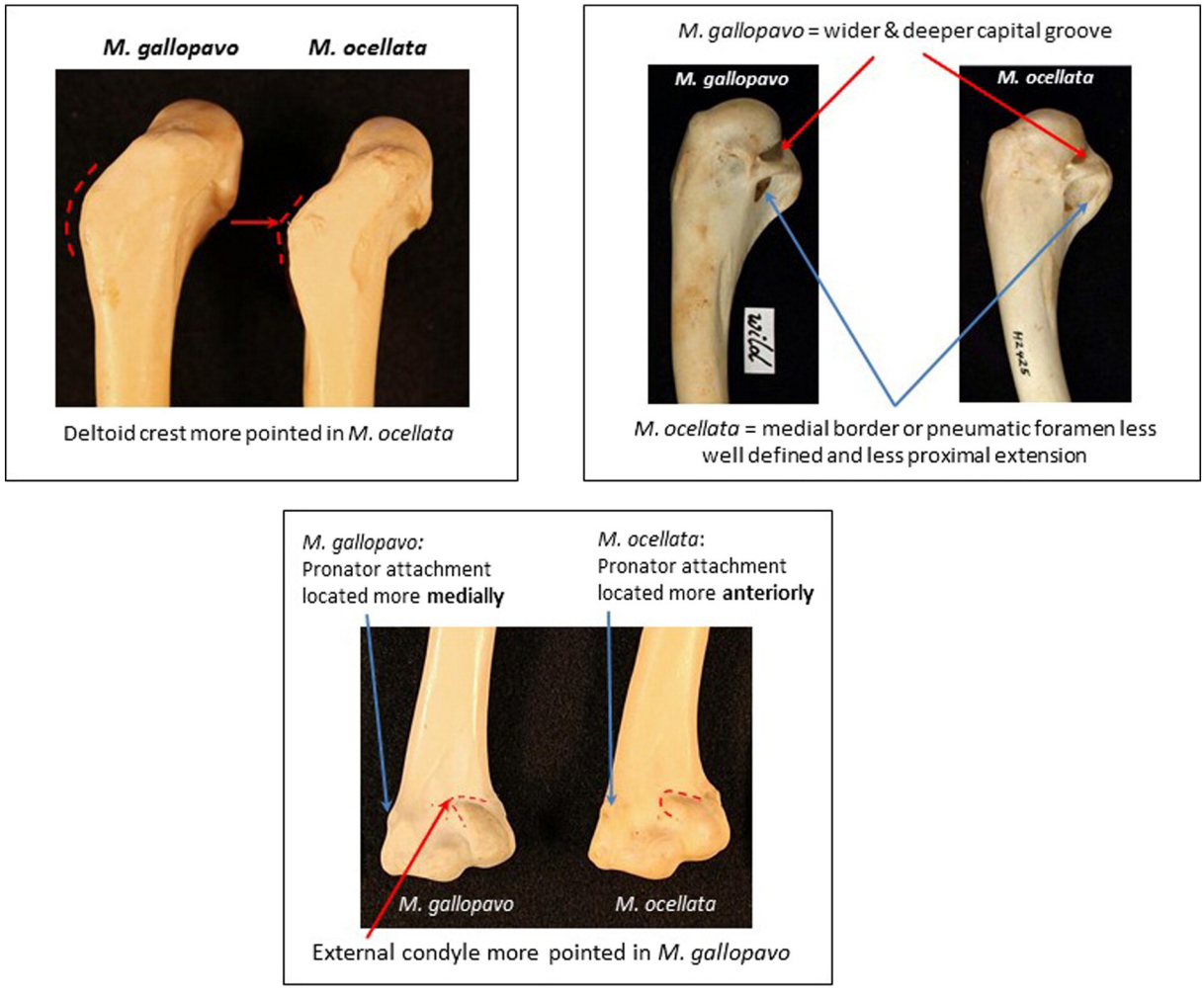

Fig. 3. Medial rim of pneumatic foramen and location of the pronator attachment in humerus.
Image and descriptors by Thornton.

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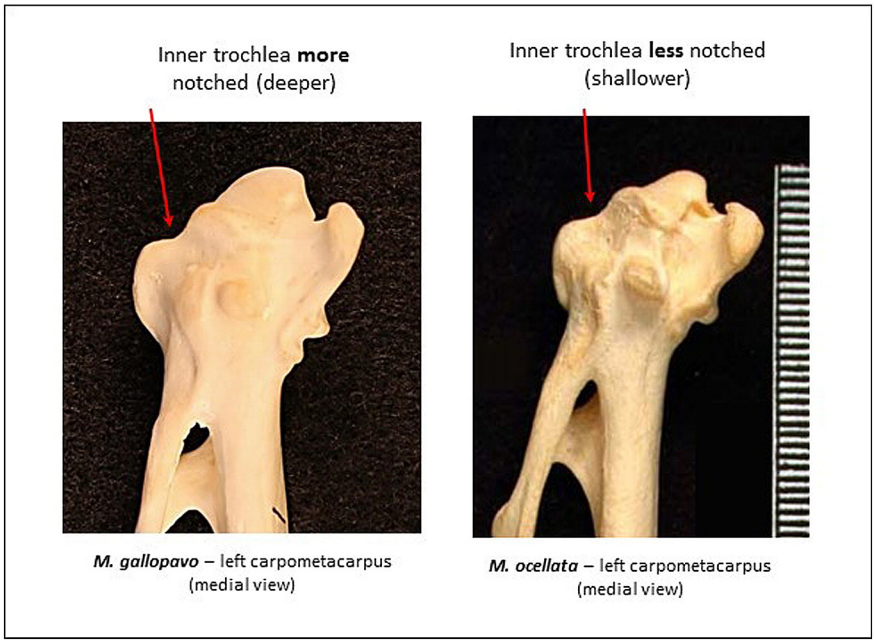

Fig. 4. Notching of inner trochlea in the carpometacarpus. *Image and descriptors by Thornton.*

have been subjected to morphometric analysis. These remains are curated at FLMNH-EA, UADY, and the Anthropology departments of Trent University, SUNY Albany, and New Mexico State University (NMSU). To select these samples, and to ensure that our coverage was as complete as possible, we reviewed hundreds more large bird specimens from other Maya sites within the various collections and by correspondence with other researchers. The resulting assemblage represents a range of geographic regions that include the southern and northern lowlands, and Atlantic, Gulf, and Pacific coasts. The remains were recovered from deposits dating to the Middle Preclassic through Colonial periods. We do not review the

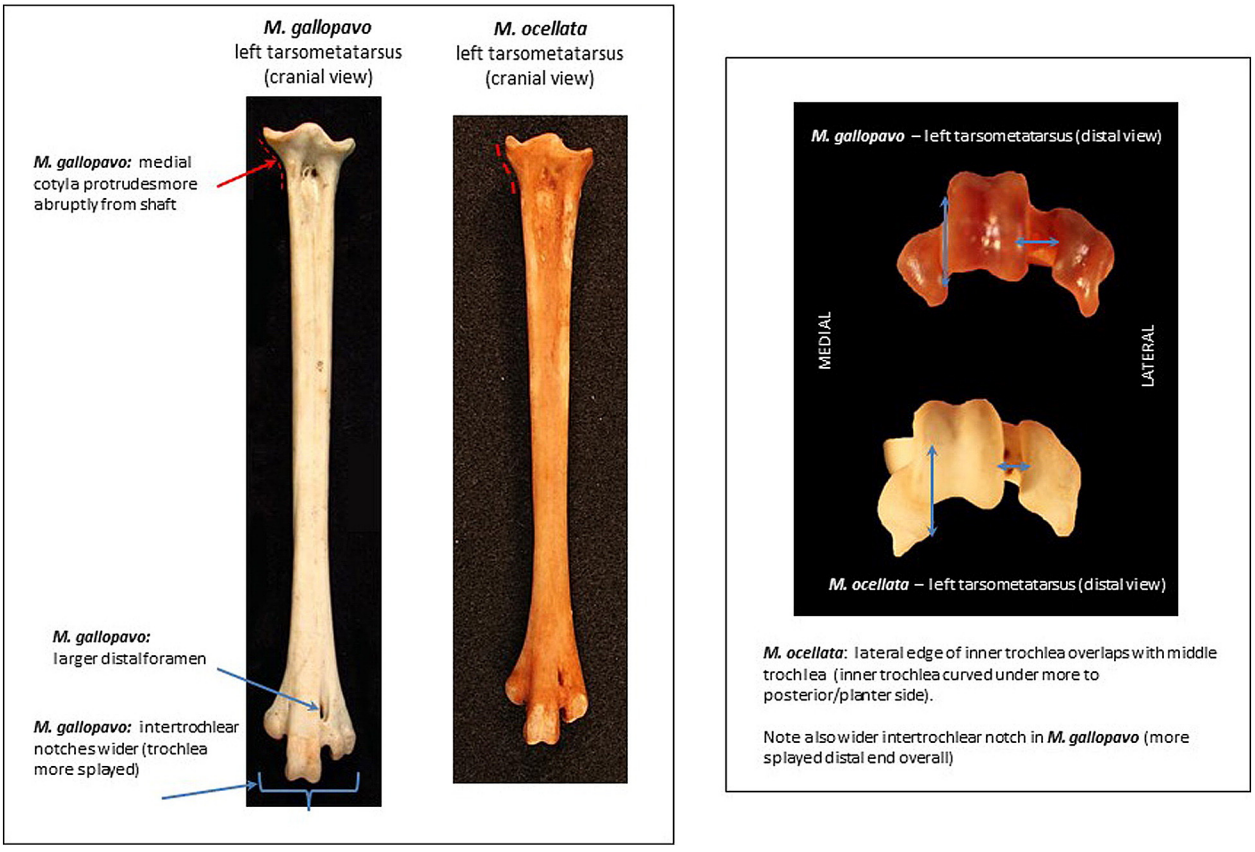

Fig. 5. Rotation of the intertrochlear notches, slope of the outer trochlea, width of intertrochlear notches all on the tarsometatarsus. Image and descriptors by Thornton.

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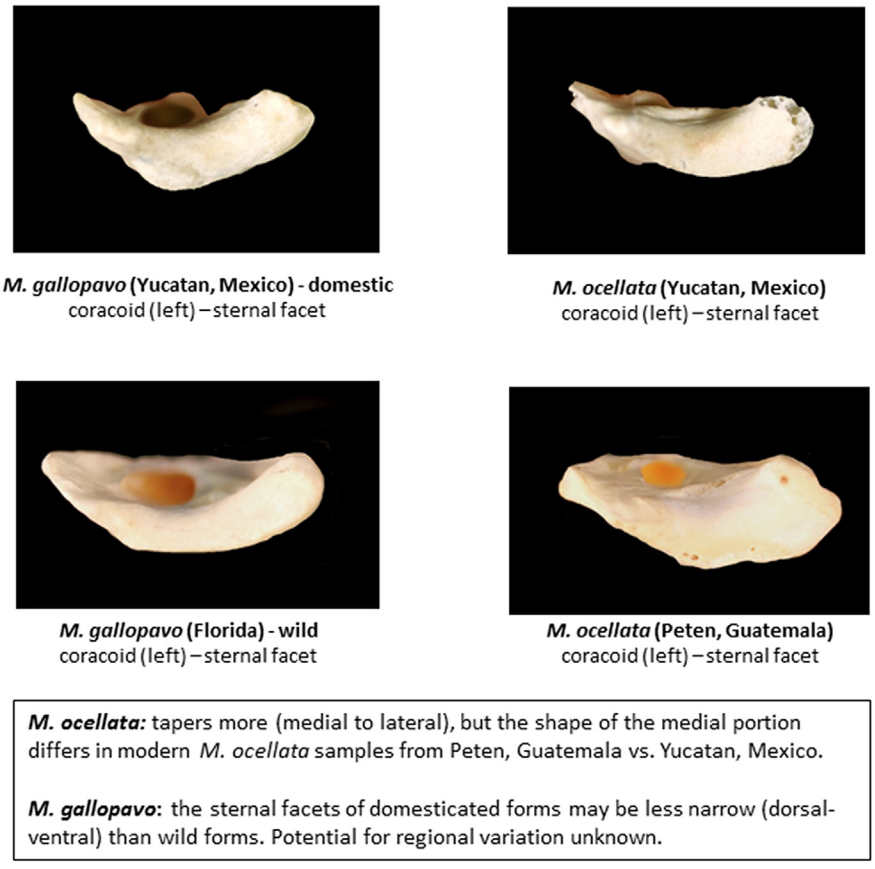

Fig. 6. Comparison of the sternal facet of the coracoid between Petén/Florida and Yucatan *M. gallopavo* and *M. ocellata*. *Image and descriptors by Thornton.*

Table 3
Morphological character assessment in blind testing of three birds. Note that overall score is the relative accuracy of identifications based on overall element morphology, not on any specific trait. All other identifications were made solely on the basis of the trait being evaluated.

Element	N	Overall score	Trait	Trait score	Trait confidence
Coracoid	33	96.97	SF	87.88	1.8
			DM-1	87.88	2.1
			DM-2	90.91	1.5
			CL	84.85	1.8
			VM	72.73	2.3
Scapula	33	78.79	AC	78.79	2.2
			FU	66.67	2.2
			VM	72.73	2.7
Humerus	33	78.79	PF	72.73	2.3
			DC	48.48	3.2
			PR	81.82	1.9
			EC	69.70	2.7
			CG	78.79	2.5
Ulna	33	72.73	SC	54.55	1.8
			BR	51.52	1.3
Radius	33	51.52	UL	15.15	3.5
			CH	78.79	2.4
			RC	60.61	2.4
Carpometacarpus	33	78.79	IT	78.79	2.3
Phalanx 1	21	95.24	FV	95.24	1.5
			PE	90.48	1.4
Femur	33	57.58	SC	78.79	2.0
			GT	54.55	2.5
			LT	48.48	2.1
Tibiotarsus	33	36.36	IN	18.18	3.4
Tarsometatarsus	30	63.33	OCR	50.00	2.8
			IC	46.67	2.6
			GR	70.00	2.6
			DF	56.67	2.2
			IT	60.00	2.1
			TN	80.00	2.1

archaeological sample in this paper except by comparison with the assessed morphometrics of the modern assemblage. Further details on the characteristics of the archaeological collection are below.

4. Results of the morphological analysis

4.1. Assessment of the reliability of morphological characters

In any comparative study of taxa that are difficult to distinguish, it is vital to assess the reliability and replicability of morphological characters used (for excellent examples of such studies, see McCuaig Balkwill and Cumbaa, 1992; Zeder and Lapham, 2010; Zeder and Pilaar, 2010). In this study, our early review of possible morphological characters in seventeen modern individuals in the four closest galliform taxa (Table 1) confirmed that although the four largest species of Mesoamerican galliform birds are superficially similar, there are several features that clearly distinguish most elements to the family level of Cracidae and Phasianidae (see for e.g., Dyke et al., 2003; Frank-Hoeflich et al., 2007).

However, the distinction between *M. gallopavo* and *M. ocellata* is much more problematic. These two birds are generally considered skeletally almost indistinguishable by Maya zooarchaeologists who therefore most often leave identifications at the genus level for these birds. For the purposes of this zooarchaeological study, we then compared the selected traits to a subset of the *M. gallopavo* and *M. ocellata* individuals curated in the FLMNH Environmental Archaeology and Ornithology collections. These were ranked as good, fair, or subtle/inconsistent based on our own ability to observe and define differences in the trait between individuals of the two taxa (Table 2). Some traits were rejected during this process, and a final compilation was created from the remainder.

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The final compilation included several traits we considered to be both consistent and readily distinguished, including: all five traits of the coracoid, the AC and VM of the scapula, PF, DC, and PR of the humerus, UL, CH, RC, of the radius, IT of the carpometacarpus, and IT, TN, and SL of the tarsometatarsus (Figs. 2-5). The comparative sample used in our assessment remains small and the rating system informal. More detailed studies will be completed in the next phase of our research to confirm or reject these diagnostic features as useful for Maya zooarchaeology.

4.2. Assessment of regional variation in species

To address the issue of regional species variability, we compared our morphological trait list to two turkey specimens (UADY 220 - *M. gallopavo*, and UADY 5 - *M. ocellata*) from Yucatan, Mexico which was not geographically represented in the original set of comparative specimens analyzed at FLMNH. In this comparison, most diagnostic traits were accurately scored (species correctly identified in both cases) and with the highest confidence values (1 on a scale of 1–4), however, some notable exceptions were found. The ventral muscular line (VM) was not observed on the coracoid (neither individual could be identified using this trait, and confidence in the trait was listed as 4), and although the shapes of the clavicular articular facets (CL) could be distinguished, those of the *M. gallopavo* were different than the Ornithology specimens studied at FLMNH (Fig. 6). In the humerus, both *M. gallopavo* and *M. ocellata* external condyles (EC) were pointed leading to misidentification of one specimen despite very high confidence in observations of the trait (1), and although the width of the capital groove (CG) was different allowing identification of the species, there was no difference in depth between the two species, so confidence in this character was low (3). The extension of the femoral greater trochanter was identical in the two species and resembled that of *M. ocellata* leading to misidentification of one individual although again confidence in the trait was high (1). Finally, the protrusion of the inner cotyla and depth of the metatarsal groove of the tarsometatarsus were not clearly distinguishable on the Yucatan birds and the identification of the taxa was reversed for these characters despite high trait confidence (1). In all cases, the variation from the characters presented on the original individuals studied at the FLMNH was very obvious, indicating that the Yucatan birds were morphologically quite separate from the FLMNH specimens. This finding requires greater investigation and reminds us that very large, and potentially geographically diverse, comparative samples are required to confidently assign diagnostic character traits.

4.3. Results of the blind test using morphological traits

As a second evaluation of the selected morphological characters, we used blind testing by volunteers unfamiliar with the specifics of Maya turkey morphology (Table 3). We hoped to discover which traits were clear enough and well enough defined that even non-experts could identify them. Our blind tests were not surprisingly less successful with our untrained volunteers than they had been with ourselves, but nonetheless, they were remarkably good. The proportion of correct scores for the testers ranged from 53% to 76% with an average of 63%. The testers included highly trained zooarchaeologists with some familiarity with Maya fauna but no experience with turkeys (2), highly trained zooarchaeologists with little or no familiarity with Maya fauna (4), zooarchaeologists with intermediate level training (2), and non-zooarchaeologists (2). We found little correlation between years of zooarchaeological training and accuracy rate, and no correlation between experience with Maya fauna and accuracy. This suggests that familiarity with avian bones and with the Maya turkeys does not influence the ability to use the criteria being evaluated. Confidence scores ranged from 0 (most confident) to 4 (least confident) and fairly closely followed accuracy of identification (Pearson's $R = -0.8293$, $p < 0.05$, a strong negative correlation between accuracy and confidence) indicating that the analyst themselves could evaluate whether the trait was diagnostic for the specimen.

Overall, accuracy in identification ranged from 97% (coracoid) to 36% (tibiotarsus) with individual trait scores ranging from 95% accuracy to 18%. Coracoid identification was overall excellent, with 97% correct identification based on the overall trait complex, and 91–72% accuracy for each trait. The first phalanx was also very well identified with 95% accuracy in overall identification and 90–95% for the traits and confidence in those traits listed as 1.4–1.5. No other elements were identified with between 80 and 90% accuracy, but some individual traits did reach that level of accuracy including the SF, DM-1 and DM-2 in the coracoid, the PR in the humerus, and the TN in the tarsometatarsus. The scapula, humerus and carpometacarpus were identified with almost 79% accuracy. By far the least identifiable element was the tibiotarsus (36% accuracy overall) with an exceedingly low accuracy for the single trait IN (18% with a confidence of only 3.4). Also below 50% accuracy in the testing were the radius UL (15%, the lowest success rate for any trait), the femur LT (48%), and the tarsometatarsus IC (47%). The radius UL trait was primarily not understood or could not be seen on the specimens by the testers (in 73% of the cases) and in 12% of the cases was used but misidentified the element. In the case of the IC in the tarsometatarus, although the trait could not be recognized 10% of the time, 43% were errors in identification on the basis of the trait. For the tibiotarsus lone character (IN), in 54% of the cases the tester listed the trait as unclear, but in 27% of the cases misidentified the element using the trait. The femur trait LT was recognized by all testers but 51.51% of the time the identification using this trait was wrong, suggesting that the trait was incorrectly used. Further testing will evaluate whether trait identification consistency can be improved with better descriptions and illustrations.

5. Results of the metric analysis

The second facet of our study is intended to assess the value for zooarchaeology of the measurement sets that we are using as predictors of taxa and sex. Earlier metric evaluations by Steadman (1980) and Bochenski and Campbell (2006) provide basic size range data on various parameters. As these earlier studies point out, single measurements often do not effectively distinguish the two turkey species due to the overlap in size between males of the smaller *M. ocellata* and the females of the larger *M. gallopavo* (Fig. 7). Our analyses provide further information on useful metrics, but as yet should be considered preliminary since our results also show high individual variation, particularly among domestic birds and emphasize the need for a larger data set to verify these initial findings (Table 4).

In the analysis presented here, we conducted several multivariate analyses to provide a more robust measure of variation between the species and sexes of the Mesoamerican galliforms. We included only adult birds of well-determined taxonomy. All elements, including both left and right sides, were measured in our analysis. For the purposes of statistical testing, we used only right side measurements except where right side measurements were missing (when entire elements were missing or when the specimen could not be measured in certain dimensions). In these cases, we substituted left side measurements. To ensure that this substitution was justified based on the overall similarity between left and right sides in these birds, we used two-sample *t*-tests to compare left and right side metrics for the birds. In this test, means were obtained from the sums of all measured variables per specimen. The *t*-tests predict the probability of equality among the groups (right vs left sides) while treating them as independent datasets, so a low p value at the cutoff point of $p < 0.05$, indicates that the groups are significantly different. In the left-right test, we included left/right pairs from 249 skeletal elements from 37 individuals. Overall means differed by 0.07 mm and standard deviations by 0.13 mm. Our p-values ($t = 0.0055438$, $p = 0.99558$) indicate that the null hypothesis of equality

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Table 4
Measurement definitions and counts. Table includes 30 *M. gallopavo*, 29 *M. ocellata*, and 26 *C. rubra* element specimens for a total of 85 specimens.

	Total #measures	Measurement description: S = Steadman (1980); D = von den Dreisch (1976); B = Bochenski and Campbell (2006)
Coracoid (n = 70)	62	[S]A = head to external end of sternal facet
		[D]GL = greatest diagonal length
		[B]A = total length, measured between Processus acrocoracoideus and Angulus lateralis
	62	[S]B = head to internal distal angle
		[D]Lm = medial length
		[B]B = medial length, measured between Processus acrocoracoideus and Angulus medialis
	63	[D]Bb = greatest basal breadth
	59	[D]BF = breadth of the basal articular surface
	61	[S]C = head to pneumatic foramen
	69	[S]D = head through scapular facet
		[B]D = height of cranial end, measured between Processus acrocoracoideus and Cotyla scapularis
	69	[S]E = depth of head
		[B]C = width of Facies articularis clavicularis
	66	[S]F = least width of shaft
Subtotal measures	*511*	
Scapula (n = 68)	51	[D]GL = greatest length
	66	[S]B = tip of acromion to external tip of glenoid facet
		[D]Dic = greatest cranial diagonal
		[B]A = maximum articular length
	66	[S]A = proximal width
	63	[S]C = depth of glenoid facet
	65	[S]D = least width of neck
Subtotal measures	*311*	
Humerus (n = 69)	64	[S]A = total length
		[D]GL = greatest length
		[B]A = total length, measured between Caput humeri and Condylus ventralis
	68	[S]B = proximal width
		[D]Bp = breadth of the proximal end
		[B]B = proximal width
	65	[D]SC = smallest breadth of the corpus
	66	[S]C = width of midshaft
		[B]D = width at midshaft
	66	[S]E = distal width
		[D]Bd = greatest breadth of the distal end
		[B]F = distal width
	66	[S]D = depth of midshaft
		[B]E = depth at midshaft
	65	[B]G = depth of condylus dorsalis
	61	[B]A/G = ratio of total length to depth of condylus dorsalis
Subtotal measures	*521*	
Ulna (n = 64)	54	[S]A = total length
		[D]GL = greatest length
	58	[D]Dip = greatest diagonal of the proximal end
	58	[S]B = proximal width
		[D]Bp = greatest breadth of the proximal end
	59	[S]C = width of midshaft
		[D]SC = smallest breadth of the corpus
	61	[D]Did = greatest diagonal of the distal end
	60	[S]D = depth of midshaft
	62	[S]E = distal depth
Subtotal measures	*412*	
Radius (n = 67)	59	[S]A = total length
		[D]GL = greatest length
	64	[S]D = least width of shaft
		[D]SC = smallest breadth of the corpus
	63	[S]F = distal width
		[D]Bd = greatest breadth of the distal end
	66	[S]B = proximal width
	66	[S]C = proximal depth
	66	[S]E = least depth of shaft
Subtotal measures	*384*	
CMC (n = 66)	62	[S]A = total length
		[D]GL = greatest length
	61	[D]L = length of metacarpus II
	60	[S]B = proximal depth
		[D]Bp = greatest breadth of the proximal extremity
	63	[D]Did = diagonal of the distal end
	60	[S]C = length of metacarpal I
	62	[S]D = least width of metacarpal II
	62	[S]E = least depth of metacarpal II
	58	[S]F = greatest intercarpal distance
	58	[S]G = distal depth
	58	[S]H = protrusion of metacarpal III beyond metacarpal II
Subtotal measures	*604*	
Phalanx 1 (n = 62)	61	[D]GL = greatest length
	58	[D]L = length from articular surface to articular surface
Subtotal measures	*119*	
Femur (*n* = 68)	59	[S]A = total length
		[D]GL = greatest length
	61	[D]Lm = medial length
	63	[S]B = proximal width
		[D]Bp = greatest breadth of the proximal end
	64	[D]Dp = greatest depth of the proximal end
	62	[D]SC = smallest breadth of the corpus
	63	[S]D = width of midshaft
	64	[S]F = distal width
		[D]Bd = greatest breadth of the distal end
	66	[S]G = depth of internal condyle
		[D]Dd = greatest depth of the distal end
	64	[S]C = depth of head
	63	[S]E = depth of midshaft
	64	[S]H = depth of external condyle
	63	[S]J = depth of fibular condyle
Subtotal measures	*756*	
Tibiotarsus (*n* = 64)	59	[D]GL = greatest length
	55	[S]A = length without cnemial crest
		[D]La = axial length
	63	[D]Dip = greatest diagonal of the proximal end
	63	[D]SC = smallest breadth of the corpus
	62	[S]C = width of the midshaft
	62	[S]D = depth of midshaft
	62	[S]E = distal width
		[D]Bd = greatest breadth of the distal end
	61	[S]G = depth of external condyle
		[D]Dd = depth of the distal end
	62	[S]B = width of the head
	61	[S]F = depth of internal condyle
Subtotal measures	*610*	
TMT (n = 75)	70	[B]G = distance between dorsal surface of the base of Trochlea metatarsi III and plantar side of Trochlea metatarsi II
	73	[S]A = total length
		[D]GL = greatest length
	75	[S]B = proximal width
		[D]Bp = greatest breadth of proximal end
	73	[D]SC = smallest breadth of corpus
	73	[S]C = least width of shaft
	73	[S]L = distal width
		[D]Bd = greatest breadth of the distal end
		[B]F = distal width
	73	[S]D = least depth of shaft
	14	[S]E = proximal end to middle of spur core
	14	[S]F = top of spur core to end of middle trochlea
	14	[S]G=middle of spur core to end of middle trochlea
	14	[S]H = width of spur core
	14	[S]J = length of spur core
	1	[S]K = angle of spur core
	72	[S]M = depth of inner trochlea
	73	[S]N = depth of middle trochlea
	71	[S]*P*1 = maximum diagonal measurement
Subtotal measures	*867*	
Total measures of 773 elements	**5535**	**142 measurement types**

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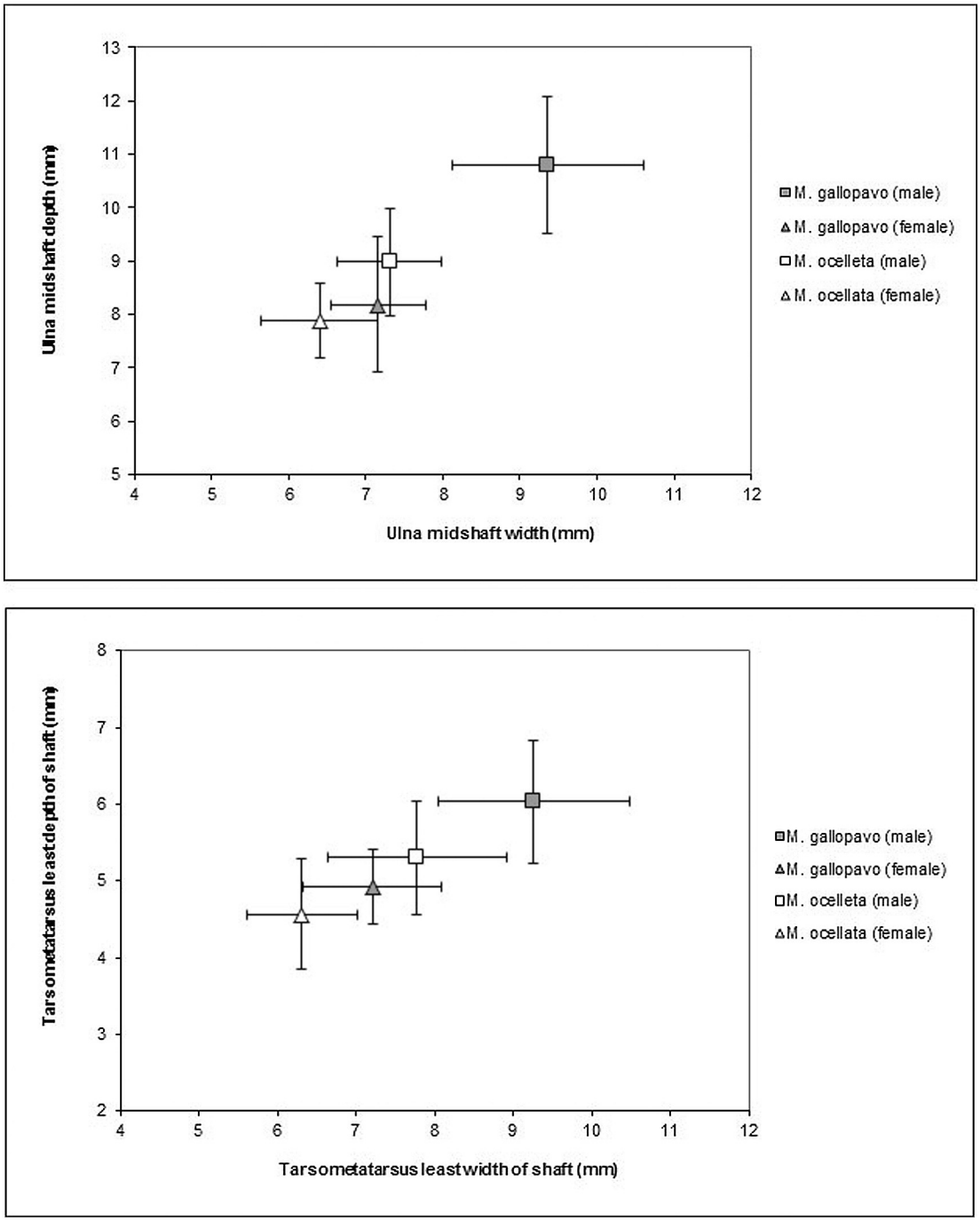

Fig. 7. Examples of overlap between taxa and sexes in flat metric analyses of size ranges between male and female meleagrids (based on ranges provided in Steadman, 1980). Figure by Thornton, adapted by Emery.

cannot be rejected and, in fact, that the left and right side elements are essentially identical.

Considerable concern has been attributed to the bias introduced by variations caused by single-analyst and multiple-analyst metric studies (for example, Blumenschine et al., 1996; Gobalet, 2001). To evaluate the consistency of measurements between analytic episodes by the same analyst, we used two-sample *t*-tests to compare re-measurements of a sample of 12 elements from 10 individuals, all adult, but including males and females. These included three coracoids, one scapula, three humeri, one carpometacarpus, two femurs, one tibiotarsus, and one tarsometatarsus. Means were obtained from the sums of all measured variables per specimen. The *t*-tests predict the probability of equality among the groups (first vs. second measurement episode), so a low p value indicates that the groups are significantly different. Overall means differed by 0.58 mm and standard deviations by 0.19 mm, and our p-values are ($t = 0.0164$, $p = 0.98706$) indicate a very high degree of consistency between measurements by the same analyst. This also argues for the accuracy of our metric instructions and illustrations and their utility for standardizing measurements. In a later study it would be important to test for variability among analysts, and particularly among inexperienced vs. experienced analysts.

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Table 5
PERMANOVA and pairwise test results for comparisons of taxa among large galliforms. Values significant below 0.05 are bolded. TSS = Total sum of squares, W-G SS = Within-group sum of squares.

PERMANOVA (Permutation N: 9999)		Pairwise (bold = sig):			
CORACOID	N = 31				
TSS:	5.121		*P. purpurascens*	*C. rubra*	*M. ocellata*
W-G SS:	2.448	*C. rubra*	0.0814		
F:	9.829	*M. ocellata*	0.1021	**0.0002**	
p (same):	**0.0001**	*M. gallopavo*	0.0963	**0.0001**	**0.0193**
SCAPULA	N = 28				
TSS:	3.755		*P. purpurascens*	*C. rubra*	*M. ocellata*
W-G SS:	1.047	*C. rubra*	**0.0118**		
F:	20.69	*M. ocellata*	**0.0279**	**0.0001**	
p (same):	**0.0001**	*M. gallopavo*	**0.0209**	**0.0003**	**0.0094**
HUMERUS	N = 32				
TSS:	2.752		*P. purpurascens*	*C. rubra*	*M. ocellata*
W-G SS:	1.577	*C. rubra*	**0.0128**		
F:	6.956	*M. ocellata*	0.3215	0.0841	
p (same):	**0.0007**	*M. gallopavo*	**0.0138**	**0.0057**	**0.0081**
ULNA	N = 31				
TSS:	2.506		P. purpurascens	C. rubra	M. ocellata
W-G SS:	1.559	*C. rubra*	**0.0201**		
F:	5.466	*M. ocellata*	0.093	**0.0133**	
p (same):	**0.0016**	*M. gallopavo*	**0.0143**	**0.0401**	**0.0234**
RADIUS	N = 32				
TSS:	2.484		*P. purpurascens*	*C. rubra*	*M. ocellata*
W-G SS:	1.639	*C. rubra*	**0.0152**		
F:	4.814	*M. ocellata*	0.0724	**0.0076**	
p (same):	**0.001**	*M. gallopavo*	**0.0145**	0.0548	**0.035**
CMC	N = 33				
TSS:	4.054		*P. purpurascens*	*C. rubra*	*M. ocellata*
W-G SS:	2.68	*C. rubra*	**0.0115**		
F:	4.955	*M. ocellata*	0.0625	0.075	
p (same):	**0.0003**	*M. gallopavo*	**0.018**	**0.0077**	**0.028**
FEMUR	N = 33				
TSS:	5.919		*P. purpurascens*	*C. rubra*	*M. ocellata*
W-G SS:	3.387	*C. rubra*	**0.0107**		
F:	7.226	*M. ocellata*	0.2279	**0.0036**	
p (same):	**0.0004**	*M. gallopavo*	0.0672	**0.0062**	**0.006**
TIBIO	N = 32				
TSS:	4.343		*P. purpurascens*	*C. rubra*	*M. ocellata*
W-G SS:	2.403	*C. rubra*	**0.0158**		
F:	7.533	*M. ocellata*	0.3246	**0.0245**	
p (same):	**0.0005**	*M. gallopavo*	**0.0149**	**0.0075**	**0.0038**
TMT	N = 45				
TSS:	3.954		*P. purpurascens*	*C. rubra*	*M. ocellata*
W-G SS:	2.373	*C. rubra*	**0.0179**		
F:	7.326	*M. ocellata*	**0.0054**	**0.0072**	
p (same):	**0.0001**	*M. gallopavo*	**0.0232**	**0.0319**	**0.0123**

5.1. Metric identification of *M. gallopavo*, *M. ocellata*, *C. rubra*, and *P. purpurascens*

We began the metric evaluation of taxonomic and sex separation by testing the significance of patterning among the four galliform taxa using one-way PERMANOVA and pairwise tests (Table 5) for all elements except the phalanx (for which only two measures were available - these were found to be significantly non-random using *t*-tests for equality of mean [t = 3.2064, p = 0.002156]). PERMANOVA is a robust test of variation for grouped, non-parametric data. In all cases, the PERMANOVA probability (*p*) that the specimens were randomly distributed was exceedingly low, and thus the groupings are statistically significant for all elements. The pairwise tests of equality of means between the different taxa found less statistical strength in the separation of pairs of taxonomic groups. In other words, these tests revealed that although the size distributions were significantly non-random, the separation between any two taxa within the four galliforms was not always significant. These less significant values are due in large part to the inclusion of only two specimens of guan (*P. purpurascens*) which makes it more difficult to reject the possibility that these are randomly distributed. Putting aside the guans, significant separation was found between the curassows (*C. rubra*) and meleagrids in all but the humerus and carpometacarpus (no separation from *M. ocellata*), and the radius (no separation from *M. gallopavo*). In all cases *M. ocellata* and *M. gallopavo* were found to be significantly separated. Thus we can argue that using the multiple measures together, the taxa are distinguishable using metric characters.

We next graphed the complete set of metrics for each element in a principal component analysis, labeled by taxa and sex, to provide a more robust model of individual variation among specimens in each group. We plotted the natural logarithm (ln) normalized or transformed values based on Euclidian distance. Spur core metrics, valid only on males, were excluded for analyses including both male and female individuals.

The value of the larger set of measurements is clear when we use the PCA to reduce the multivariate measurements to strong bivariate plots on axes defined by groups of measurements. This method also allows us to test which measurements provide significant information on the variable characters of the elements. In each set of analyses we reviewed clustering for the first three components which in all cases explained at least 90% of the variation among the metrics. The PCA eigenvalue loadings provide detail on the measurements within the components with the greatest impact on the differentiation. Here we present only the PCAs for scapula and femur, since these are the ones that best reveal the separations between all four species. Separations between the guans, curassows, and the meleagrid group (but not between the two species of meleagrid) were also found in the coracoids, ulna, tibiotarsus, and tarsometatarsus.

In PCA of the scapula, PCs 1–3 explain 99% of the variance (see Supporting Info 1). In combination PC1 + 2 separate the curassows, guans, and meleagrids (Fig. 8 – PCA). Although a subset of the *M. gallopavo* and *M. ocellata* overlap on the PC 1 axes, the PC 2 provides slight separation between the overlapping subgroups of *M. gallopavo* and *M. ocellata*. PC 1, dominated by A (proximal width) and to a lesser extent D (least width of the neck), effectively separates guans at the lower end and a portion of the *M. gallopavo* at the upper end. PC 2 is positively dominated primarily by GL (greatest length), and separates the curassows from the meleagrids and guans.

For the femur, PCs 1–3 explain 96% of the variance (Supporting Info 1 – eigenvalues). PC 1 is very evenly distributed suggesting it is controlled by overall size, and provides limited separation between the two meleagrids (Fig. 9 – PCA). PC 2 is controlled primarily by Lm (medial length) and SC (smallest breadth of the corpus), but to almost the same extent by D (width of midshaft). This separates the curassows from both meleagrids and guans. PC 3, dominated by E (depth of midshaft) clearly separates the guans from the other birds.

Together the statistical and PCA results on all taxa combined indicate that while only the humerus, carpometacarpus, and radius are somewhat problematic for separations between taxa within the galliforms, the scapula and femur can effectively separate the two species of meleagrids. Although the PERMANOVA and pairwise tests confirm that the meleagrid species are separate groups, the PCAs, with the exception of the femur and scapula, do not clearly distinguish these. The results also clarify that the source of most overlap between the taxa is the broad range of sizes among the meleagrids, both of which exhibit more variation than the curassows. This is most likely the result of greater sexual dimorphism among these taxa, an issue we explore next.

5.2. Metric identification of sex in turkeys (*M. ocellata* and *M. gallopavo*)

Our goal in these metric studies is to differentiate not only between taxa, but also between sexes because particularly for the two turkeys, it is the overlap between large male *M. ocellata* and small female *M. gallopavo* that is most problematic. For the next set of analyses, we

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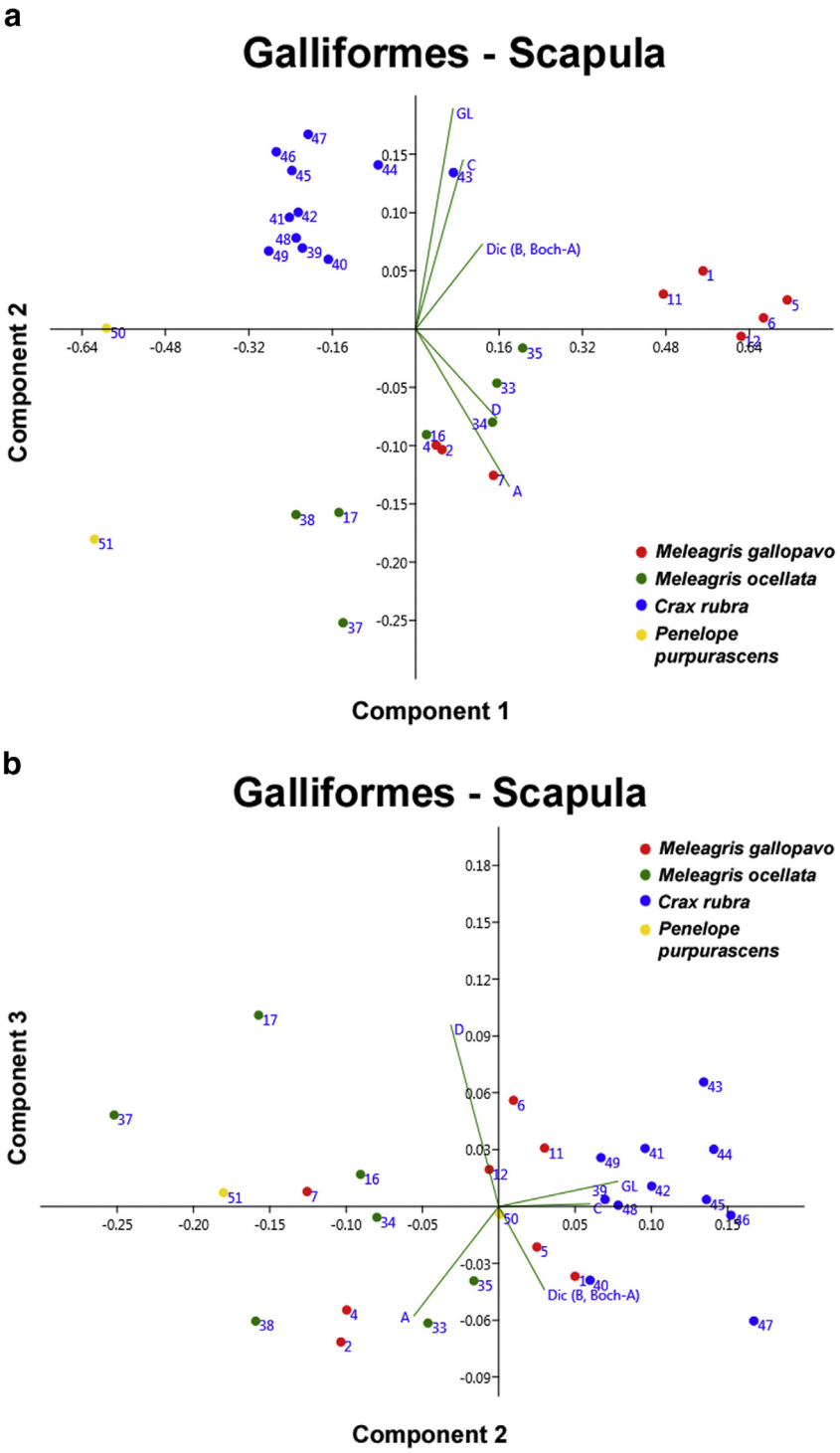

Fig. 8. a: PCA galliform scapula, components 1 and 2. b: PCA galliform scapula, components 2 and 3. Figures by Sharpe.

included only *M. gallopavo* and *M. ocellata* to increase the information available on distributions of the sexes within the meleagrids by removing the noise of the other taxa. Again, we began with PERMANOVA (this time two-way to compare both taxa and sex) and pairwise tests, both following the same procedures described above. For this study we also included a male-only test of tarsometatarsi which was evaluated using the one-way PERMANOVA.

Taxonomic and sex groups among the meleagrids were found to be statistically significant for all elements (ranging from $p = 0.0001$ to 0.0068 for taxa and 0.0001 for sex, Table 6) based on the PERMANOVA and thus that the null hypothesis of random distribution in a single population be rejected for every element. The exception is the male tarometatarsus which was not significantly separated between the taxa (likely a result of the very low number of male *M. gallopavo* specimens - only two in the sample). The interactive scores were somewhat higher, indicating that not all groups (taxa × sex) could be separated. Only the coracoid ($F = 8.1183$, $p = 0.0069$) and scapula ($F = 2.8524$, $p = 0.0202$) were statistically significant in terms of the interactive groupings. The pairwise tests show that this is due in most cases to the overlap among members of the sex + taxa groups, caused by the

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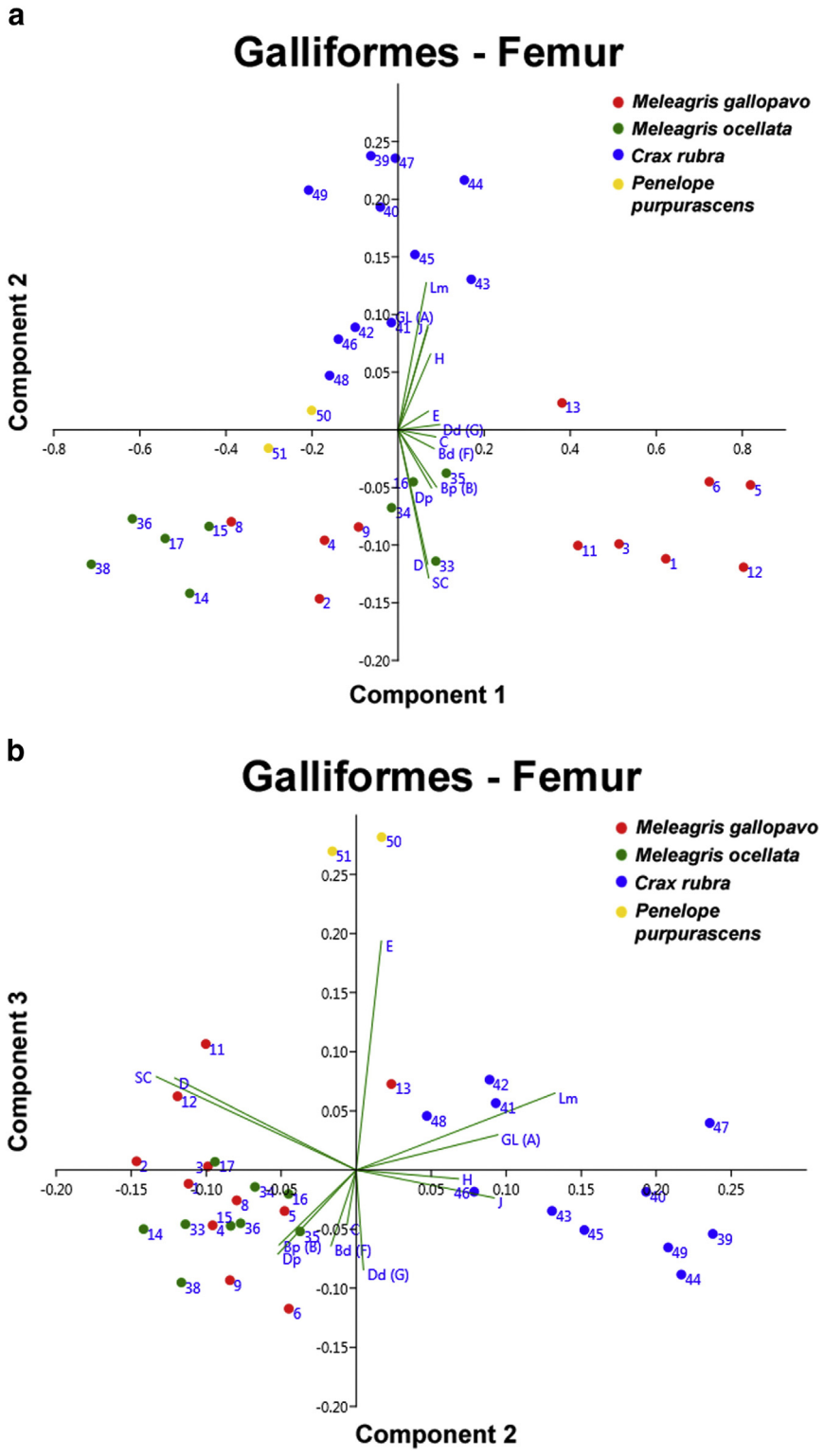

Fig. 9. a: PCA galliform femur, components 1 and 2. b: PCA galliform femur, components 2 and 3. Figures by Sharpe.

wide divergence in metrics for the female *M. gallopavo* specimens. The *M. gallopavo* females overlap the *M. ocellata* females in the ulna, radius, and scapula, and the *M. ocellata* males in the scapula, humerus, phalanx, and tibiotarsus. It is noteworthy that the overlap is very weak in all cases where female *M. gallopavo* and *M. ocellata* overlap, and in the overlap between female *M. gallopavo* overlaps male *M. ocellata* on the humerus. This indicates the possibility that, with additional samples, the probability of separation between these cases will be stronger.

Again, we used PCAs (natural log normalized and based on Euclidian distance) to provide information on the specific details of the groupings revealed by the PERMANOVAs and pairwise tests. Our analysis focuses on PCAs 1, 2, and 3 which explain between 83 and 99% of the variation

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Table 6
PERMANOVA and pairwise test results for comparisons of taxa and sex among meleagrids (*M. gallopavo* and *M. ocellata*), and taxa only for male tarsometatarsi. Values significant below 0.05 are bolded. TSS = Total sum of squares, W-G SS = Within-group sum of squares.

Two-way PERMANOVA (Permutation = 9999)						Pairwise (bold = sig):			
Coracoid									
Source	Sum of sqrs	df	Mean square	F	p		*M.g (f)*	*M.o (f)*	*M.o (m)*
Taxa	0.52748	1	0.52748	21.931	**0.0006**	*M.g (m)*	**0.0102**	**0.0102**	**0.0287**
Sex	1.5504	1	1.5504	64.464	**0.0001**	*M.g (f)*		**0.0315**	**0.0236**
Interaction	0.19525	1	0.19525	8.1183	**0.0069**	*M.o (f)*			**0.0295**
Residual	0.31267	13	0.024051						
Total	2.5858	16							
Scapula									
Source	Sum of sqrs	df	Mean square	F	p		*M.g (f)*	*M.o (f)*	*M.o (m)*
Taxa	0.52293	1	0.52293	32.078	**0.0001**	*M.g (m)*	**0.0198**	**0.0487**	**0.0079**
Sex	0.63103	1	0.63103	38.709	**0.0001**	*M.g (f)*		0.1011	0.3963
Interaction	0.0465	1	0.0465	2.8524	**0.0202**	*M.o (f)*			0.0685
Residual	0.16302	10	0.016302						
Total	1.3635	13							
Humerus									
Source	Sum of sqrs	df	Mean square	F	p		*M.g (f)*	*M.o (f)*	*M.o (m)*
Taxa	0.59718	1	0.59718	40.947	**0.0001**	*M.g (m)*	**0.0093**	**0.0078**	**0.0077**
Sex	1.2616	1	1.2616	86.504	**0.0001**	*M.g (f)*		**0.0315**	0.0547
Interaction	−0.0813	1	−0.0813	-5.5746	1	*M.o (f)*			**0.0286**
Residual	0.18959	13	0.014584						
Total	1.9671	16							
Ulna									
Source	Sum of sqrs	df	Mean square	F	p		*M.g (f)*	*M.o (f)*	*M.o (m)*
Taxa	0.32481	1	0.32481	18.155	**0.0008**	*M.g (m)*	**0.0052**	**0.0048**	**0.0094**
Sex	1.1869	1	1.1869	66.342	**0.0001**	*M.g (f)*		0.1178	**0.0298**
Interaction	−0.11881	1	−0.11881	−6.6409	1	*M.o (f)*			**0.0299**
Residual	0.25048	14	0.017891						
Total	1.6434	17							
Radius									
Source	Sum of sqrs	df	Mean square	F	p		*M.g (f)*	*M.o (f)*	*M.o (m)*
Taxa	0.22262	1	0.22262	6.7	**0.0068**	*M.g (m)*	**0.0095**	**0.008**	**0.0249**
Sex	0.86213	1	0.86213	25.947	**0.0001**	*M.g (f)*		0.083	**0.0459**
Interaction	−0.04869	1	−0.04869	−1.4653	0.6944	*M.o (f)*			**0.0299**
Residual	0.46518	14	0.033227						
Total	1.5012	17							
CMC									
Source	Sum of sqrs	df	Mean square	F	p		*M.g (f)*	*M.o (f)*	*M.o (m)*
Taxa	0.38515	1	0.38515	8.5345	**0.004**	*M.g (m)*	**0.0084**	**0.0097**	**0.0299**
Sex	1.3801	1	1.3801	30.581	**0.0001**	*M.g (f)*		**0.0311**	**0.0076**
Interaction	−0.05135	1	−0.05135	−1.1379	0.488	*M.o (f)*			**0.0161**
Residual	0.63181	14	0.045129						
Total	2.3457	17							
Phalanx									
Source	Sum of sqrs	df	Mean square	F	p		*M.g (f)*	*M.o (f)*	*M.o (m)*
Taxa	0.066793	1	0.066793	18.602	**0.0013**	*M.g (m)*	**0.0083**	**0.0288**	**0.0304**
Sex	0.13211	1	0.13211	36.793	**0.0001**	*M.g (f)*		**0.0216**	0.304
Interaction	0.008236	1	0.008236	2.2939	0.0886	*M.o (f)*			**0.0309**
Residual	0.046678	13	0.003591						
Total	0.25382	16							
Femur									
Source	Sum of sqrs	df	Mean square	F	p		*M.g (f)*	*M.o (f)*	*M.o (m)*
Taxa	1.3446	1	1.3446	31.344	**0.0001**	*M.g (m)*	**0.0038**	**0.0053**	**0.0088**
Sex	2.7541	1	2.7541	64.203	**0.0001**	*M.g (f)*		**0.0284**	**0.0268**
Interaction	−0.4183	1	−0.4183	−9.7514	1	*M.o (f)*			**0.0268**
Residual	0.60055	14	0.04289						
Total	4.2809	17							
Tibiotarsus									
Source	Sum of sqrs	df	Mean square	F	p		*M.g (f)*	*M.o (f)*	*M.o (m)*
Taxa	0.94639	1	0.94639	19.279	**0.0002**	*M.g (m)*	**0.008**	**0.008**	**0.0082**
Sex	1.4741	1	1.4741	30.029	**0.0001**	*M.g (f)*		**0.0161**	0.5024
Interaction	−0.09233	1	−0.09233	−1.8808	0.9137	*M.o (f)*			**0.0299**
Residual	0.68723	14	0.049088						
Total	3.0154	17							
TMT									
Source	Sum of sqrs	df	Mean square	F	p		*M.g (f)*	*M.o (f)*	*M.o (m)*
Taxa	0.50445	1	0.50445	18.81	**0.0001**	*M.g (m)*	**0.0278**	**0.0003**	**0.0008**
Sex	1.865	1	1.865	69.543	**0.0001**	*M.g (f)*		**0.0005**	**0.0007**

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Table 6 (*continued*)

Two-way PERMANOVA (Permutation = 9999)						Pairwise (bold = sig):	
Interaction	−0.12143	1	−0.12143	−4.528	0.1782	*M.o (f)*	**0.0001**
Residual	0.69726	26	0.026818				
Total	2.9453	29					
Male TMT							
				F	p		
TSS:	3.061			2.418	0.1382		
W-G SS:	2.509						

in the data (Supporting Info 2). The combined effects of these three components reveal clustering of the taxa and sexes for several elements. Thus, in combination, the metric data clarify the distinctions between the four groups.

We use these clusters to better define which measurements may be most effective at identifying the turkey taxa and sexes. The best separation between the four groups of taxa × sex is found in the coracoid, femur, and tarsometatarsus. For the coracoid, PC 1 is evenly affected by all measures indicating it is primarily representative of allometric size (Fig. 10). Size thus separates *M. ocellata* females and *M. gallopavo* males, and fairly effectively also *M. gallopavo* females and *M. ocellata* males. PC 2 is strongly affected by BF and to a lesser degree by Bb and these measures separate the *M. ocellata* males from the other taxa and sexes. The PC 1 for the femur, although primarily overall size, has some greater effects from Bp, Dd, and C (Fig. 11). This component provides fair separation between all taxa and sexes. Again, for the tibiotarsus, PC represents predominantly overall size, but with a greater effect from B and Dip and separates the sexes within the taxa and with a single exception (specimen 8896: domestic *M. gallopavo,* Petén, Guatemala) separates all groups (Fig. 12). Finally, for the tarsometatarsus, PC 1 is dominated by GL and to a lesser extent by C, but likely still represents overall allometric size (Fig. 13). This PC effectively separates all taxa and sexes with a single specimen exception overlap between *M. gallopavo* females and *M. ocellata* males, a captive male from Busch Gardens, Tampa. When compared only between males to understand the impact of spur morphology, PC 1, in this case does not appear to be allometric size, and is dominated by J with a somewhat lesser effect from H (Fig. 14). These however, do not separate the males of the two species. PC 2 is a more generalized combination of measures with some dominance of F and G, and this does clearly separate the two taxa. Unfortunately only two of the *M. gallopavo* specimens used in this study had spurs, so the sample size biases the results. Later work will increase the sample size for this measure.

In upcoming analyses, we will compare other modern bird specimens outside our study to the modeled distributions to evaluate the effectiveness of fit of these metrics to all Mesoamerican galliform birds. We have not done this here because our metrics were chosen, and our model was generated, from the modern birds already in the sample. However, it is interesting to review the locations of the Yucatan, Mexico birds which fall within the clusters for all PCAs though often defining the outer edges, and the single domestic *M. gallopavo* tibiotarsus from Petén, Guatemala, which falls far outside any other metric on all components.

6. Tests of 3D replicates for comparative analysis

Our results have also clarified that none of the characters, metric or morphological, is easily replicated without reference to a modern comparative specimen. Morphological descriptions are qualitative and based on relative differences in character shape or size. Similarly, it is very difficult to standardize a metric on a fragmentary archaeological sample if you do not have a modern comparison in hand to understand where, for example, the mid-shaft might have been. In order to make this diagnostic regime accessible, all analysts would need access to sufficient comparative specimens to allow for assessment of individual variation.

With this difficulty in mind, a final step in our testing of methods for deriving standardized and replicable morphological and metric procedures was to evaluate the utility of 3D models for comparison in multiple labs and by multiple colleagues (S3). We used a Next Engine 3D laser scanner and associated software to scan and post-process key individuals from our comparative assemblage. With assistance from the University of Florida FabLab, we printed replicas using the Zprinter 450. This printer solidifies powder using resins and provides excellent print resolution and fidelity to original both because of the powder/binder system and because this process provides better structural support through the processing. We tested several different resolutions but highest definition scans were necessary to accurately reproduce all features. To assess the accuracy of the models, we subjected them to blind morphological testing by Thornton (who was not part of the 3D scanning project), and a full metric analysis by Duffy and Cunningham-Smith.

Thornton was able to correctly identify each specimen based on our morphological characters. She noted only three areas in which the scan was more difficult to use for morphological identification than was the original (these were the ventral muscular line on the coracoid which did not replicate with sufficient resolution, and on the tarsometatarsus, the size of the distal foramen and the width of the intertrochlear notches), both of which were obscured by infiltered resin. These are related more to the final detail post-process rendering, not an intrinsic flaw with the process.

We compared the metric dimensions of the 3D model bones to their real counterparts to test for divergence. For this comparison we used two-sample *t*-tests in which means were obtained from the sums of all measured variables per specimen. We included 27 real/model pairs of elements from the three individuals modeled. Overall means differed by 1.19 and standard deviations by 1.24 mm. *t*-Tests were used to predict the probability of equality among the groups (model vs real bone). p-Values were very high ($t = 0.029392$, $p = 0.97666$) which does not support rejecting the null hypothesis of equality and, therefore, indicates that the model and real elements are essentially identical.

7. Implications of the morphometric study for zooarchaeological analysis

This paper specifically discusses the utility of our analytical methods for accuracy and replicability in a zooarchaeological assemblage. A prime issue in this equation is the study sample most likely to be presented for analysis. Thus, although we do not present the archaeological results in this paper, we use the general characteristics of the archaeological sample to clarify the subset of elements of particular interest for morphological and metric character representation. Later publications, when all research is complete, will discuss the full results of our archaeological morphometric findings.

Of the archaeological specimens that were sufficiently preserved to be identified as large galliforms, 89% allowed metric and 49% morphological analysis. Considered by element, the more robust bones of the hind limb (femur, tibiotarsus, tarsometatarsus) and upper wing

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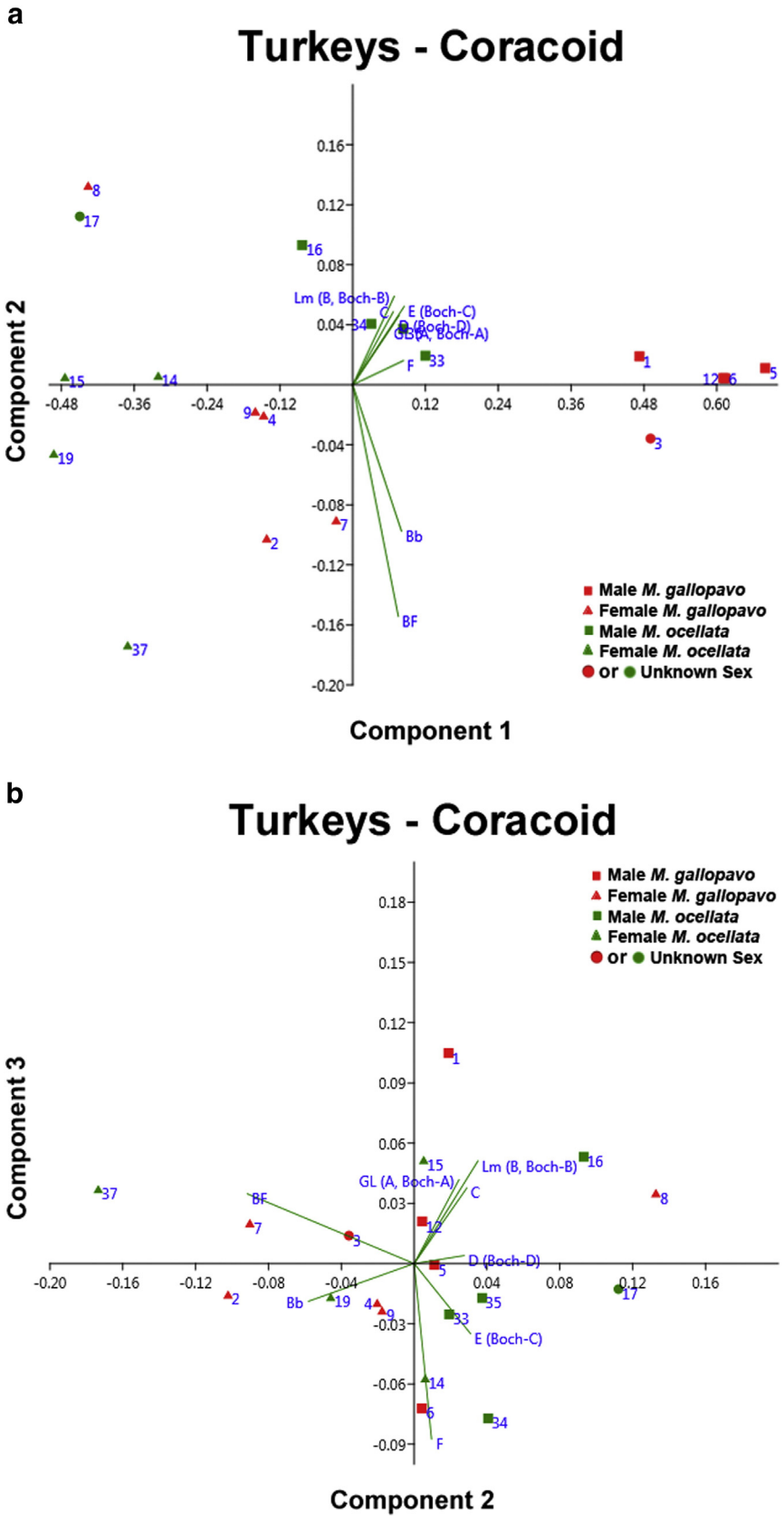

Fig. 10. a: PCA meleagrid coracoid, components 1 and 2. Note 17 = FLMNH-OR-38861, is likely a female. Specimen 8 = FLMNH-EA-5710 is a subadult, hence overlaps with female *M. ocellata*. b: PCA meleagrid coracoid, components 3 and 4. Note 17 = FLMNH-OR-38861, is likely a female. Specimen 8 = FLMNH-EA-5710 is a subadult, hence overlaps with female *M. ocellata*. Figures by Sharpe.

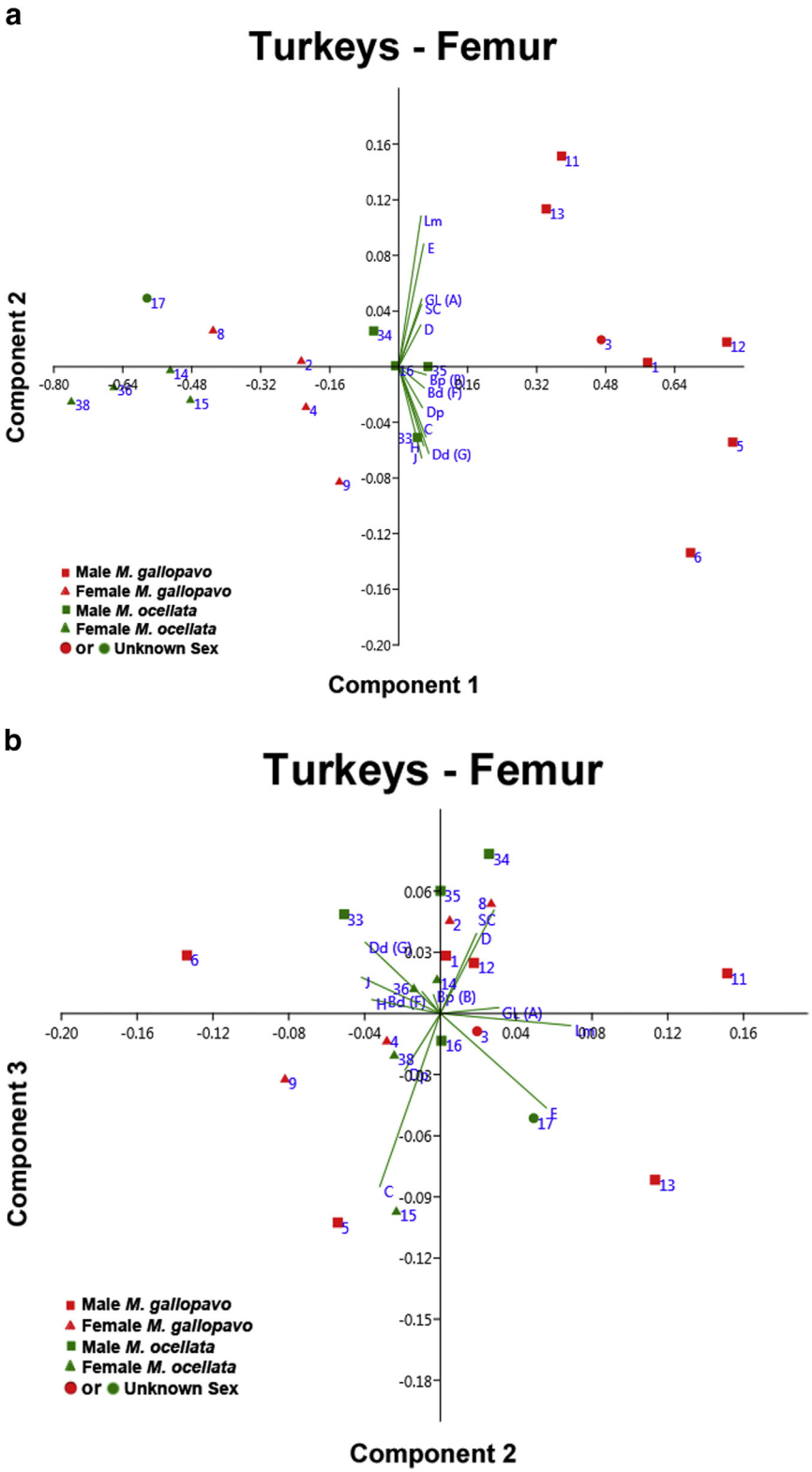

Fig. 11. a: PCA meleagrid femur, components 1 and 2. b: PCA meleagrid femur, components 2 and 3. Figures by Sharpe.

(humerus, ulna, radius) were most often well enough preserved to allow measurement and/or morphological characterization, while the cranium, sternum, scapula, radius, and phalanx were the least well-preserved for these studies (Table 7). Unfortunately, osteological analyses suggest that most diagnostic morphological characters are located on the cranial and girdle portions. For example, Bochenski and Campbell (2006:53) note that over half of their 55 characters were located on the head, sternum, and parts of the shoulder girdle.

Preservation of the archaeological turkey remains also varies among the different regions of each element. The best preserved segments are most often the central shafts while morphological characters and useful

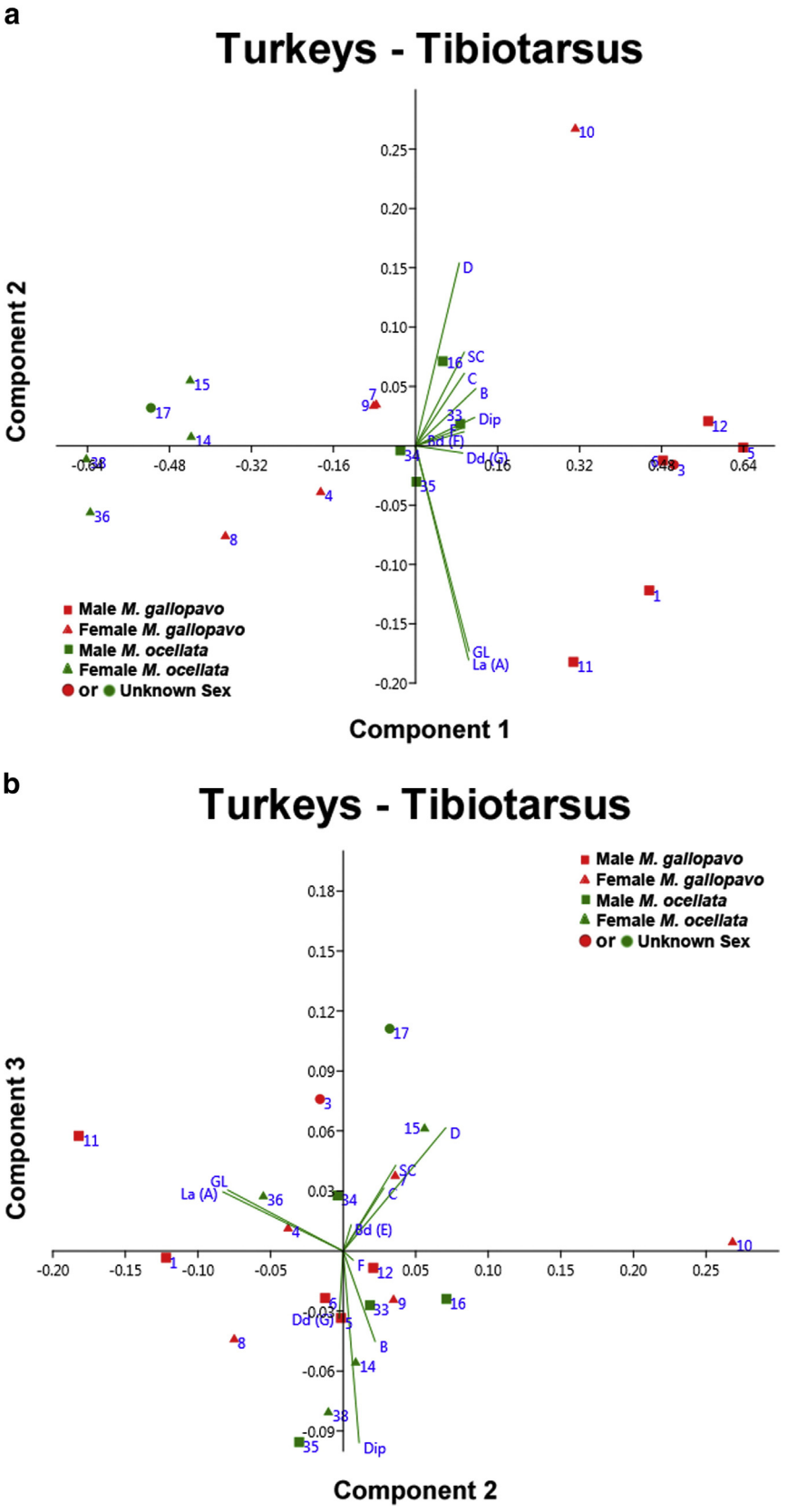

Fig. 12. a: PCA meleagrid tibiotarsus, components 1 and 2. Note 10 = FLMNH-EA-8896, a domestic *M. gallopavo* from the Petén. b: PCA meleagrid tibiotarsus, components 2 and 3. Note 10 = FLMNH-EA-8896 a domestic *M. gallopavo* from the Petén.
Figures by Sharpe.

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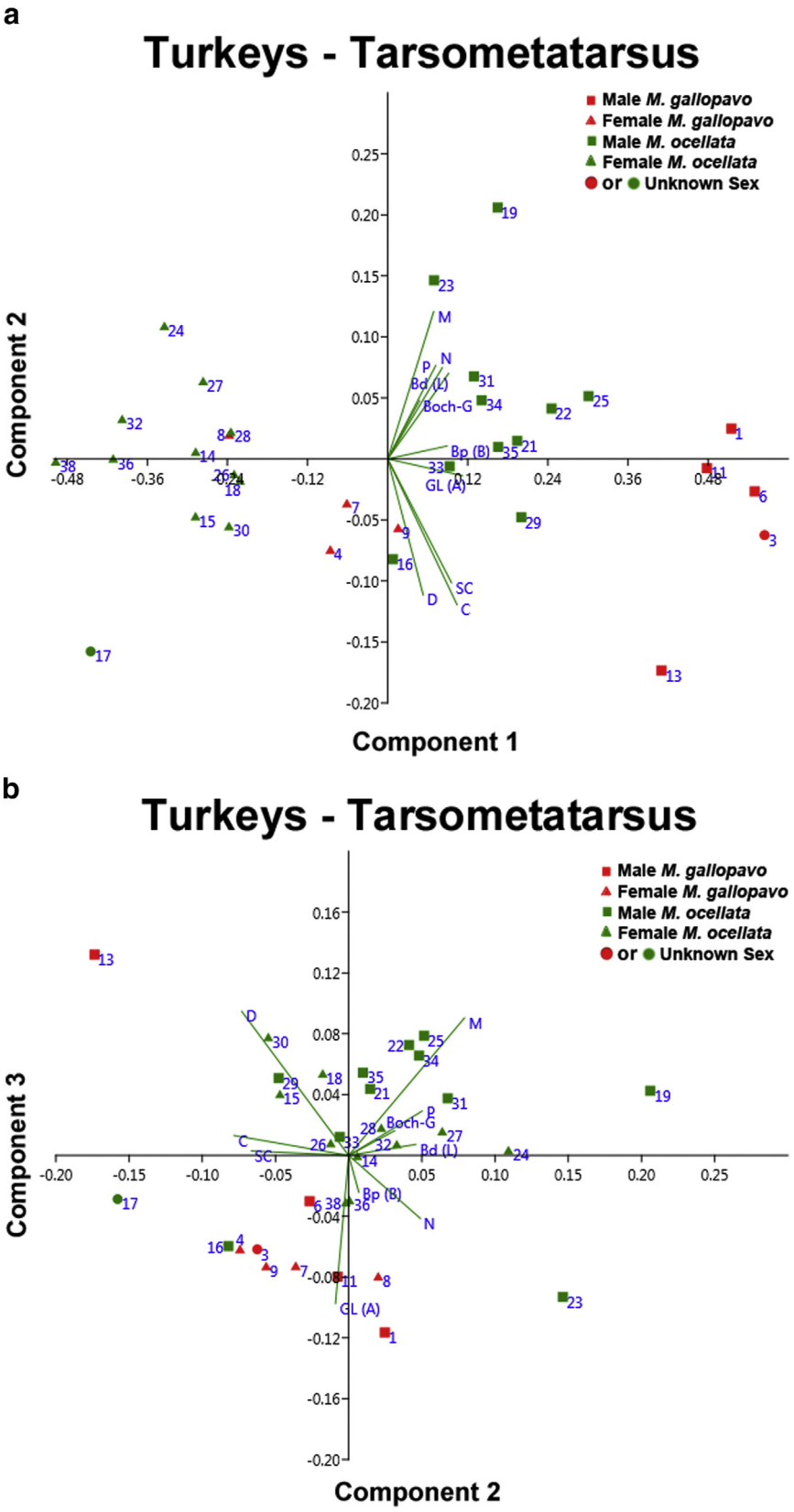

Fig. 13. a: PCA meleagrid tarsometatarsi, components 1 and 2. Note 16 = FLMNH-OR-24105, a captive male from Busch Gardens, ranges in with the female *M. gallopavo*. b: PCA meleagrid tarsometatarsi, components 2 and 3. Note 16 = FLMNH-OR-24105, a captive male from Busch Gardens, ranges in with the female *M. gallopavo*.
Figures by Sharpe.

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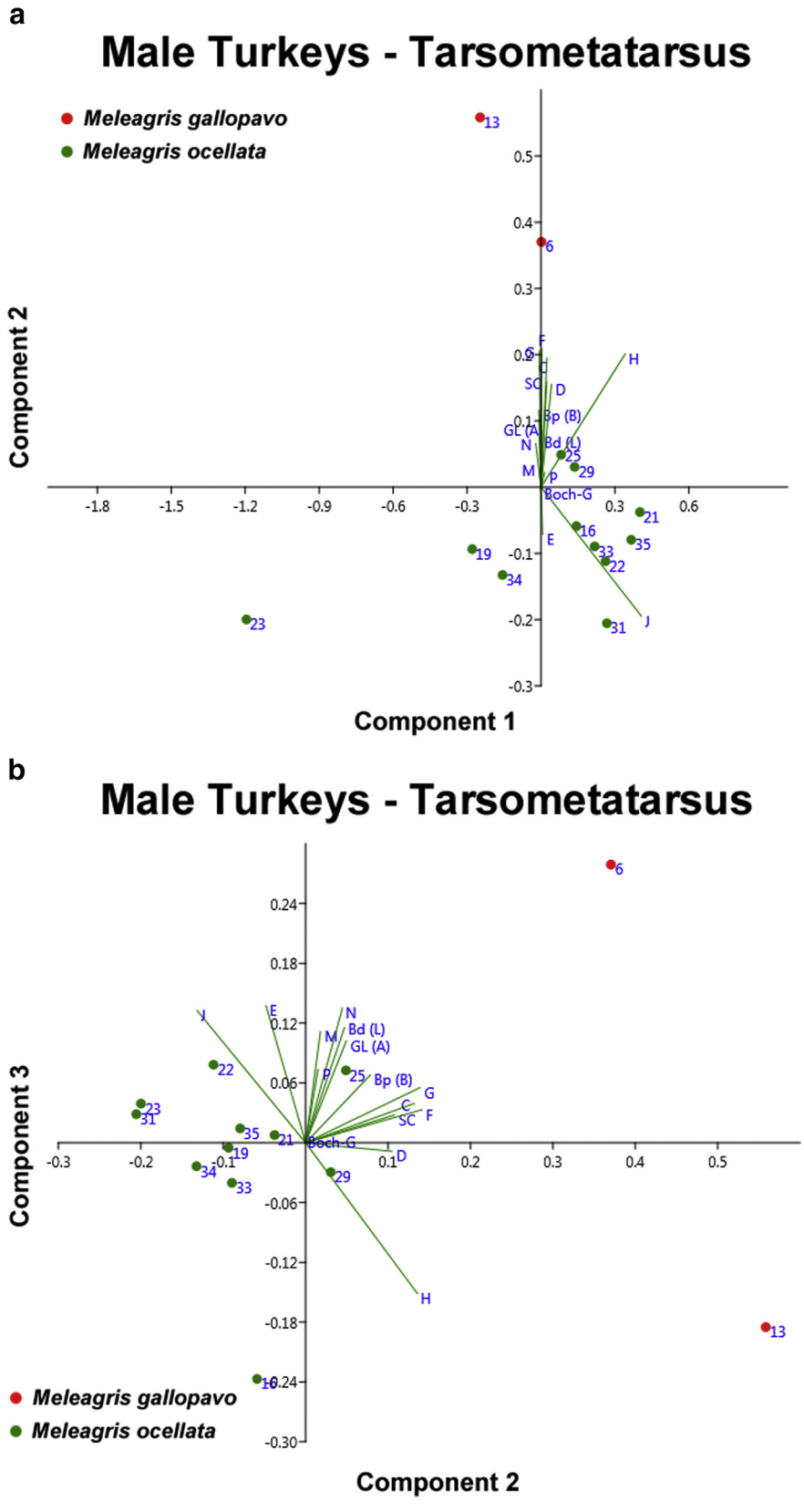

Fig. 14. a: PCA male meleagrid tarsometatarsi, components 1 and 2. Note that only two specimens of *M. gallopavo* are used in the comparison. b: PCA male meleagrid tarsometatarsi, components 2 and 3.
Figures by Sharpe.

markers for metric analysis, unfortunately, are most often the distal and proximal portions. However, in the archaeological galliform sample, this is not always the case. The proximal portions of the coracoid, radius, and particularly scapula, are fairly well represented and even distal portions (though not final distal ends) are fairly well represented in the humerus, tibiotarsus, and tarsometatarsus. Least well represented are the

Table 7
Number of archaeological element specimens subjected to metric and/or morphological study. Since the overall proportion of elements is roughly equivalent to normal skeletal distribution, this distribution is assumed to represent the proportion of measurable elements in each category.

Element	Metric analysis		Morphological	
	#	%	#	%
Radius	48	2.26	26	2.22
Scapula	73	3.44	38	3.25
Carpometacarpus	132	6.22	79	6.76
Coracoid	170	8.02	99	8.47
Femur	202	9.52	124	10.61
Humerus	263	12.40	115	9.84
Ulna	345	16.27	198	16.94
Tibiotarsus	427	20.13	191	16.34
Tarsometarsus	461	21.74	275	23.52
Phalanx 1	–	–	24	2.05
Total/% of total N = 2380	2121	89.12	1169	49.12

Note: metric analysis for phalanx is not included in this evaluation.

distal end of the scapula, the proximal end of the tibiotarsus and both ends of the ulna. (See Table 8.)

We can compare the archaeological preservation patterns with our morphometric assessments to generate some preliminary statements regarding what element portions have the best potential for morphometric species and sex identification in archaeological assemblages. For example, the most abundant element, the tarsometatarsus, is typically best preserved in the distal portion, where fortunately there are several morphological characters that can be used for species distinction (as well, of course, as the spur which can define sex). Osteometric analysis of the tarsometatarsus appears to separate well between galliform taxa and sexes among the meleagrids, but the separation is based on two measures that are typically problematic with fragmentary elements: the greatest length and least width of the shaft. Metric analysis of the femur can also be used to separate both galliform taxa and meleagrid species and sexes. It is less frequently found in the archaeological collection, and the portion typically recovered is the distal end, which unfortunately lacks any effective morphological traits for identification. The metric traits as well could be problematic with fragmentary elements since most require recognition of the mid shaft or smallest diameters of the shaft. The coracoid is perhaps the most diagnostic element and it is also the most accurately identified using this group of morphological characters (97%), but it is unfortunately not as common in the archaeological assemblage. This element is best preserved at the proximal end and there are several good characters for identification in this area of the element. Most of the metrics require complete elements, however, and all those for distinguishing sex are found at the distal end. Taphonomic factors may therefore greatly affect zooarchaeologists' ability to accurately apply many morphometric traits for taxonomic and sex identification, which have been generated using modern comparative specimens.

8. Discussion and conclusions

Zooarchaeologists are faced with a dilemma in the identification of osteologically and metrically similar taxa, particularly when the taxa are sexually dimorphic and morphologically variable across populations and individuals. We are dependent on our comparative collections, which despite our best efforts, can never be truly representative of the full range of intraspecific variation. Quite often, these are limited to one or at most two specimens of a single taxa. We can also draw on the literature for the metric and osteological characters used by neontologists, but quite often these are very limited since neontological specimens are more often described on the basis of soft tissue characters and measures. Even in cases where osteological studies do exist, these are sometimes dependent themselves on small sample sizes and on specimens drawn from single geographic regions. The use of small numbers of individuals, or geographically circumscribed samples, results in character trait lists that are not necessarily applicable to all individuals, a fact that is sometimes not recognized by zooarchaeologists reliant on the trait lists for identification of problematic taxa. Another fact that is often not recognized is that trait expression is rarely 100% even for the most clearly distinguishable taxa. Neontologists do sometimes publish their ranked trait lists with expression proportions, but because molecular research is now at the forefront, fewer and fewer taxonomic distinction publications even include character traits among the DNA data unless it is in a compiled version used for statistical analysis of taxonomic relatedness.

In our research on the galliforms of the Maya world, all of this is definitely true. Steadman (1980:132) notes that his sample of 16 *M. gallopavo* and seven *M. ocellata* provided more effective characters for separation than did smaller samples analyzed by earlier researchers. Bochenski and Campbell's (2006) comparative collection was much more substantial including 51 specimens from the Ornithology Collections of the Natural History Museum of Los Angeles County. However, we suggest that even these sample sizes might be insufficient when compared to the variation found between geographically separated populations, particularly of taxa such as the turkeys that are known to have been husbanded and/or domesticated, perhaps in multiple locations and events, through their osteological evolution.

In this study, we strive to evaluate the combined morphological and metric traits used by ornithologists in order to recommend a suite of accurate and useful diagnostic tools for the zooarchaeological analyst. This goal requires that we also carefully evaluate our own methods to ensure data consistence and accuracy throughout. We have evaluated both osteological traits and metrics through repeated back-testing and blind-testing, and we have used statistical tests to describe the variation in our measures and evaluate the extent to which different diagnostic characters can accurately predict taxa. This work is on-going and our sample sizes are still lower than we feel will be necessary to ensure real accuracy in understanding trait expression across space and time for the turkeys. Our evaluation of the archaeological samples used in

Table 8
Proportion of diagnostic zones for all galliform elements as a proportion of total number of individual specimens (NISP) analyzed. Shorter elements have fewer zones. Note that because most elements were analyzed for diagnostic zone representation, the number of specimens for this analysis is higher than either of the counts for those subjected to metric or morphological analysis.

		Proximal							Distal
	NISP	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8
Coracoid	170	60.29	75.92	73.05	50.74	44.71	37.06	30.44	
Scapula	73	84.59	88.70	65.07	35.62	20.21	4.79		
Humerus	263	22.72	30.61	53.80	61.31	65.49	64.92	48.19	27.66
Ulna	345	16.30	41.67	78.55	80.36	76.74	42.83	18.26	
Radius	48	60.94	64.06	52.60	41.67	41.67	56.25	44.79	
Carpometacarpus	132	59.28	68.94	60.04	53.22	50.19			
Femur	202	37.38	52.48	59.28	70.54	70.79	41.09		
Tibiotarsus	427	11.07	23.13	28.04	37.88	74.82	69.73	48.89	
Tarsometatarsus	461	24.46	38.18	34.54	40.13	38.83	59.82	63.67	45.66

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our study gives us a foundation for considering the best evaluation means for identifying both taxa and sex among the galliforms. These sorts of correlations, still preliminary here, will hopefully allow us to create a solid recommendation for best evaluative mechanisms for any turkey element or portion thereof that is recovered at a Maya archaeological site. However, these preliminary studies have also revealed a number of cautions about the identification characters and metrics we hope to evaluate. One of these is the need for large samples of modern birds from a range of areas to properly understand individual variation. In our comparison of morphological traits between the Yucatan and US/Petén birds, we found several traits that expressed quite differently in the Yucatan birds than in our overall assemblage. These were found in both upper and lower limb elements. This finding emphasizes the importance of reviewing more of the Mesoamerican modern birds to explore the diversity in character expression across geographic space. It is possible that some of this variation could be attributed to different husbandry and breeding histories for both the *M. gallopavo* and *M. ocellata* in separate regions since, although the birds were likely traded on occasion, for the most part, the populations from one area would not have mixed extensively with those from another, even within the relatively small Maya world.

We found more variation in sexual dimorphism among the birds than we had expected from the literature. We find that both turkeys show more sexual dimorphism than the curassow, and we suggest that the broad range of sizes in the *M. gallopavo* females in most elements, and particularly wing elements, and thus greater phenotypic variation in this bird, is perhaps indicative of phenotypic plasticity inherent in the meleagrids and possibly encouraged in the husbandry/domestication process. This is based on a very small dataset and suggests a worthy direction for future study.

We are also surprised to find that even modern ornithological collections are not as accurate in definition of sex and age as we might expect. Several cases our PCA tests suggested that the sex of individuals was either misidentified or misrecorded, or in cases where sex was not recorded, the PCA results were able to suggest the sex of the specimen. It is therefore essential that comparative specimens be carefully evaluated for sex identification, particularly in the case of older specimens collected when such details were not given as much attention as they are today. As well, we find that age will be a complicating factor particularly in the analysis of birds. Birds can be osteologically recognized as fledglings and as juveniles, but the subadult phase often does not have any osteological expression. We removed all birds that were osteologically recognizable as juveniles, but found that individuals identified as subadults often lay on the margins of the PCA clusters created by the assemblage as a whole. This suggests the importance of such statistical evaluations of metrics to clarify age stages beyond those identifiable on the bones themselves and of ensuring that such evaluations are published alongside results (Atici et al., 2012; Driver, 2011; Wolverton, 2013).

In sum, these studies emphasize the value of detailed assessment of the characters and metrics used by zooarchaeologists in identifying difficult-to-distinguish species, and quality testing of the variation, reproducibility and accuracy of the use of these traits by various analysts.

Supplementary data to this article can be found online at http://dx.doi.org/10.1016/j.jasrep.2016.08.018.

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References

Atici, L., Kansa, S.W., Lev-Tov, J., Kansa, E.C., 2012. Other people's data: a demonstration of the imperative of publishing primary data. Archaeol. Method Theory 20 (4), 663–681.
Blumenschine, R.J., Marean, C.W., Capaldo, S.D., 1996. Tests of inter-analyst correspondence and accuracy in the identification of cut marks, percussion marks, and carnivore tooth marks on bone surfaces. J. Archaeol. Sci. 23, 493–507.
Bochenski, Z.M., 2008. Identification of skeletal remains of closely related species: the pitfalls and solutions. J. Archaeol. Sci. 35, 1247–1250.
Bochenski, Z.M., Campbell, K.E., 2005. The Identification of Turkey Remains to Species - a Metrical Approach. In: Grupe, G., Peters, J. (Eds.), Feathers, Grit and Symbolism: Birds and Humans in the Old and New Worlds. Verlag Marie Leidorf GmbH, Rahden/Westfalen, pp. 19–25.
Bochenski, Z.M., Campbell, K.E., 2006. The Extinct California Turkey, *Meleagris californica*, from Rancho La Brea: Comparative Osteology and Systematics. 509. Contributions in Science, Natural History Museum of Los Angeles Country, pp. 1–92.
Bochenski, Z.M., Tomek, T., 2000. Identification of bones of galliform hybrids. J. Archaeol. Sci. 27, 691–698.
Brodkorb, P., 1964a. Catalogue of fossil birds: part 2 (Anseriformes through Galliformes). Bull. Fla. State Mus. 8 (3), 195–335.
Brodkorb, P., 1964b. Notes on fossil turkeys. Q. J. Florida Acad. Sci. 27 (3), 223–229.
Camacho-Escobar, M.A., Jiménez-Hidalgo, E., Arroyo-Ledezma, J., Sánchez-Bernal, E., Pérez-Lara, E., 2011. Historia Natural, Domesticación y Distribución del Guajalote (*Meleagris gallopavo*) en Mexico. 27. Universidad de Ciencia, pp. 352–360.
Corona, M.E., 2008. Las Aves Como Recurso Curativo en el Mexico Antiguo y sus Posibles Evidencias en la Arqueozoologia. Archaeobios 2 (1), 11–18.
Corona, M.E., 2013. Birds of the Pre-Hispanic Domestic Sphere of Central Mexico. In: Gotz, C., Emery, K.F. (Eds.), The Archaeology of Mesoamerican Animals. Lockwood Press, Atlanta, GA, pp. 81–94.
Driver, J.C., 2011. Identification, classification and zooarchaeology. Ethnobiol. Lett. 2, 19–39.
Dyke, G.J., Gulas, B.E., Crowe, T.M., 2003. Suprageneric relationships of galliform birds (Aves, Galliformes): a clasdistic analysis of morphological characters. Zool. J. Linnean Soc. 137 (2), 227–244.
Frank-Hoeflich, K., Silveira, L.F., Jesús, E.-L., García-Koch, A.M., Ongay-Larios, L., Piñero, D., 2007. Increased taxon and character sampling reveals novel intergeneric relationships in the Cracidae (Aves: Galliformes). J. Zool. Syst. Evol. Res. 45 (3), 242–254.
Gobalet, K.W., 2001. A critique of faunal analysis: inconsistency among experts in blind tests. J. Archaeol. Sci. 28, 377–386.
Hale, E.B., Schein, M.W., 1962. The Behavior of Turkeys. In: Hafey, E.S.E. (Ed.), The Behavior of Domestic Animals. Bailliere, Tindell and Cox, London, UK, pp. 531–564.
Hammer, Ø., Harper, D.A.T., Ryan, P.D., 2001. PAST: paleontological statistics software package for education and data analysis. Palaeontología Electronica 4 (1), 1–9.
Howard, H., 1927. A Review of the Fossil Bird *Parapavo californicus* (Miller) from the Pleistocene Asphalt Beds of Rancho La Brea. 17. University of California Publications in Geological Sciences, pp. 1–56 (1).
Kockelman, P., 2011. A Mayan ontology of poultry: selfhood, affect, animals, and ethnography. Lang. Soc. 40 (4), 427–454.
McCuaig Balkwill, D., Cumbaa, S.L., 1992. A Guide to the Identification of Postcranial Bones of *Bos taurus* and *Bison bison*. Canadian Museum of Nature Syllogeus No. 71. Canadian Museum of Nature, Ottawa, ON.
Morey, D.F., 2014. In search of Paleolithic dogs: a quest with mixed results. J. Archaeol. Sci. 52 (300–307).
Nimis, M.M., 1982. The Contemporary Role of Women in Lowland Maya Livestock Production. In: Flannery, K.V. (Ed.), Maya Subsistence: Studies in Memory of Dennis E. Puleston. Academic Press, New York, pp. 313–326.
Olsen, S.J., 1968. Fish, amphibian, and reptile remains from archaeological sites, with an appendix on the osteology of the turkey. Papers of the Peabody Museum of Archaeology and Ethnology 56 (2). Harvard University, Cambridge, MA.
Owen, J., Dobney, K., Evin, A., Cucchi, T., Larson, G., Vidarsdottir, U.S., 2014. The zooarchaeological application of quantifying cranial shape differences in wild boar and domestic pigs (*Sus scrofa*) using 3D geometric morphometrics. J. Archaeol. Sci. 43, 159–167.
Pohl, M.D., 1983. Maya Ritual Faunas: Vertebrate Remains from Burials, Caches, Caves, and Cenotes in the Maya Lowlands. In: Leventhal, R.M., Kolata, A.L. (Eds.), Civilization in the Ancient Americas: Essays in Honor of Gordon R. Willey. University of New Mexico Press, Albuquerque, N.M, pp. 55–103.
Pohl, M.D., Feldman, L.H., 1982. The Traditional Role of Women and Animals in Lowland Maya Economy. In: Flannery, K. (Ed.), Maya Subsistence. Academic Press, New York, pp. 295–311.
Rea, A.M., 1980. Late Pleistocene and Holocene Turkeys in the Southwest. Contributions in Science, Natural History Museum of Los Angeles County. 330 pp. 209–224.

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Schorger, A.W., 1966. The Wild Turkey: Its History and Domestication. University of Oklahoma Press, Norman.
Serjeantson, D., 2009. Birds. Cambridge Manuals in Archaeology, Cambridge, GB.
Sharpe, A., 2014. A reexamination of the birds in the central Mexican codices. Anc. Mesoam. 25 (2), 317–336.
Shufeldt, R.W., 1914. On the skeleton of the ocellated Turkey (*Agriocharis ocellata*) with notes on the osteology of other Meleagrididae. Aquila 21, 1–52.
Steadman, D.W., 1980. A review of the osteology and paleontology of turkeys (Aves: Meleagridinae). Contributions in Science 330. Natural History Museum of Los Angeles County, Los Angeles.
Steadman, D.W., Stull, J., Eaton, S.W., 1979. Natural History of the Ocellated Turkey. 4. World Pheasant Association, pp. 15–37.
Thornton, E.K., Emery, K.F., Speller, C., Steadman, D., Matheny, R., Yang, D., 2012. Earliest Mexican turkeys (*Meleagris gallopavo*) in the Maya region: implications for pre-Hispanic animal trade and the timing of Turkey domestication. PLoS One 7 (8), e42630.
Tozzer, A.M., 1941. Landa's Relacion de las Cosas de Yucatan. Harvard University, Papers of the Peabody Museum of American Archaeology and Ethnology. 18 (Cambridge MA).
Tozzer, A.M., Allen, G.M., 1910. Animal Figures in the Maya Codices Papers of the Peabody Museum. 4. Harvard University, Cambridge, MA (No. 3).
Valadez, Azúa, Raúl, 2003. La domesticación animal. Editoriales Plaza y Valdez, México.
von den Driesch, A., 1976. A Guide to the Measurement of Animal Bones from Archaeological Sites. Peabody Museum of Archaeology and Ethnology Bulletin 1Harvard University, Cambridge.
Williams, L.E., Bauer, E.H., Eichholz, N.F., 2010. The Ocellated Turkey in the Land of the Maya. Real Turkeys Publishers, Cedar Key, FL.
Wolverton, S., 2013. Data quality in zooarchaeological faunal identification. Archaeol. Method Theory 20, 381–396.
Zeder, M.A., Lapham, H., 2010. Assessing the reliability of criteria used to identify postcranial bones in sheep, *Ovis*, and goats, *Capra*. J. Archaeol. Sci. 37, 2887–2905.
Zeder, M.A., Pilaar, S.E., 2010. Assessing the reliability of criteria used to identify mandibles and mandibular teeth in sheep, *Ovis*, and goats, *Capra*. J. Archaeol. Sci. 37, 225–242.

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