Prehistoric and historical insights in avian zooarchaeology, taphonomy and ancient bird use

Frank J. Dirrigl Jr¹ · Timothy Brush¹ · Arturo Morales-Muñiz² · László Bartosiewicz³

Received: 6 August 2019 / Accepted: 14 January 2020 / Published online: 29 January 2020
© Springer-Verlag GmbH Germany, part of Springer Nature 2020

The study of bird bones from archaeological sites, ornithoarchaeology or avian zooarchaeology/archaeozoology focuses on the study of past bird-human relationships (Davis 2012; Morales-Muñiz 1993; Reitz and Wing 1999; Bartosiewicz 2001, 2008; Serjeantson 2009). Studies of bird remains in prehistory and history or avian zooarchaeology appear in many contexts, including as musical instruments (Morejohn and Galloway 1983), cultural symbols, art and iconography (David 1989; Sparkes 1997), tools (Olsen 1979), adornment with feathers (Berdan 2006), food (Peterson 1973), ethnology (Rea 2007) and medicine (Bezerra et al. 2013). Bird bone identification and chronicling domestication history demands the development of studies in comparative osteology (Cohen and Serjeantson 1996; Gilbert et al. 1996), pathology (Shufeldt 1893; Brothwell 2002; Gál 2008a, 2008b, 2013) and identification and ancient DNA studies (DeCupere et al. 2005; Camilla et al. 2010). Depositional histories, preservation biases and distinguishing of cultural from noncultural modification rely on taphonomic investigations (Bickart 1984; Ericson 1987; Livingston 1989; Bocheński 2002; Bovy 2002). All these topics are of research interests that can involve field excavation, actualistic study or experimentation, and ethnoarchaeology and ethnographic evidence, as well as laboratory analysis (Serjeantson 1998; Best and Mulville 2013; Soma 2013; Gomes 2016).

Treatises addressing the topic of avian zooarchaeology include Grigson and Clutton-Brock (1983), Purdue et al. (1991) and Serjeantson (2009) and works presented at the Bird Working Group (BWG) Meetings of the International Council for

Archaeozoology (Serjeantson 1994; *Archaeofauna* 1993(2); *International Journal of Osteoarchaeology* 1997(7); *Acta Zoologica Cracoviensia* 2002(45, special issue); Grupe and Peters 2005a; Prummel et al. 2010; Bejenaru and Serjeantson 2014). In January 2016, the 8th BWG Meeting was held at the University of Texas Rio Grande Valley (UTRGV), Edinburg, TX, USA. The meeting was hosted by the Department of Biology, College of Sciences, and the Office of Sustainability. Researchers from Australia, New Zealand, Japan, the UK, the USA, Mexico, France and Argentina gathered to present findings and participate in birding events. The Lower Rio Grande Valley (Starr, Hidalgo, Cameron and Willacy counties) provides habitat supporting about 520 resident, migratory and rare bird species, almost half of the 1114 recorded occurring in the USA as a whole. The presence of many tropical bird species encourages birders to visit in large numbers. Regional ecotourism that includes birding generated (as of ca. 2010) more than \$300 million in local yearly revenue (Woosnam et al. 2011; Leslie 2016). We review the articles resulting from this first meeting in the USA and place them in contexts of taphonomy, hunting and domestication, and prehistoric and historic bird use.

Taphonomy

Bird bone biology challenges the preservation and recovery of skeletal elements from archaeological sites. Bird bone reflects adaptations to flight, except for flightless birds, and egg laying through (1) structural matrix (e.g. trabecula), (2) relatively

This article is part of the Topical Collection on *Avian Zooarchaeology: Prehistoric and Historical Insights*

✉ Frank J. Dirrigl, Jr
frank.dirrigl@utrgv.edu

Timothy Brush
timothy.brush@utrgv.edu

¹ Department of Biology, University of Texas Rio Grande Valley,
1201 W University Drive, Edinburg, TX 78539, USA

² Laboratorio de Arqueozoología, Universidad Autónoma de Madrid,
E-28049 Madrid, Spain

³ Osteoarchaeological Research Laboratory, University of Stockholm,
Stockholm, Sweden

high bone density and low thickness, (3) pneumatization and (4) medullary bone (Dacke et al. 1993; Cubo and Casinos 2000; Dumont 2010; Doube et al. 2011). Bird size may also challenge bone recovery, for many species are small and may only be retrieved through water-sieving and fine screening (Clason and Prummel 1977). This is not a standard practice in many excavations, especially during rescue work where time and resources are limited (James 1997). However, bird remains can be frequently recovered from carefully collected soil core samples and even from archaeobotanical assemblages (Ramsay et al. 2016). Taphonomic research on the preservation, recovery and representation of bird bones continues to be of interest to archaeologists. In this special issue, taphonomic research is found in the contributions of Dirrigl et al., Tellkamp, and Hawkins et al.

Dirrigl et al. (this issue) examine the effects of salinisation of bird bones, by exposing bird wing bones to laboratory conditions simulating salt lake substrate and overlying salt water. They exposed domestic chicken humeri, ulnae and radii to simulated salt lake conditions for up to 32 weeks. Data gathered included bone mineral content from ashed bone and chemical concentrations and element to phosphorus ratios using inductively coupled plasma optical emission spectroscopy (ICP-OES). Their results demonstrated that in salt lake environs, exposed wing bones increased significantly in bone mineral content, which indicated that wing bones most likely became stronger. Additionally, they found the ionic concentrations of Ca^{2+} , K^+ , Mg^{2+} , Na^+ , P^{5+} , Si^{2+} and Si^{4+} , except Fe^{3+} , to change significantly among all wing bones with saline exposure. Changes in bone mineral content and ion concentration took place in as little as 4 weeks. Element to phosphorus ratios suggested that in an ionic substitution, where Mg^{2+} replaced Ca^{2+} , occurred in bird bone, which further became Na^+ -enriched when exposed to the mimicked saline lake conditions. Their contribution would be important to consider in future stable isotope and x-ray fluorescence studies that include bird bones recovered from sedimentary contexts of saline soils, flooded coastal marine sites, remnant saline lakebeds and geographical areas sensitive to airborne salt drift (Grupe and Peters 2005a; Buddhachat et al. 2016).

Screening or sieving bias of archaeological bone has long been recognised by zooarchaeologists; however, studying the effect of screening on bird bone is less common (Steward and Wigen 2003; Gordon 1993; see also review in Lyman 2012). Tellkamp (this issue) offers new insights into the importance of using 1/8 in. (3.175 mm) or finer mesh to recover Passeriformes (songbirds) and Columbiformes (doves) from archaeological sites. Using bird bone data from three Ecuadorian sites in the Santa Elena Peninsula, the researchers found that the differences among sites for Passeriformes and Columbiformes bones recovered reflected taphonomic, screening and resource use by Guangala peoples across four cultural phases. The unusual abundance of these taxa perhaps reflects a prehistoric specialisation of small bird hunting, later forest conversion with agricultural

intensification and Ecuadorian coastal paleoecology. Tellkamp's findings provide continued evidence for bird exploitation that includes hunting specialisation on small songbirds during past prehistoric droughts.

Cave assemblages containing bird bones are evidence of raptor predation and human consumption. However, it is often difficult to distinguish one from the other (Bocheński and Tomek 1997; Gál 2008b; Blasco and Peris 2009; Peresani et al. 2011). On the island portion of Timor-Leste (East Timor), Hawkins et al. (this issue) investigate excavated bird remains from a cave and examined the bones for modification and digestion patterns. Quail (Galliformes represented by *Cortunix* and *Turnix*) and songbirds (Passeriformes) dominated among the 730 bird bones. The assemblage exhibited bone breakage potentially from owl consumption or post-depositional processes, pitting and corrosion from owl digestion and minor discoloration not originating from food preparation or disposal (i.e. cultural burning). Additionally, the data support a higher survivorship for sternum, wing and leg bones. Hawkins et al. suggest that the evidence demonstrates a prehistoric episode, where Pleistocene Laili peoples did not hunt commonly for birds. These findings are relevant in the discussion of avian extinction events and the role of prehistoric peoples. Because the bird bone assemblage is attributed to owl predation, Hawkins et al. heed caution to other researchers interpreting human behaviour from cave archaeofaunal deposits and recommend continued taphonomic examination.

Hunting and domestication

Birds play an important role in ancient economies and culture (Serjeantson 2006; Twiss 2012). Beyond hunting and seasonal exploitation of birds among terrestrial and aquatic habitats, fowling and domestication reflect people-bird interactions and selection (Shrubb 2013). Fowling differs from hunting or husbandry of large mammals and livestock in techniques and social meaning (Nørrevang 1986). Specific aspects of using birds may be reflected in patterns of consumption most directly represented by food refuse and ritual deposits of birds having presumed symbolic meaning (Benn 1989). Relationships between hunting and meat utility are investigated more often for mammals, such as white-tailed deer, caribou, guanaco and seal (Binford 1978; Lyman et al. 1992; Madrigal and Holtz 2002; Borrero 2014).

Giardina's (this issue) research provides needed bird economic utility indices for the Rheidae (rhea family), and compares his rhea data with other flightless ratites, such as the emu (*Dromaius novaehollandiae*) and kiwi (Apterygidae) previously reported (Kooyman 1990; Garvey et al. 2011). In addition to determining the meat utility index (MUI) of *Rhea pennata* (Darwin's rhea), Giardina also provides the marrow index (MI), white grease index (WGI) and general utility (GUI) indices. He found the pelvis and sacrum followed by the proximal tibiotarsus and distal femur to have the greatest

MUI. Comparatively, the proximal and distal tibiotarsi reflected the maximum marrow index (MI). Similar to the MUI, the pelvis and sacrum had the greatest WGI followed by the sternum, proximal tibiotarsus and distal femur. Finally, he calculated the $GWI_{\text{standardised}}$ and modified general meat utility (MGUI), finding the greatest values in the pelvis and sacrum followed by the proximal tibiotarsus and distal femur. Giardina also properly considers the effects of bone mineral density previously reported (Cruz and Elkin 2003) and found a positive correlation. His investigation demonstrates how his rhea economic utility indices can be used to examine archaeological assemblages to infer hunting and transportation for other ratites based on utilisation rather than meat weight.

The class Aves is taxonomically far more diverse than the group of mammals routinely identified at archaeological excavations worldwide (Bartosiewicz and Gál 2007). Thus, the zoological identification of bird bones and recognition of morphological evidence for domestication pose logistic problems (MacDonald 1992). Domestic chicken research necessitates accurate dating of assemblages, comparative osteology and cross-comparisons among sites. Eda et al. (this issue) study Neolithic and Bronze Age sites in the Zhejiang Province, China. Their work reflects each of these demands in the examination of bird remains. Particularly, they examined the Tianluoshan site located along the lower Yangtze river to determine the evidence for chicken (*Gallus Gallus domesticus*) domestication from wild red jungle fowl (*G. gallus*). This examination focused on comparing the morphology and metrics of a single recovered Phasianidae (pheasants and fowl) scapula to those of modern specimens. Eda et al. adopted the proper conservative identification approach to determine that the scapula could possibly be from six different Phasianidae species. With the low representation of Phasianidae at the site among 11 avian families and 10 orders, the results contradict other researchers' suggestions for early Holocene exploitation of domestic chicken. Moreover, they found no evidence of red jungle fowl northward expansion during the Early and Middle Holocene.

Prehistoric and historic bird use

Prehistoric, historic and ethnographic examples of bird use and people-bird relationships are useful in cross-validating archaeological interpretations between different geographic regions and time periods (Murty 1981; Makowiecki et al. 2014). These interpretations often transcend basic bird use for food. Beyond Egyptian burials, purposeful bird carcass interment with people in burials in Eastern and Western Europe, Russia and North America is repeated (Ubelaker and Wedel 1975; Lauwerier 1993; Mannernmaa 2008; Mannernmaa et al. 2008; Kristensen and Holly 2013; Baron 2018a, 2018b). Bird remains in an archaeological site can also indicate distinguished social status. For example, hawking

evidence not only identifies bird-people intimate relationships but also infers status based on bird species and sex kept (Dobney and Jaques 2002).

Ledogar et al. (this issue) reported on bird remains found in association with a cemetery from the Eneolithic in western Ukraine. Most bird remains were of wild species that were probably eaten, such as black grouse (*Tetrao tetrix*) and common quail (*Coturnix coturnix*), but also the domestic chicken (*Gallus gallus*). Chickens may have occurred due to movements of nomads from the northern Black Sea area or (controversially) due to early domestication in what is now western Ukraine. Very few waterbirds were found, perhaps due to the site's location away from major wetland/riverine environments. Most species are characteristics of woodland or grassland habitats and still occur regularly in the area. Some birds of prey were found. However, at least for owls, these may have originated from individuals using the caves as roosting or nesting sites. Overall, the abundance of bird remains from galliform birds suggests that the site represents a mortuary feast, although other uses could not be ruled out.

Kysely and Meduna (this issue) analysed the early archaeological and historical evidence of Turkey (*Meleagris gallopavo*) in what is now the Czech Republic. Turkeys were probably introduced into the area by the later 1500s, after explorers and traders brought them back from the Americas (probably from Mexico). Evidence suggests that serving exotic turkey at feasts was an indication of high social status for royalty and important politicians. Turkeys were soon bred domestically, at first by the wealthy, and much later by diverse landowners. Turkeys replaced peafowl (*Pavo cristatus*), which had been consumed since the twelfth century, as the former became more commonly available.

Goffette et al. (this issue) analyse bird remains from a wide variety of archaeology sites across modern-day Belgium, from the Iron Age onward. Widely varying numbers and types of sites prevented a systematic presentation of trends in bird species or their groups, but important trends can be seen. Domestic chickens (*Gallus*) were abundantly represented, indicating their use even as early as the Roman period. Greylag geese (*Anser anser*) and mallards (*Anas platyrhynchos*) were also commonly present, but it was difficult to determine which were caught in the wild versus being domesticated. Other species, including geese and galliform birds, such as human-raised turkey, peafowl and pheasant, were less abundant, as was the wild grey partridge (*Perdix perdix*). Among other bird groups, corvids were most frequent, probably reflecting the greater likelihood of recovering bones of these large-bodied passeriformes since sieving was not always done. A wide variety of other birds, including many passerines, were found and the trends generally follow proportions in the current avifauna, with some exceptions.

Large birds of prey, such as the white-tailed eagle (*Haliaeetus albicilla*), often serve as charismatic

representatives of bird communities and as indicators of ecosystem health. Zeiler (this issue) documents the changing status of the white-tailed eagle in the Netherlands. In the relatively intact ecosystems with low human populations of the Neolithic, white-tailed eagles were regularly hunted for food and possibly ceremonial uses. Hunting pressure seems to have increased in the Roman period, and then eagle populations likely declined during the Medieval period, probably due to human population growth and altered habitats. Persecution, encouraged by authorities, likely caused continued declines of white-tailed eagles as the human population grew, and the species was slow to recover, with a significant increase in wintering birds especially after DDT was banned in the 1970s. Currently, the small breeding population is carefully protected and is viewed as a symbol of *primaeva* nature.

Russell (this issue) analyses the birds remains from the archaeologically well-known Neolithic site of Çatalhöyük in central Turkey. Although many birds were likely taken for food, the data suggest that many were exploited for ceremonial reasons. Particularly, vulture feet were well-represented, likely indicating their symbolic importance. Many wetland birds such as geese, ducks, herons and egrets were killed, probably reflecting both their dietary and ceremonial significances and the proximity of the settlement to a significant wetland, no longer present. Human-associated species such as white storks (*Ciconia ciconia*) were not well-represented, but scavenged feathers may have been used ceremonially. Other large birds, such as great bustards (*Otis tarda*), were taken in numbers suggesting their past abundance in pristine steppe habitat, while currently shrinking populations reflect the intensive human use of steppes. Although some common species were not well-represented, the avian remains generally reflected the diverse bird communities in the Çatalhöyük area functioning as an important wintering site, breeding site and migratory stopover in central Anatolia.

Leonardi and Sutton (this issue) tackles the taxonomic and nomenclatural history of the Lanner Falcon (*Falco biarmicus*), a large falcon traditionally placed in the subgenus *Hierofalco*, along with Gyr Falcon (*F. rusticolus*) and Saker Falcon (*F. cherrug*). Interestingly, it is the third most frequently mummified bird in Egypt. The bird's easy training in falconry prompted the word 'lanier' to be associated with cowardice, even by the emperor Frederick II, who brought birds back from the Crusades. Leonardi reports that there was some confusion with Saker Falcon due to similarity in plumage and overall size. *Falco lanarius* was sometimes used as scientific name for the Lanner Falcon, based on earlier behavioural descriptions, not on the softness of the plumage. The description of Lanner Falcon by Linnaeus more closely matched the Gyr Falcon. There was confusion about their geographic range and taxonomy in Europe into the 1800s, cleared up by Strickland (1840), who named the species *F. biarmicus*. Confusion about subspecies limits and validity was cleared

up somewhat by Hartert (1912, 1915), but concerns remain. Overall, Leonardi reports the Lanner Falcon is a polytypic species with several disjunct breeding populations in Mediterranean Europe and Asia Minor, in need of genetic and morphological analyses including closely related Gyr Falcon and Saker Falcon. Leonardi's work compliments the extensive literature regarding falconry (Gersmann and Grimm 2018).

Prospects

Future avian archaeology research should continue to address how people globally hunted and used birds, as well as questions concerning their domestication, osteology, identification and taphonomy. Whereas archaeological sites provide information to interpret past bird use, ethnographic accounts that include both gender- and age-related observations constitute oft-neglected tools for ornithoarchaeologists that will continue to prove useful (Hollmann 2005; MacDonald 2007; Smith et al. 2009). Equally important is the archaeologist's ability to interpret bird use and distinguish between cultural versus non-cultural bird bone deposits (Laroulandie 2005). Determining the evidence for bird domestication even beyond gallinaceous birds shares equal value, for which genetic evidence has advanced understanding of events (Birkhead et al. 2004; Kanginakudru et al. 2008; Speller et al. 2010; Eda et al. 2016).

Reports on bird bone osteology, comparative morphology and measurement, identification and taxonomic distinction is essential to avian archaeology (Morales-Muñiz 1993; Stewart and Carrasquilla 1997; Bocheński and Tomek 2000; Wojcik 2002; Tomek and Bocheński 2009). This is particularly problematic with ageing bird bones. For example, the recognition of fowling and stockbreeding practices to age group (i.e. cohort) is coarse at best (Lefèvre 1997). Bird skeletons lack teeth and independent fusion centres on limb bones, precluding calendars such as those that exist for mammals (Wolfson 1955; Louchart and Viriot 2011; Sullivan et al. 2017). Further research would assist in reporting immature from adult birds and hunting targets could prove helpful in explaining past extinctions and local population crashes (Duncan et al. 2002; Serjeantson 2002).

Likewise, expanded osteological collections that provide chick to adult specimens of known age are vital to developing ontogenetic measurement tables (Picasso 2012; Watanabe and Matsuoka 2013) and generating sexual dimorphism data, although bone measurements may limit sexual distinctions, taxonomic identifications or phenotypic size distinctions among small birds (Rising and Somers 1989; Hutt 1929). With restrictions on exporting reference specimens and archaeological finds (Lindsay 1990; Renner et al. 2012), the future development of bird osteological collections should incorporate 3D

bone scans and other digital resources (Estevez et al. 2002; Causey and Trimble 2005; see Aves 3D at <https://aves3d.org>).

In addition to stable isotope analysis, advances in the use of ancient DNA (aDNA) and zooarchaeology by mass spectrometry (ZooMS) to fingerprint birds continue to be a research area worthy of focus as existing methods are improved and new extraction and replication procedures are developed to distinguish phenotypically similar taxa (Barnes et al. 2000; Herrmann and Hummel 2012; Collins et al. 2010). Recently, advances in using peptide markers in bird eggshell and geometric morphometrics show promise in distinguishing wild from domestic fowl and breeds within chicken populations (Stewart et al. 2013, 2014; Presslee et al. 2017).

Further taphonomic studies will increase researchers' understanding of the factors that affect the preservation, recovery and analysis of bird bone. Similar to mammal-based 'mainstream' research in zooarchaeology, specialist knowledge is needed regarding taphonomy, taxonomy and archaeological interpretations. Neotaphonomic investigations that include feeding birds to predators, signatures of bone use (e.g. cooking, tool manufacturing) and burial in different contexts are useful in this endeavour (Bocheński and Tomek 1997; Nicholson 1998; Peresani et al. 2011). Ideally, coordinated faunal and geoarchaeological examinations of bird remains would be useful. Too often the bone assemblage is reported in an article, but the assemblage is not examined from an archaeological point of view, within burial context and stratigraphy. Further histological investigations of recent bird bone may also prove fruitful (Eda et al. 2010; Villagran et al. 2017).

In conclusion, global cooperation and dialogue between scholars are essential to further avian archaeology. Although avifauna comparisons between different geographical regions can be problematic (Stewart 2004), questions of preservation, identification and osteology, recovery and laboratory methods need to be discussed and coordinated internationally (Bocheński 2008). Clearly, Bird Working Group and International Council for Archaeozoology (ICAZ) meetings have provided forums for such needed sharing of knowledge and discussions. The presenters and attendees of the 8th BWG Meeting held at the University of Texas Rio Grande Valley, Edinburg, TX, USA, have contributed to this global endeavour.

Acknowledgements Author order reflects degree of contribution to writing the manuscript. We would like to give a heartfelt thanks to John Trant, past Dean of the College of Sciences, UTRGV, for providing monetary support, which made hosting this meeting possible. We also thank Marinella Franklin and Naomi Keith of the UTRGV Office of Sustainability, and also Gloria Gilpatrick and Leo Vazquez of the College of Sciences, for all their assistance. The meeting was a definite success, thanks to all their coordination. Beta Analytic funded the opening reception held at the South Texas History Museum featuring the UTRGV Mariachi Aztlán. Local places providing birding opportunities for the meeting group included Quinta Mazatlan World Birding Center

(WBC), National Butterfly Center, Valley Nature Center, South Padre Island WBC, Santa Ana National Wildlife Refuge, Laguna Atascosa National Wildlife Refuge, Estero Llano Grande State Park and WBC and the Sabal Palm Sanctuary. John Brush provided his birding expertise to everyone on these trips. Other meeting assistance was provided by the students Daniel Dirrigl, Marcela Pena and Edgar Martinez, and for that we are grateful. We thank the anonymous reviewers for their suggestions at improving the manuscript.

References

- Barnes I, Young JPW, Dobney KM (2000) DNA-based identification of goose species from two archaeological sites in Lincolnshire. *J Archaeol Sci* 27:91–100
- Baron H (2018a) From arthrosis to necrosis: many, many pathological chickens from the Avar Cemetery at Vienna Csokorgasse, Austria: In: Bartosiewicz, Gál E (eds) *Care or neglect? Evidence of Animal Disease in Archaeology*. Oxford, Oxbow, pp 208–229
- Baron H (2018b) Quasi liber et pictura. Die Tierknochenfunde aus dem Gräberfeld an der wiener Csokorgasse - eine anthrozoologische Studie zu den awarischen Bestattungssitten. Mainz, Monographien des Römisch-Germanischen Zentralmuseums, Band 143
- Bartosiewicz L (2001) Archaeozoology or zooarchaeology? A problem from the last century. *Archaeologia Polona* 39:75–86
- Bartosiewicz L (2008) Taphonomy and palaeopathology in archaeozoology. *Geobios* 41:69–77
- Bartosiewicz L, Gál E (2007) Sample size and taxonomic richness in mammalian and avian bone assemblages from archaeological sites. *Archeometriai Műhely* 1:37–44
- Bejenaru L, Serjeantson D (eds) (2014) 7th meeting: proceedings of the 7th meeting of the ICAZ Bird Working Group in Iasi, Romania (27.08-01.09.2012). *Birds and archaeology: new research*. Special Issue, *Int J Osteoarcheol* 24(3):245–246
- Benn DW (1989) Hawks, serpents, and bird-men: Emergence of the Oneota mode of production. *Plains Anthropol* 34:233–260
- Berdan FF (2006) Circulation of feathers in Mesoamerica. Feather creations, materials, production and circulation. *Hispanic Society-Institute of Fine Arts* 17-19/06/2004
- Best J, Mulville J (2013) Between the sea and sky: the archaeology of avian resource exploitation in Scottish island environments. In: Daire MY, Dupont C, Baudry A, Billard C, Large JM, Lespez L, Normand E, Scarre C (eds) *Ancient maritime communities and the relationship between people and environment along the European Atlantic coasts*. Proceedings of the HOMER 2011 Conference, Va. British Archaeological Reports International Series 2570. Archaeopress, Oxford, pp 417–426
- Bezerra DMM, de Araujo HFP, Alves AGC, Alves RRN (eds) (2013) *Birds and people in semiarid northeastern Brazil: symbolic and medicinal relationships*. *J Ethnobiol Ethnomed* 9:3
- Bickart KJ (1984) A field experiment in avian taphonomy. *J Vert Paleo* 4: 525–535
- Binford LR (1978) *Nunamiut Ethnoarchaeology*. Academic Press, New York
- Birkhead TR, Schulze-Hagen K, Kinzelbach R (2004) Domestication of the canary, *Serinus canaria*-the change from green to yellow. *Archiv Nat Hist* 31:50–56
- Blasco R, Peris JF (2009) Middle Pleistocene bird consumption at level XI of Bolomor cave (Valencia, Spain). *J Archaeol Sci* 36:2213–2223
- Bocheński ZM (2002) Owls, diurnal raptors and humans: signatures on avian bones. In: O'Connor T (ed) *Bioshere to lithosphere*, 9th ICAZ conference, Durham, vol 2002, pp 1–45
- Bocheński ZM (2008) Identification of skeletal remains of closely related species: the pitfalls and solutions. *J Archaeol Sci* 35:1247–1250

- Bocheński ZM, Tomek T (1997) Preservation of bird bones: erosion versus digestion by owls. *Inter J Osteoarchaeol* 4:372–387
- Bocheński ZM, Tomek T (2000) Identification of bones of Galliform hybrids. *J Archaeol Sci* 27:691–698
- Borrero LA (2014) Fuego-Patagonian bone assemblages and the problem of communal guanaco hunting. In: Davis LB, Reeves BOK (eds) *Hunters of the recent past*. Unwin Hyman, London
- Bovy KM (2002) Differential avian skeletal part distribution: explaining the abundance of wings. *J Archaeol Sci* 29:965–978
- Brothwell D (2002) Ancient avian osteopetrosis: the current state of knowledge. *Acta Zool Crac* 45:315–318
- Buddhachat K, Klinhom S, Siengdee P, Brown JL, Nomsiri R, Kaewmong P, Thitaram C, Mahakkanukrauh P, Nganvongpanit K (2016) Elemental analysis of bone, teeth, horn and antler in different animal species using non-invasive handheld X-ray fluorescence. *PLoS One* 11(5):e0155458
- Camilla F, Speller BM, Kemp SD, Wyatt CM, Monroe C, Lipe WD, Arndt UM, Yang DY (2010) Ancient mitochondrial DNA analysis reveals complexity of indigenous North American Turkey domestication. *PNAS* 107(7):2807–2812
- Causey D, Trimble J (2005) Old bones in new boxes: osteology collections in the new millennium. *Auk* 122:971–979
- Clason AT, Prummel (1977) Collecting, sieving and archaeozoological research. *J Archaeol Sci* 4:171–175
- Cohen A, Serjeantson D (1996) *A manual for the identification of bird bones from archaeological sites*. Archetype Publications, London
- Collins M, Buckley M, Grundy HH, Thomas-Oates J, Wilson J, van Doorna N (2010) ZooMS: the collagen barcode and fingerprints. *Spectrosc Eur* 22(2):6–10
- Cruz I, Elkin D (2003) Structural bone density of the lesser Rhea (*Pterocnemia pennata*) (Aves: Rheidae). *Taphonomic and archaeological implications*. *J Archaeol Sci* 30:37–44
- Cubo J, Casinos A (2000) Incidence and mechanical significance of pneumatization in the long bones of birds. *Zool J Linnean Soc* 130:499–510
- Dacke CG, Arkle S, Cook DJ, Wormstone IM, Jones S, Zaidi M, Bascal ZA (1993) Medullary bone and avian calcium regulation. *J Exper Biol* 184(1):63–88
- David WB (1989) Hawks, serpents, and bird-men. *Plains Anthropol* 34(125):233–260
- Davis SJ (2012) *The archaeology of animals*. Routledge, London UK
- De Cupere BD, Neer WV, Monchot H, Rijmenants E, Udrescu M, Waelkens M (2005) Ancient breeds of domestic fowl (*Gallus gallus f. domestica*) distinguished on the basis of traditional observations combined with mixture analysis. *J Archaeol Sci* 32:1587–1597
- Dobney K, Jaques D (2002) Avian signatures for identity and status in Anglo-Saxon England. *Acta Zool Crac* 45:7–21
- Doube M, Kłosowski MM, Wiktorowicz-Conroy AM, Hutchinson JR, Shefelbine SJ (2011) trabecular bone scales allometrically in mammals and birds. *Proc Royal Soc B: Biol Sci* 278(1721):3067–3073
- Dumont ER (2010) Bone density and the lightweight skeletons of birds. *Proc Royal Soc B: Biol Sci* 277(1691):2193–2198
- Duncan RP, Blackburn TM, Worthy TH (2002) Prehistoric bird extinctions and human hunting. *Proc Royal Soc B: Biol Sci* 269(1490):517–521
- Eda M, Lu P, Kikuchi H, Li Z, Li F, Yuan J (2016) Reevaluation of early Holocene chicken domestication in northern China. *J Archaeol Sci* 67:25–31
- Eda M, Yashima S, Kusuhaara S, Inoue T (2010) Histological analysis of medullary bones from archaeological sites in Japan. In: Prummel W, Zeiler JT, Brinkhuizen DC (eds) *Birds in archaeology: proceedings of the 6th meeting of the ICAZ Bird Working Group in Groningen (23.8–27.8.2008)*, Groningen Archaeological Studies, vol 12. Barkhuis Publishing/Groningen University Library, Groningen, pp 255–260
- Ericson PGP (1987) Interpretations of archeological bird remains: a taphonomic approach. *J Archaeol Sci* 14:65–75
- Estevez J, Mameli L, Goodall N (2002) An expert system to help taxonomic classification in avian archaeology: a first attempt with bird species from Tierra del Fuego. *Acta Zool Crac* 45:383–391
- Gál E (2008a) Broken-winged: fossil and subfossil pathological bird bones from recent excavations. In: Miklíková Z, Thomas R (eds) *Current research in animal palaeopathology*, BAR Inter Ser, vol 1844. Oxbow, Oxford, pp 80–86
- Gál E (2008b) Faunal and taphonomic analyses of a Late Pleistocene bird bone assemblage from a cave deposit in north-west Hungary. *Geobios* 41:79–90
- Gál E (2013) Pathological changes in bird bones. In: Bartosiewicz L (ed) *Shuffling nags, lame ducks. The archaeology of animal disease*. Oxford, Oxbow, pp 216–237
- Garvey J, Cochrane B, Field J, Paley C (2011) Modern emu (*Dromaius novaehollandiae*) butchery, economic utility and analogues for the Australian archaeological record. *Environ Archaeol* 16(2):97–112
- Gersmann K-H, Grimm O (eds) (2018) *Raptor and human - falconry and bird symbolism throughout the millennia on a global scale*. Wachholtz Verlag, Kiel / Hamburg
- Gilbert BM, Martin LD, Savage HG (1996) *Avian osteology*. Missouri Archaeological Society, Springfield, MO
- Gomes N (2016) Some traditional native Hawaiian bird hunting practices on Hawai'i Island. *Hawaiian J Hist* 50:33–51
- Gordon EA (1993) Screen size and differential faunal recovery: a Hawaiian example. *J Field Archaeol* 20(4):453–460
- Grigson C, Clutton-Brock J (1983) *Animals and archaeology: 2. Shell middens, fishes, and birds*. BAR 183, Oxford
- Grupe G, Peters J (2005a) Stable isotope analysis of archaeological avian bones. In: Grupe G, Peters J (eds) *Feathers, grit and symbolism: birds and humans in the Old and New Worlds*, *Doc Archaeobiol*, vol 3. Verlag Marie Leidorf, Rahden-Westfalen, pp 57–67
- Grupe G, Peters J (eds) (2005b) *Feathers, grit and symbolism: birds and humans in the Old and New Worlds*, *Doc Archaeobiol*, vol 3. Verlag Marie Leidorf, Rahden-Westfalen
- Hartert E (1912) (published in 1922) *Die Vögel der paläarktischen Fauna systematische Übersicht der in Europa, Nord-Asien und der Mittelmeerregion vorkommenden Vögel*, Vol. II. Friedländer, Berlin
- Hartert E (1915) Notes on falcons. *Novitates Zoologicae* 22:167–185
- Herrmann B, Hummel S (eds) (2012) *Ancient DNA: recovery and analysis of genetic material from paleontological, archaeological, museum, medical, and forensic specimens*. Springer-Verlag, New York
- Hollmann JC (2005) 'Swift-people': therianthropes and bird symbolism in hunter-gatherer rock-paintings, Western and Eastern Cape provinces, South Africa. *South African Archaeological Society Goodwin Series* 9:21–33
- Hutt FB (1929) Sex dimorphism and variability in the appendicular skeleton of the Leghorn fowl. *Poultry Sci* 8(4):202–218
- James SR (1997) Methodological issues concerning screen size recovery rates and their effects on archaeofaunal interpretations. *J Archaeol Sci* 24(5):385–397
- Kanginakudru S, Metta M, Jakati RD, Nagaraju J (2008) Genetic evidence from Indian red jungle fowl corroborates multiple domestication of modern day chicken. *BMC Evol Biol* 8(1):174
- Kooyman BP (1990) Moa procurement: communal or individual hunting? In: Davis LB, Reeves BOK (eds) *Hunters of the recent past*. Unwin Hyman, London, pp 327–351
- Kristensen TJ, Holly DH (2013) Birds, burials and sacred cosmology of the indigenous Beothuk of Newfoundland, Canada. *Camb Archaeol J* 23(1):41–53
- Laroulandie V (2005) Anthropogenic versus non-anthropogenic bird bone assemblages: new criteria for their distinction. *Biosphere to lithosphere. New studies in vertebrate taphonomy* O'Connor T (ed). Oxbow Books, Oxford, pp 25–30

- Lauwerier RC (1993) Bird remains in Roman graves. *Archaeofauna* 2: 75–82
- Lefèvre C (1997) Sea bird fowling in southern Patagonia: a contribution to understanding the nomadic round of the Canoeros Indians. *Inter J Osteoarchaeol* 7(4):260–270
- Leslie Jr DM (2016) An international borderland of concern—conservation of biodiversity in the lower Rio Grande Valley: U.S. Geological Survey Scientific Investigations Report 2016–5078, Washington DC
- Lindsay MF (1990) The recovery of cultural artifacts: the legacy of our archaeological heritage. *Case Western J Intl Law* 22:165–182
- Livingston SD (1989) The taphonomic interpretation of avian skeletal part frequencies. *J Archaeol Sci* 16:537–547
- Louchart A, Viriot L (2011) From snout to beak: the loss of teeth in birds. *Trends Ecol Evol* 26:663–673
- Lyman RL (2012) The influence of screen mesh size, and size and shape of rodent teeth on recovery. *J Archaeol Sci* 39(6):1854–1861
- Lyman RL, Savelle JM, Whitridge P (1992) Derivation and application of a meat utility index for phocid seals. *J Archaeol Sci* 19(5):531–555
- MacDonald K (2007) Cross-cultural comparison of learning in human hunting. *Human Nat* 18(4):386–402
- Madrigal TC, Holt JZ (2002) White-tailed deer meat and marrow return rates and their application to eastern woodlands archaeology. *Am Antiq* 67(4):745–759
- MacDonald KC (1992) The domestic chicken (*Gallus gallus*) in sub-Saharan Africa: a background to its introduction and its osteological differentiation from indigenous fowls (Numidinae and *Francolinus* sp.). *J Archaeol Sci* 19(3):303–318
- Makowiecki D, Tomek T, Bocheński ZM (2014) Birds in early medieval greater Poland: consumption and hawking. *Int J Osteoarchaeol* 24(3):358–364
- Mannermaa K (2008) Birds and burials at Ajvide (Gotland, Sweden) and Zvejnieki (Latvia) about 8000–3900 bp. *J Anthropol Archaeol* 27(2):201–225
- Mannermaa K, Panteleyev A, Sablin M (2008) Birds in late Mesolithic burials at Yuzhnyi Oleniy Ostrov (Lake Onega, Western Russia)—what do they tell about humans and the environment? *Fennoscandia Archaeologica* 25:3–25
- Morales-Muñiz AM (1993) Ornithoarchaeology: the various aspects of the classification of bird remains from archaeological sites. *Archaeofauna* 2:1–13
- Morejohn GV, Galloway JP (1983) Identification of avian and mammalian species used in the manufacture of bone whistles recovered from a San Francisco Bay area archaeological site. *J Calif Great Basin Anthropol* 5(1/2):87–97
- Murty ML (1981) Hunter-gatherer ecosystems and archaeological patterns of subsistence behaviour on the south-east coast of India: an ethnographic model. *World Archaeol* 13(1):47–58
- Nicholson RA (1998) Bone degradation in a compost heap. *J Archaeol Sci* 25(5):393–403
- Nørrevang A (1986) Traditions of sea bird fowling in the Faroes: an ecological basis for sustained fowling. *Ornis Scand* 1:275–281
- Olsen SL (1979) A study of bone artifacts from grasshopper Pueblo, Az P:14:1. *Kiva* 44:341–373
- Peresani M, Fiore I, Gala M, Romandini M, Tagliacozzo A (2011) Late Neandertals and the intentional removal of feathers as evidenced from bird bone taphonomy at Fumane Cave 44 ky BP, Italy. *Proc Natl Acad Sci* 108(10):3888–3893
- Peterson N (1973) Camp site location amongst Australian hunter-gatherers: archaeological and ethnographic evidence for a key determinant. *Archaeol Phys Anthropol Oceania* 8:173–193
- Picasso MB (2012) Postnatal ontogeny of the locomotor skeleton of a cursorial bird: greater rhea. *J Zool* 286(4):303–311
- Presslee S, Wilson J, Woolley J, Best J, Russell D, Radini A, Fischer R, Kessler B, Boano R, Collins M, Demarchi B (2017) The identification of archaeological eggshell using peptide markers. *Sci Tech Archaeol Res* 3(1):89–99
- Prummel W, Zeiler JT, Brinkhuizen DC (eds) (2010) Birds in archaeology: proceedings of the 6th meeting of the ICAZ Bird Working Group in Groningen (23.8–27.8.2008), Groningen archaeological studies, vol 12. Barkhuis Publishing/Groningen University Library, Groningen
- Purdue JR, Klippel, WE, Styles BW (eds) (1991) Beamers, bobwhites, and blue-points: tributes to the career of Paul W. Parmalee. *Scientific Papers Vol. XXIII*, Illinois State Museum, and Report of Investigations No. 52, Department of Anthropology, University of Tennessee. Illinois State Museum, Springfield
- Ramsay J, Tepper Y, Weinstein-Evron M, Aharonovich S, Liphshitz N, Marom N, Bar-Oz G (2016) For the birds—an environmental archaeological analysis of Byzantine pigeon towers at Shivta (Negev Desert, Israel). *J Archaeol Sci Rep* 9:718–727
- Rea AM (2007) Wings in the desert: a folk ornithology of the northern Pimans. University of Arizona Press, Tucson
- Reitz EJ, Wing ES (1999) Zooarchaeology. Cambridge University Press, Cambridge UK, Cambridge manuals of archaeology
- Renner SC, Neumann D, Burkart M, Feit U, Giere P, Groger A, Paulsh A, Paulsh C, Sterz M, Vohland K (2012) Import and export of biological samples from tropical countries—considerations and guidelines for research teams. *Organisms Divers Evol* 12:81–98
- Rising JD, Somers KM (1989) The measurement of overall body size in birds. *Auk* 106(4):666–674
- Shufeldt RW (1893) Notes on paleopathology. *Popular Science Monthly* 42:679–684
- Serjeantson D (1994) Subsistence and symbol: the interpretation of bird remains in archaeology. *Int J Osteoarchaeol* 7:255–259
- Serjeantson D (1998) Archaeological and ethnographic evidence for sea-bird exploitation in Scotland. *Archaeozoöl* 2:209–224
- Serjeantson D (2002) Goose husbandry in Medieval England, and the problem of ageing goose bones. *Acta Zool Crac* 45:39–54
- Serjeantson D (2006) Birds: food and a mark of status. In: Woolgar CM, Serjeantson D, Waldron T (eds) *Food in Medieval England: diet and nutrition*. Medieval History and Archaeology. Oxford University Press, Oxford, GB, pp 131–147
- Serjeantson D (2009) Birds. Cambridge manuals of archaeology. Cambridge University Press, Cambridge UK
- Shrubb M (2013) Feasting, fowling and feathers: a history of the exploitation of wild birds. T & AD Poyser, London
- Smith J, Easton P, Saylor B, Wiedman D, LaBelle J Jr (2009) Harvested food customs and their influences on valuable functioning of Alaska native elders. *Alaska J Anthropol* 7:101–121
- Speller CF, Kemp BM, Wyatt SD, Monroe C, Lipe WD, Arndt UM, Yang DY (2010) Ancient mitochondrial DNA analysis reveals complexity of indigenous north American Turkey domestication. *Proc Natl Acad Sci* 107(7):2807–2812
- Sparkes BA (1997) Painted birds at Pompeii. In: Serjeantson D (ed) *Subsistence and symbol*. Papers from the ICAZ Working Group Meeting, 1995. *Int J Osteol* 7:350–353
- Soma T (2013) Ethnoarchaeology of ancient falconry in East Asia. Encounters and exchanges, The Asian conference on cultural studies 2013:81–95
- Stewart JR (2004) The use of modern geographical ranges in the identification of archaeological bird remains. In: Grupe G, Peters J (eds) *Feathers, grit and symbolisms*. Birds and archaeology in the Old and New Worlds, Proceedings of the ICAZ Bird Remains Working Group meeting in Munich, vol 2004. Documenta Archaeobiologiae, Verlag Marie Leidorf, Rahden-Westfalen, pp 43–54
- Stewart JRM, Allen RB, Jones AKG, Penkman KEH, Collins MJ (2013) ZooMS: making eggshell visible in the archaeological record. *J Archaeol Sci* 40(4):1797–1804

- Stewart JRM, Allen RB, Jones AKG, Kendall T, Penkman KEH, Demarchi B, O'Connor T, Collins MJ (2014) Walking on eggshells: a study of egg use in anglo-Scandinavian York based on eggshell identification using ZooMS. *Inter J Osteoarchaeol* 24(3):247–255
- Stewart JR, Carrasquilla FH (1997) The identification of extant European bird remains: a review of the literature. *Inter J Osteoarchaeol* 7(4): 364–371
- Stewart KM, Wigen RJ (2003) Screen size and the need for reinterpretation: a case study from the northwest coast. *Bulletin of the Florida Museum of Natural History* 44(1):27–34
- Strickland HE (1840) List of birds procured in Kordofan by Mr. J Petherick. *Ann Mag Nat Hist* 9:342–349
- Sullivan TN, Wang B, Espinosa HD, Meyers MA (2017) Extreme lightweight structures: avian feathers and bones. *Mater Today* 20(7): 377–391
- Tomek T, Bocheński ZM (2009) A key for the identification of domestic bird bones in Europe: Galliformes and Columbiformes. Institute of Systematics and Evolution of Animals. Polish Academy of Sciences, Kraków
- Twiss K (2012) The archaeology of food and social diversity. *J Archaeol Res* 20(4):357–395
- Ubelaker DH, Wedel WR (1975) Bird bones, burials, and bundles in plains archaeology. *Am Antiq* 40:444–452
- Villagran XS, Huisman DJ, Mentzer SM, Miller CE, Jans MM (2017) Bone and other skeletal tissues. Archaeological soil and sediment micromorphology. In: Nicosia C, Stoops G (eds) *Archaeological soil and sediment micromorphology*. Wiley Blackwell, Hoboken NJ, pp 11–38
- Watanabe J, Matsuoka H (2013) Ontogenetic change of morphology and surface texture of long bones in the Gray Heron (*Ardea cinerea*, Ardeidae). *Paleornithological Research* 2013:279–306
- Wojcik JD (2002) The comparative osteology of the humerus in European thrushes (Aves: *Turdus*) including a comparison with other similarly sized genera of passerine birds-preliminary results. *Acta Zool Crac* 45:369–381
- Wolfson A (1955) *Recent studies in avian biology*. University of Illinois Press, Urbana
- Woosnam KM, Dudensing RM, Hanselka D, An S (2011) An initial examination of the economic impact of nature tourism on the Rio Grande Valley: AgriLife extension. Texas A&M University, College Station, Texas

Publisher's note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.