DIFFERENTIATING HUMAN FROM NONHUMAN BONE: INSIGHTS FROM A MEDICAL EXAMINER'S COLLECTION, KENOSHA, WISCONSIN

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ABSTRACT

DIFFERENTIATING HUMAN FROM NONHUMAN BONE: INSIGHTS FROM A MEDICAL EXAMINER'S COLLECTION, KENOSHA, WISCONSIN
by

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Forensic anthropologists who work in medical examiner's offices or similar contexts frequently need to differentiate nonhuman from human skeletal or partially decomposed remains. If we, forensic anthropologists, were more aware of which nonhuman bones were most common in such situations, we might be able to improve our training programs. The Office of the Chief Medical Examiner in Kenosha County, southwest Wisconsin, accumulated over 1,940 nonhuman bones over a period of several years, most likely primarily between 2000 and 2005. These are the focus of this thesis, which presents a quantitative analysis of the most frequently encountered taxa and elements. The majority of the nonhuman remains were mammalian (74%), and roughly the size of adult human bones, although smaller sizes were also represented in the sample. The top three mammalian species identified were white-tailed deer (*Odocoileus virginianus*), pig (*Sus scrofa*), and domestic cow (*Bos taurus*). Among the bird bones identified, turkey (*Meleagris gallopavo*) was the most common. Considering that nonhuman bones may make up a sizable fraction of overall casework, forensic education programs may be well-served by increasing training in human and nonhuman differentiation.

Dedicated to

the loving memory

of my Dad

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Chapter 1: INTRODUCTION

This thesis concentrates on a collection of nonhuman remains that were brought to the medical examiner's office (MEO) in Kenosha County in southeastern Wisconsin. Kenosha is in proximity to the coastline of Lake Michigan, and two major urban centers (Milwaukee and Chicago), as well as to farmland and other rural land (see Figure 1.1). The remains are evaluated for insights into which nonhuman elements and taxa are most commonly recovered and perplexing enough to be brought to the MEO.

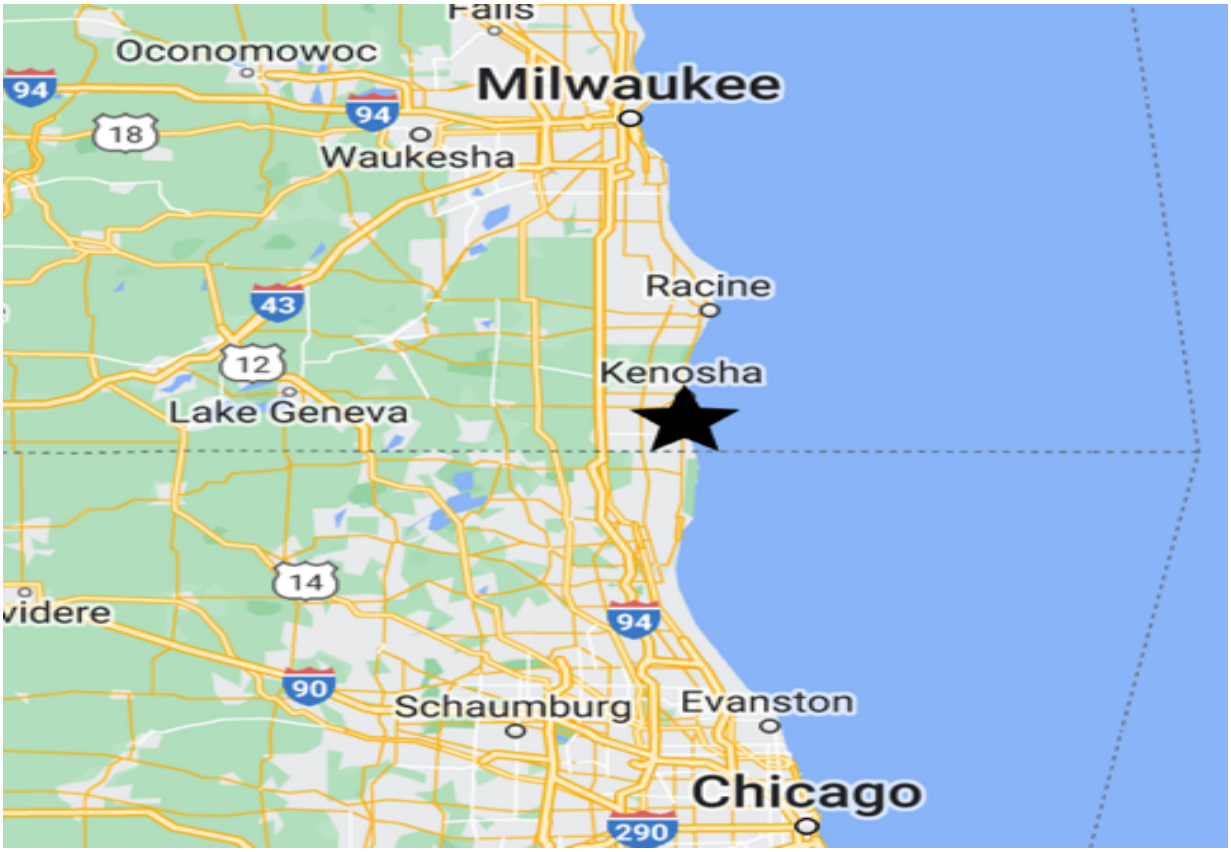

Figure 1.1. Map indicating Kenosha (star indicating location) in relation to Lake Michigan, Milwaukee, and Chicago.

The specific objectives of this thesis include determining which taxa and elements dominate in the collection, analyzing any patterning in the taphonomic processes evidenced as these may relate to identification challenges, and evaluating whether the developmental age of the animal plays a role. One end goal of this study is to highlight potentially useful nonhuman osteological material during the training of forensic anthropologists, law enforcement, medical examiners, coroners, and non-specialists who find bones to identify the origin of skeletal elements in the field and have responsibility for establishing their potential medicolegal significance. It is hoped that by teaching law enforcement and non-specialists how to identify the key taxa and elements and their diagnostic traits the number of nonhuman skeletal elements that are brought into an MEO might be decreased in the future.

1.1 Significance

A significant research subject in the discipline of anthropology is the study of how to distinguish human from nonhuman bone. It has relevance in the fields of archaeology, bioarcheology, zooarchaeology, and biological anthropology. It has critical applications in forensic aspects of criminal justice and compliance with the Native American Graves Protection and Repatriation Act (NAGPRA) in the United States. It takes scientific expertise and a thorough understanding of skeletal morphology to discern between human and nonhuman bone. In fieldwork or casework, unidentified skeletal remains are a common occurrence for forensic anthropologists and archaeologists, and numerous researchers have worked to develop and refine methods to differentiate human bones from nonhuman bones (e.g., Adams and Crabtree 2008; France 2009, 2011, 2021; Garvin et al 2021; White and Folkens 2005; White, Black, and Folkens 2012).

Despite these advances, challenges remain. For instance, when bone is encountered in the field, it is frequently found by people who have not received specialized training in human osteology. In forensic situations, the determination of whether found remains are human or not constitutes one of the key criteria for whether those remains are accepted into the medicolegal system and therefore subject to investigation.

The medicolegal system in the United States deals with all deaths that occur as homicides, suicides, or accidental violence, as well as deaths of persons unattended by a physician, or that are categorized as suspicious. The authorities in this system are medical examiners and coroners. In the US, there is a patchwork system in which some counties have medical examiners (usually larger, more urban areas), and other counties have coroners (usually smaller, more rural areas). Coroners are elected officials who may or may not come from a forensics or medical background. Medical examiners, on the other hand, are not elected and are required to have some degree of medical training, although this also varies by location. The highest degree of training is that of a licensed physician with medical board certification in forensic pathology. Both coroners and medical examiners can sign death certificates, but only medical examiners are authorized to conduct autopsies. These authorities, and their assistants, such as death investigators, process death scenes to gather information but also sometimes receive remains to examine at their offices. There are therefore multiple situations in which medicolegal authorities can encounter remains and need to determine whether those remains are human.

When human remains are severely burned, in advanced stages of decomposition, or fully skeletonized, the medicolegal authorities often recruit other experts to further the investigation of an unknown death. Forensic anthropology, forensic archaeology, and forensic odontology are

useful in these situations. Identification of people from their skeletons is one focus of forensic anthropology. Its purpose is to give law enforcement personnel a demographic breakdown (estimating the sex, age, ancestry, and stature) of decedents so that they can compare it to the list of people in their missing person files and work to begin the process of making a positive identification.

When skeletonized remains are involved, one of the primary tasks of the forensic anthropologist is to help the ME or coroner establish medicolegal significance. Medicolegal significance refers to remains that the medicolegal community has defined as needing investigation; that is persons who have died within the last 50 years while not in the care of a physician. Therefore, there is a protocol presented as a series of questions that the forensic community uses when confronted with decomposed bodies or skeletonized remains in order to determine if those remains are of medicolegal significance (Microsoft Word - 150_Std_e1(aafs.org)).

The series of questions for the protocol in order to determine medicolegal significance are:

1) Is it bone?

2) Is the bone human or nonhuman?

3) Is the bone contemporary (within the last 50 years) or noncontemporary (older than 50 years)?

If all of these answers point to needing further investigation (yes it is bone, yes the bone is human, and yes it is contemporary), then the medicolegal significance has been established (see Appendix D). If not, then there is no need for further investigation and usually the forensic anthropologist, medical examiner's office or coroner's office usually disposes of the remains.

However, the second question in relation to this thesis is of utmost importance. This is the deciding factor into whether or not the third question should even be considered, because if the bone is nonhuman than there would be no need to even evaluate whether or not the bone is contemporary. Therefore, determining whether a bone is human, or nonhuman is key for medicolegal authorities because, that decision ultimately determines whether remains are formally processed or not, so a mistake at this stage is costly.

This raises the question, what are some of the most common forms of ambiguity? Are particular taxa and elements more often a problem? This thesis examines one set of answers to those questions by evaluating the nonhuman bone accumulated in a particular medical examiner's office located in the state of Wisconsin.

Because the MEO provides expertise in decedents and human remains, and sometimes in sorting human from nonhuman, and thus serves as a collection point for ambiguous bones, it is ideal for this type of study. Pokines (2015) published one such study, based on a collection of 355 cases collected over three years at MEO in Massachusetts. This thesis evaluates another, larger collection of 1,940 nonhuman bones collected over approximately six years by MEO in Wisconsin. By contrasting a Midwest location with a Northeast location in the United States, geographical variations can also be evaluated.

1.2 Research questions

What types of bones are most often brought into a medical examiner's office for confirmation of whether or not they are human bone? This question primarily reflects the perceptions of the non-specialist. It is hoped that by identifying the most common sources of confusion and reviewing diagnostic criteria that could be applied in the field by the non-expert,

such information could be shared in a way that might free up time and resources for law enforcement, medical examiners, and coroners to devote to other matters.

The research questions of this thesis are as follows:

1) Which classes of fauna are the most common among the nonhuman bones brought into the ME's office?

2) Which mammal elements are most common?

3) Which species were represented by the most abundant mammal elements?

4) Which bird elements were most abundant?

5) Looking at the bird elements that were complete enough to be identified to taxon, what species were represented?

6) Do developmental age or particular taphonomic processes contribute to ambiguity in identifying bone as clearly animal versus possibly human?

The research goals of this thesis are as follows:

1) To inventory a large sample (skeletal element N=1940) of nonhuman bone brought into a Wisconsin MEO over a span of several years to identify which taxa and which elements were the most common sources of uncertainty for the non-specialist when first encountered in the field.

2) To compare these results with those previously published for a similar study of a smaller sample from the Massachusetts's MEO in Boston (Pokines 2015; see also Woods and Pokines 2013 and Pokines et al. 2017).

3) To review diagnostic features for some of the species and elements most commonly encountered in the Wisconsin sample.

1.3 Case studies

There are many examples of forensic and archaeological situations when it is critical to distinguish between human and nonhuman skeletal remains. Two of these are reviewed here, the Jeffrey Dahmer murders (Owsley et al. 1993) and the terrorist attack of September 11, 2001 (Warnasch 2016, Mundorff 2006, and Blau & Briggs 2011).

Partial or fragmented remains of unknown origins are often discovered in criminal forensic situations. In these situations, identifying the remains is crucial to the investigation and to the legal proceedings. The Jeffery Dahmer forensic case is a well-known illustration of how human remains must be identified in order to bring the victims justice (Owsley et al. 1993). Dahmer was a serial killer who targeted young men who accepted his offers of payment for photography sessions. Once they entered his home, he drugged, strangled, and dismembered them; he also claimed to have engaged in cannibalism. Anthropologists were dispatched from the Smithsonian Institution in Washington, D.C. to the crime scene of his fist victim. Steven Hicks' remains were found at Dahmer's parents' house when the police, after interrogating Dahmer, decided to search the home to look for more forensic evidence to aid in the investigation. Numerous fragmentary human bones were discovered among nonhuman bones that were later identified as belonging to domesticated animals. There were 250 fragments of human bone and they all turned out to be from Steven Hicks.

Jeffrey Dahmer, who was a native of Milwaukee, Wisconsin committed 17 murders before being captured in 1991. Dahmer was finally apprehended on the evening of July 22, 1991, when one of his victims escaped and sought assistance. Inside Dahmer's apartment, the remains of 11 victims were discovered. Evidence found there was submitted to FBI Headquarters for

forensic examination. The Bureau examined the evidence by running DNA profiles, chemical, biological, and tool mark studies, as well as computer and photographic exams.

The jury found him guilty in each of the 17 murders and Dahmer was sentenced to 15 consecutive life sentences. He died unexpectedly in 1994 after being attacked by another prisoner. The forensic investigation that was undertaken to identify the victims in Dahmer's case, consequently, was unparalleled at the time.

Crime scenes represent one type of forensic situation, mass disasters represent another. The outcome of the terrorist attacks at the World Trade Center (WTC) is an example of commingled human and nonhuman fragmentary remains. The American forensic community was unprepared for the scale of the task of identifying those who were lost in the September 11, 2001, terrorist attack, which consisted of the hijacking of four airplanes and attempts to crash them into populated buildings. Two planes hit the WTC in New York City, one crashed into a rural area in Pennsylvania, and one crashed into the Pentagon near Washington, D.C.. The largest forensic challenge ever taken on in this country (Warnasch, 2016), their identification was made more difficult by the sheer number of victims (2,479), the nature of their remains, and the length of the recovery process. The remains at the WTC were collected over a 1-year period. The goal was to identify every person or every fragment from the three sites so they could be returned to their families.

Teams of anthropologists were deployed to distinguish between human and nonhuman remains, separate the commingled material, and identify every fragment at the WTC, the Pentagon, and the site of the United 93 flight crash in Shanksville, Pennsylvania. The impact of the airplanes created high degrees of fragmentation and dispersal. Obtaining DNA samples from the victims' families was also key, and the entire recovery process was complicated by the

degree of shock that may be experienced. The scale of the effort and the volume of material produced unique challenges in managing the chain of custody. As a result of the work that followed the terrorist attacks of September 11, 2001, there are improved protocols for identifying victims of mass disasters (Blau and Briggs 2011:1).

These two examples, the Dahmer murder case and the 9/11 terrorist attack, help to illustrate the importance of being able to distinguish human and nonhuman bone in forensic cases. In both cases fragmentary human remains were recovered in situations where nonhuman bones were comingled, referring to the intermixing of remains from more than one individual.

1.4 Thesis Outline

This thesis is organized into the following chapters. Chapter 2 presents prior research, including general methods for the identification of human bone as well as special attention to prior studies of the material that comes into MEOs and FBI labs, and a summary of some of the existing publications that illustrate methods for differentiating human from nonhuman bone. Chapter 3 details the methods used in this thesis, including the identification of taxa and element, the use of mammalian size categories, and the evaluation of the state of individual bones in terms of their completeness, developmental age, and surface condition and modifications. Chapter 4 details the quantitative results of the evaluation of taxa and element and other attributes, with special attention to patterns of relative abundance and dominant patterns. Chapter 5 concludes the thesis with a discussion of the outcomes of the study and their interpretation, comparison with prior studies, and suggestions for future research. There are four appendices: Appendix A provides a list of the nonhuman osteological comparatives used in identifications; Appendix B provides the detailed inventory of the 1,940 nonhuman bones that were the subject of this study;

Appendix C provides a list of photos illustrating the osteometrics for the ribs, vertebrae, and phalanges; and Appendix D provides a decision tree for how one can establish medicolegal significance.

Chapter 2: PRIOR RESEARCH

Experts in osteology employ a variety of techniques to distinguish human and nonhuman bone. I will provide a brief overview of some of those here, including both macroscopic methods and microscopic methods, as well as those that involve chemical analysis and the use of X-ray systems. I will first review some of the previous research that has been done to answer the question of what kinds of nonhuman bones are submitted to medical examiners and coroners.

2.1 What is brought to medical examiners and coroners?

The bones that are brought to MEO and coroners are important because it could explain the taxa and elements that are most difficult for non-specialists to identify when the bone is first encountered. Therefore, Pokines' work is relevant to this discussion because of its focus on human and nonhuman bone accumulated by a medical examiner's office. A preliminary study by Woods and Pokines (2013) was based on 173 cases of nonhuman bone brought into the Boston MEO that were analyzed through physical macroscopic examination and of analysis of photographs. The taxa present, the bones' state of fusion, their skeletal representation, and taphonomic modifications to the bones — such as animal chewing, weathering state, maritime alteration, breakage, and soil staining — were all recorded. When possible, mammals were identified according to species level. It should be noted that Woods and Pokines quantified their taxa by the percentage of forensic cases they were part of, rather than as a percent of total bone recovered.

Skeletal elements of white-tailed deer (*Odocoileus virginianus*) were discovered in 34% of cases, making it the most often represented taxon, although the contribution of cattle (*Bos taurus*) was roughly equivalent (32%). Pig (*Sus scrofa*) contributed to 23% of the cases, and

birds (Aves) were present in 19% of cases. Other frequent taxa were domestic dogs and coyotes (Canis spp.), which were present in 5% of cases, seals (Phocidae), which were present in 5% of cases, and sheep and goats (Ovis/Capra), which were present in 4% of cases. For analytical purposes, Woods and Pokines categorized all birds under the vertebrate class (Aves), while bony fish were categorized by their superclass (Osteichthyes) and were present in less than 4% of the cases. They note that the state of Massachusetts' extensive and highly populated coastline contributed to the inclusions of fish and sea mammals (seals and dolphins).

The most frequent species of recognized bird taxa were domestic chicken (*Gallus gallus*), then turkey (*Meleagris gallopavo*), geese (Anserinae), and gulls (Laridae). The taxa identified for both birds and mammals represent domesticated fauna raised as food as well as local wild fauna. This makes it significant to note in 42% of the cases examined at least one bone element had evidence of (modern) machine butchery. This suggests that animal bone resulting from human butchery and/or consumption comprise a significant part of the nonhuman bone that finds its way into an MEO, at least for the MEO studied by Woods and Pokines.

Another study done by Pokines (2015) is especially relevant to this discussion because his data came from an expanded sample of 355 cases that were submitted to the MEO in Boston. The environments that were sampled included urban or suburban areas, agricultural land, coastal margins, freshwater and saltwater wetlands, and evergreen, mixed, or deciduous forests. Bones encountered on private ground by individuals or those discovered during construction or home repair were frequent sources.

Identification was through physical macroscopic examination of physical remains, except for one case employing histological examination of highly fragmented bone. The taxa that were present, the fusion state of bones, and the skeletal elements were all recorded. To verify the

alleged provenance and environment of discovery of the remains, taphonomic information was also acquired to determine whether the environments where the elements were found resulted in taphonomic alterations. Mammals, birds, and reptiles were identified down to the species level when possible, although in some cases these taxa could only be classified by higher taxonomic groupings.

The results showed that remains, usually skeletonized, from domesticated cows (*Bos taurus*) were most abundant, found in 29.6% of cases, very closely followed by white-tailed deer (*Odocoileus virginianus*), found in 29.3% of cases, and then by pig (*Sus scrofa*), found in 26.2%. These results diverge only slightly from the original 2013 study. Other categories included seals (Phocidae), unidentified large bird taxa, chicken (*Gallus gallus*), domesticated dogs (*Canis familiaris*), and sheep/goat (*Ovis aries/Capra hircus*), each representing less than 7% of the cases. He notes that in his sample of cases the nonhuman bones accounted for approximately 90% of the forensic casework including recovered or turned-in remains.

In summary, for both the original and the expanded study, white-tailed deer (*Odocoileus virginianus*), domesticated cow (*Bos taurus*), and pig (*Sus scrofa*) remains are the three most common taxa of nonhuman bones that were brought into the Boston MEO. Pokines also notes that the nonhuman remains accounted for approximately 90% of the forensic casework. He compares this with previously published levels in the range of 10% to 30% and suggests that there is a trend over time towards an increasing level of nonhuman bone contributing to forensic caseloads, possibly due in part to what he cites as "the CSI effect" (2015:237). He also notes that the composition of nonhuman taxa may vary by region. Pokines' analysis highlights the need for forensic educational programs that include a focus on their identification which should be targeted at law enforcement personnel, MEO, coroners, and non-specialists.

Pokines' 2015 study also references an earlier study by Grisbaum and Ubelaker (2001), who calculated the percentage of nonhuman cases out of 474 cases with significant skeletal remains that had been presented to the Smithsonian Institution for the period 1962 to 1994. These cases were compiled from non-archaeological cases that were provided by the FBI and derived from all over the United States. They discovered that in 71.9% of cases only human remains were present, while in 13.7% both human and nonhuman remains were present, and in 14.3% of cases only nonhuman remains were present. Thus, for the Smithsonian sample, confusion between human and nonhuman bone was a much smaller issue, probably due to the local governments (FBI) do the bulk of keeping that material out of the medicolegal system. In contrast, nonhuman cases may make up a sizable portion of total casework in some MEOs; Pokines' analysis highlights the need for forensic educational programs that include a focus on their identification.

2.2 Who brings in the bones and what are the discovery contexts?

Other key aspects when it comes to nonhuman bones center on who has submitted them to the medicolegal system and where they are being found. Pokines et al. (2017) focused on the context of original discovery for a total of 161 human and 518 nonhuman cases, again in Massachusetts. A five-year span, from mid-November 2011 to mid-November 2016, was used to define, examine, and tabulate the nonhuman cases that came into the MEO. The human cases were tabulated for this same time frame, and additional cases from as early as 1979 that were analyzed by Pokines were also included.

In this study, the 518 nonhuman cases were classified according to the natural environment or the location and context of the find, emphasizing their taphonomic history and

traits: terrestrial surface, marine or shore, fresh water, saltwater marsh, or domestic contexts — e.g., under floorboards or in walls or as buried remains. Almost half (49.8%) of the nonhuman bone cases came from terrestrial surface finds. The 161 human cases were similarly cataloged, with some additional categories (burial in basement, indoor decomposition, former anatomical teaching specimens, and trophy skull). For the human bone cases the dominant contexts were burial remains in a cemetery (34.2%), marine or shore contexts (27.3%), and terrestrial surface finds (20.5%).

A subset of 144 human and 500 nonhuman cases were also tabulated according to 19 different modes of bone discovery. These included: police search (pedestrian), police seized, police search (cadaver dog), police search (inside of a building), police search (excavation), other government employees, dog digging, dog walker/owner, hunter, other pedestrians (beach, etc.), other boats (not fishing), excavation (cemetery), excavation/demolition (residence), excavation (other), fishing (net/trap), swimming, clamming, voluntary turnover (non-specialists bringing in remains to law enforcement), and other. The category of "other pedestrians" accounted for almost half the human cases (47.2%) and over half the nonhuman cases (57%).

Thus, almost half of the nonhuman bone cases (N=257) came from surface finds, and most were recovered by people out walking, with or without their dogs (about 74% of the mode of total discovery cases, [human and nonhuman combined, N=500/679]). Overall, many bones discussed by Pokines et al. 2017 were discovered by accident rather than through a planned police search (47.2% of the human subset). This suggests that general human behavior patterns may have a greater impact on successful finds of missing person's remains than planned forensic searches over large areas. This emphasizes the importance of educating the MEO, coroners, and

non-specialists on how to manage situations involving the discovery of skeletal remains and how to differentiate nonhuman bone.

This study also highlights the potential variability in the ranking of finds according to both taxa and context of discovery, and the potential role of sample size and find location on these results. These, in turn, suggest that the study proposed for this thesis, with its large sample and Midwest location, could provide valuable additional insights.

2.2.1 Taphonomy and other complicating factors

Complicating factors may contribute to ambiguities during the differentiating process when a forensic anthropologist is assessing the potential medicolegal significance of a bone. Taphonomic alterations, for instance, caused by animal activity, weathering, poor preservation, and soil staining, are the most frequently observed (Pokines 2018). Pokines (2018:4) states that these taphonomic alterations could make it more difficult to determine if a bone is human. Additionally, he states there can be indications that the bone has been altered, such as burn patterns, cut marks, and evidence that the bone has been worked (Pokines 2018:4). Other times, there is proof of diseases such as an overgrowth of bone that could change the normal osteological structure. When separating human from nonhuman bone, certain morphological traits may become obscured by the taphonomic alterations and modifications (Pokines 2018:14). In other cases, the bone may be too fractured to distinguish between human and nonhuman. To address the medicolegal significance in each of these cases, forensic anthropologists must use additional techniques.

2.3 Prior publications on how to identify bone as human or nonhuman

There is one method for distinguishing between human and nonhuman bone: macroscopic methods through osteological analysis. Macroscopic methods include comparing measurements of human and nonhuman bone (Garvin et al. 2021) and identifying morphological differences through osteological analysis (Adams et al. 2008; France 2009; White and Folkens 2005; White, Black, and Folkens 2012; Grisbaum and Ubelaker 2001).

Garvin et al. (2021) set out to evaluate the effectiveness of osteometric techniques for separating human remains from those of other species, and to provide new resources for species identification. Over 50,000 measurements were compiled from humans and from 27 nonhuman (mainly North American) species. Including white-tailed deer, horse, elk, moose, cow, pig, domestic dog, and black and brown bears. The authors' sample was made up of 20 mammals, five birds, and two turtles. They concentrated on measuring the length and diameter of five limb elements — humerus, radius, ulna, femur, and tibia — of adult specimens. The most relevant takeaway from this study is that it is possible to distinguish complete elements of human from nonhuman bone with a success rate of up to 90% based on osteometrics alone. In addition, this study used their quantitative models to create a website tool called OsteoID that allows users to enter measurements and then be given the images of potential bones and species that are close in the measurement range (OsteoID), therefore aiding in visual identification.

Grisbaum and Ubelaker (2001) focused on cases submitted for analysis from the Federal Bureau of Investigations (FBI) that occurred between 1962 and 1994. The data was gathered at the Smithsonian over the course of eight weeks in 1994. For this study, 565 cases in all were reviewed. To extract the relevant data from the case files, a data collecting form was created when performing macroscopic examination based on osteological analysis. It was noted who

discovered the remains such as children, workers, householders, animals, and others. Outdoor recreationists included hikers, hunters, and anglers (including law enforcement personnel). If there was any ambiguous information, it was noted as such. The environment (e.g., terrain) in which the remains were found was classified as either water or associated with water (which included beaches and river banks), exposed outdoors, buried outdoors, either exposed or buried outdoors, indoors, or other (which included animal crematoriums, cars, ice chests, dumps, mailboxes, and mine shafts).

The results for this study were that cases containing just human remains made up the vast majority (71.9%), and analysis of the human demographic details represented is the primary focus of their study. However, cases representing only nonhuman remains made up 14.3% of the sample, whereas those representing both human and nonhuman remains made up 13.7%, which makes this an interesting earlier study to contrast with Pokines' work. In the Grisbaum and Ubelaker study the majority (>60.1%) of the cases lacked information about who found the remains. A total of 11.1% of the cases for which these statistics were available (39.9%) were found by outdoor recreationists, 5.7% by workers and children, 4.9% by homeowners, 1.7% by animals, and 10.8% by others.

Some of the methods currently used to differentiate human and nonhuman bone rely on macroscopic observations of complete or nearly complete bones and use bone size (osteometrics) or bone shape (skeletal morphology). Some of these methods require an extensive understanding of osteology and thus may be of more use to the specialist, rather than to the person who has found a bone in a field situation and is trying to evaluate whether it should be taken to a specialist.

2.4 Illustrative and diagnostic guides

There are a variety of illustrated guides that differentiate particular sets of human and nonhuman bone, and which can be useful in field contexts. Some of the currently available ones are reviewed below.

One useful resource in the identification of human and nonhuman skeletal anatomy is *Comparative Skeletal Anatomy: A Photographic Atlas for Medical Examiners, Coroners, Forensic Anthropologists, and Archaeologists* (Adams and Crabtree 2009). In this spiral-bound volume, photographs of elements of 15 different animal species — horse, cow, bear, deer, pig, goat, sheep, dog, raccoon, opossum, cat, rabbit, turkey, duck, chicken — are shown side by side to next to the equivalent human bone. The following elements were chosen for the comparisons: the cranium, humerus, radius, ulna, femur, tibia, fibula, scapula, innominate, atlas vertebrae (C1), axis vertebrae (C2), cervical vertebrae, thoracic vertebrae, lumbar vertebrae, sternum, metapodial, caudal vertebrae, astragalus (talus), calcaneus, sacrum, metacarpals, and metatarsals. The atlas provides a list of diagnostic criteria per each element shown in photographs. For example, for the femur, the linea aspera, which resembles a protruding ridge for the muscle attachment, is well-defined and extensive in humans. Given that it serves as a point of attachment for the muscles (e.g., adductors, vastus medialis and lateralis, gluteus maximum, and biceps femoris) involved in walking on two feet, this is a peculiar human trait that is either absent or is a bifurcated ridge in other mammals. In contrast, a supercondular depression may be seen on the lateral section of the shaft of the cow's femur and is absent in humans.

There is a chapter on traces of butchery and bone working that provides a brief history of modern butchery from the 18th century to present day, butchery using cleavers and heavy knives, prehistoric butchery, and bone as a raw material. It includes illustrations of modern butchery cuts

for beef, pork, lamb, and deer. There are also images showing evidence of butchery cuts on bone. These details can be used in the field as an aid to differentiate butchering remains on domesticated fauna from possible human homicide cases. Further, there is a chapter that illustrates the bones of a human infant and compares them to nonhuman taxa with elements of similar size. A strength of this guide is the use of comparative photos and diagnostic criteria for a sample of whole elements and common North American species of wild and domesticated fauna.

White and Folkens (2005) book *The Human Bone Manual* provide another resource, a human osteology manual utilized in biological anthropology, human osteology, and archaeology. A practical feature of this book is the use of multiple views of every bone in the human body and the tips on identifying each human element or tooth. The text includes explanations of the anatomy, growth, how to side, and potential confusions for each element. There are also chapters on postmortem skeletal modifications, bone biology and variation, and anatomical terminology. The White and Folkens (2005) manual is a more portable version, which is often used in the field, whereas, there is a larger and more extensive version by White, Black, and Folkens (2012) that serves as a more comprehensive, albeit more expensive, laboratory reference volume.

France has published a number of osteological field guides (2009, 2011, 2021). The 2009 manual focuses on morphological features visible to the naked eye. France uses eight taxonomic orders, comprising 32 different species, to compare skeletal elements and portions to human bones. The field guide describes human bone osteology and the morphological features significant to certain elements and useful for differentiating human and nonhuman bone. France's 2011 field guide is similar in terms of describing human bone osteology but goes more in-depth in differentiating human bone from inorganic material, and organic material, such as wood, which can also resemble human bone.

France's 2021 field guide focuses on comparing human subadult skeletons that range in age (18 months old, two years old, three years old, six years old, seven years old, 10 years old, 12 years old, 13 years old, 14 years old, 17 years old, 18 years old, 20 years old, and to a full-term adult) to taxa similar in size to a subadult human. Also included are 11 bird species, four reptiles (alligator, crocodile monitor lizard, iguana, and snapping turtle), three marine mammals (sea otter, sea lion, and harbor porpoise), three fish (white sturgeon, Pacific cod, and three individuals of a rock fish species), and a bit of information about an amphibian (frog).

One of the main purposes of this book, other than to accurately distinguish human from nonhuman bones, is to be able to see the changes in the human subadult skeletons through various developmental ages and to compare them to nonhuman bones. France states that the furculum of large birds might be mistaken for an edentulous human mandible by non-specialists (2021:15). It is also known that black bear (*Ursus americanus*) hand and foot bones are misinterpreted as human hand and foot bones due to the similar morphology. According to France the metacarpals, metatarsals, and phalanges of birds, reptiles, and marine mammals can be mistaken for human hand and foot bones, even by experts who are familiar with human elements (2021:17). Ultimately, even the most skilled specialist may struggle to differentiate between human and nonhuman bone, especially where subadults are involved, making this an especially valuable guide.

It should be noted that all of the references mentioned above do have their limitations by not going into depth regarding diagnostic features for certain skeletal elements. Therefore, besides the illustrated guides by Adams and Crabtree (2009), White and Folkens (2005), White, Black, and Folkens (2012), and France (2009, 2011, 2021) reviewed here, which explicitly focus on differentiating human from nonhuman bone, it should be noted that there are a number of

other illustrated guides focused on the diversity of nonhuman osteology. Many of those are regionally focused, aimed at zooarchaeologists, and are illustrated with line drawings rather than photographs. For North American fauna, Olsen (1968, 1972, 1996), and Gilbert (1990, 1996) provided useful examples.

2.5 Summary

This review of prior research focused on three topics. It began with a discussion of previous studies conducted with MEO collections and highlighted that nonhuman remains can account for as much as 90% of forensic casework (Pokines 2015). It then reviewed some of the laboratory methods used by specialists, such as macroscopic methods include comparing metrics and morphology of human and nonhuman bone (Garvin et al 2021; Grisbaum and Ubelaker 2001). It then reviewed some of the currently available illustrated guides suitable for use in field or lab contexts such as the works of Adams and Crabtree (2008), White and Folkens (2005), White, Black, and Folkens (2012), and France (2009, 2011, and 2021). Finally, it highlighted the limitation of these resources, since they typically focus on a limited set of elements and nonhuman taxa. Thus, certain elements, such as (vertebrae, ribs, and phalanges, may receive only superficial treatment). Many of these guides provide useful illustrations but offer relatively little discussion of the diagnostic features that could be used to differentiate these elements from human and nonhuman bone.

Chapter 3: METHODS

This thesis focuses on the inventory of nonhuman remains accumulated over a multi-year period at the Kenosha County Medical Examiner's Office in Wisconsin. From 2000 - 2005 these bones were released to Shirley Gaines Taylor, then an employee of the office and a graduate student in the UWM Anthropology Department, for curation in the UWM Zooarchaeology Lab. It should be noted that the collection that is the basis of this study did not include any case study information or other documentation. This can be attributed to the MEO view that these bones were nonhuman and not relevant of any medicolegal investigation, and were thus deemed discardable (personal communication, Dr. Jean Hudson).

This collection represents 1,940 nonhuman bones that are currently stored in fourteen wooden trays and two cardboard boxes in Sabin Hall 171A (see Figure 3.1 and 3.2). As part of the thesis work, these nonhuman bones were inventoried according to taxon and element, entered into a digital database, and ranked according to their frequency in the sample. Additional information was recorded about developmental age, preservation, and surface modification. It should be noted that the developmental age for this thesis is based on skeletal age which is classified as three osteologically driven age categories known as adult, subadult, and juvenile.

The developmental age category adult is defined for this study as epiphyseal fusion with the epiphyseal lines being no longer visible. Subadult is defined as partial epiphyseal fusion with the epiphyseal lines still visible. Juvenile is defined as the complete lack of epiphyseal fusion with the epiphyses remaining separate from the primary centers. These definitions create age categories that are easy to operationalize with multi-species mammalian skeletal material. It should be noted that they do not correspond to age categories or definitions of adult, subadult, and juvenile as these terms may be applied to human remains.

The study began with an inventory of the 14 trays in Sabin 171A. After consultation with Dr. Jean Hudson, two additional boxes of materials that had been moved to other lab spaces were retrieved and integrated into the 14 trays. This resulted in a total count of 1,940 nonhuman bones, representing a mix of whole and nearly whole elements and fragments of elements, primarily of bone, with some teeth and antler represented. The count of bones can be understood as one element or fragment thereof equals one count.

The second step was to identify all material to taxonomic class (mammal, bird, fish, reptile, amphibian, and undifferentiated) and anatomical element. I relied on my prior UWM classroom training in human osteology (Anthro 403G), human forensics (Anthro 405G), and zooarchaeology (Anthro 525) to accomplish the bulk of these identifications, reviewing any problematic bones with Dr. Hudson. During this process, I also noted the following additional information per element: developmental age, deterioration of the element (bone loses minerals, softens, and weakens), evidence of butchery, evidence of burning, evidence of the bone being worked, animal activity, weathering (sun-bleaching and soil-staining), and pathologies present on the bone.

Species-level identifications of mammalian and bird elements were attempted for a subsample of the study collection (N=207). The comparative osteological collections of the UWM Zooarchaeology Laboratory were the main resource used to aid in these more specific taxonomic identifications. The comparatives were also used to establish osteometric parameters for two size categories of mammals, large and very large. Size-level identifications were attempted for an additional subset of the study collection (N=755). The use of comparative osteological specimens allowed me to identify mammalian femora and tibiae to species, genus,

family, or order, and to identify mammalian vertebrae, ribs, and phalanges to size. The stages of this process are detailed below.

Figure 3.1. Image of the 14 trays of nonhuman bones in Sabin 171A (trays with multiple tags).

Figure 3.2. Image of the two cardboard boxes containing additional nonhuman bones and one of the boxes laid out in Sabin 171A.

3.1 Identification and documentation

I began the initial inventory of this collection in order to establish the approximate sample size (N=1,940). After this initial inventory, I reviewed the collection bone by bone and created a digital record in Excel, noting the taxonomic class (mammal, bird, fish, reptile, amphibian, and undifferentiated) and element for each fragment. At the same time, I evaluated whether the bone was complete or incomplete, noted the part of the element present if incomplete (proximal, distal, ventral, dorsal, cranial, anterior, posterior, complete, and fragment), and noted the approximate developmental age (adult, subadult, juvenile) based on epiphyseal fusion. Adult was defined as fully fused, subadult was defined as partially fused with the line of fusion still visible, and juvenile was defined as complete lack of fusion, where the epiphysis was completely separate.

Additional documentation of the complete sample (N=1,940) was done for variables of preservation and modification. Taphonomic alterations and surface modifications can both effect the bone's integrity and make it more challenging for a forensic anthropologist to determine whether the bone is human or nonhuman. When observed, surface deterioration was recorded as D (D = surface deterioration present) and weathering was recorded as We (We = weathering). Surface deterioration for this thesis is defined as evidence of cracking, flaking, and splitting of the bone. Whereas weathering is defined as evidence of soil-staining and sun-bleaching present on the bone. Butchery has the capacity to significantly alter a bone and possibly leave a portion of it absent, when observed, evidence of saw cuts were recorded as SC.

When a bone is manipulated into a tool, the structure and integrity are substantially disrupted, which might make it more challenging to identify the element and origin, for this

reason it was noted (Wo = worked bone). Burning was recorded because when bone is exposed to fire it may cause significant damage or possibly lead the bone to become too degraded for identification (B = indications of burning).

When animal damage was observed it was recorded (RG = rodent gnawing, CG = carnivore gnawing, G = both rodent and carnivore gnawing) as such damage can obscure key morphological traits. Pathologies were documented (P = pathologies present) as these also can remodel the bone in ways that limit taxonomic identifications. See Table 3.1 for a complete list of variables and attributed recorded in the Excel database.

Once all the bones had been recorded in this manner, I used the database to evaluate which taxonomic classes and which elements were the most common in the collection. These quantitative data are presented in Chapter 4. The next step of the analysis was narrow my focus to the two most abundant classes (mammal and bird) and the five most abundant elements of mammals (ribs, vertebrae, femora, tibiae, and phalanges), to provide a more detailed perspective. While my goal was species-level identification of the mammalian femora and tibiae when preservation and diagnostic morphology allowed, in some cases identifications were made at the level of genus, family, or order.

Three of the most abundant mammalian elements, ribs, vertebrae, and phalanges, are not well-suited to species-level identifications, and for these elements the identifications focused on two size categories, very large and large, the methods for which are detailed below. In the case of bird bone, I again attempted to make species-level identifications when preservation allowed, using family-level identifications when these were more secure.

Given the extensive size of the full sample, my goal was to target the most relevant subsample for the more detailed taxonomic analysis. Critical to this effort was use of the

comparative osteological collections of the UWM Zooarchaeology Lab, which provide a representative sample of complete skeletons of regionally common species (see Appendix A for a full list of the specimens used during this process).

Table 3.1. Complete set of categories used in the excel database during data collection.

Categories:	**Options to choose from:**
Class:	mammal, bird, fish, amphibian, reptile, and undifferentiated
Element:	**Mammal**: antler, carpal, cranium, femur, fibula, humerus, innominate, mandible, metacarpal, metapodial, patella, phalanx, radius, rib, sacrum, scapula, sesamoid, sternebra, tarsal, tibia, tooth, ulna, UNID, and vertebra **Bird**: carpometacarpus, coracoid, femur, furculum, humerus, pelvis and synsacrum, rib, scapula, sternum, tarsometatarsus, tibiotarsus, ulna, UNID, vertebra **UNID**: cranium, phalanx, scapula, tibia, UNID, and vertebra
Part:	proximal, distal, dorsal, ventral, cranial, anterior, posterior, complete, and fragment
Fragmentation:	I = incomplete; C = complete
Age:	A = adult; S = subadult; J = juvenile (based on epiphyseal fusion
Preservation:	D = deterioration indicated
Saw-cut:	SC = evidence of saw-cut
Burned:	B = evidence of burning
Worked:	Wo = evidence the bone has been worked
Rodent and Carnivore Gnawing:	RG = rodent gnawing; CG = carnivore gnawing; and G = both rodent and carnivore gnawing
Weathering:	We = evidence of weathering
Pathology:	P = evidence of pathology

3.2 Comparative analyses

Another objective of this process was to gather the information that would allow me to compare my sample with that of Pokines' (2015) earlier study and to assess the similarities and differences between a Midwest location and a Northeast location for a MEO within the United States. Although both regions represent a similar, temperate climate, the regions differ in overall human population density and niche construction, which might impact the nature of the wild and domestic fauna encountered. It is also notable that while Massachusetts includes an ocean coastline, Wisconsin does not, so marine taxa are likely to be represented only for the Massachusetts MEO collection, even though Wisconsin is in proximity of Lake Michigan.

Since many of the remains examined in Pokines (2015) study were so small that they could only be a potential match for human infant or neonate remains, he states that there are some factors that may favor reporting the remains to law enforcement. These include a general overlap in size with adult human remains.

My sample size appears to be larger than Pokines (2015) study, although it should be noted that our approach to quantification differs. My quantitative methodology relies on counts of bones, whereas Pokines' quantitative data depends on cases of investigation. To compare the relative species abundance trends in my sample to those in the sample from Pokines I relied on rankings according to whichever type of quantification had been used.

For this I based my rankings on bone counts or Number of Identified Specimens (NISP) and compared these to Pokines' rankings of his data based on number of cases in which the given variable was present. Other comparisons included developmental age representations, skeletal part representations, and taphonomic modifications. My study included some information that Pokines did not publish, such as the most frequent elements per species.

3.3 Mammalian size categories

The ribs, vertebrae, and phalanges were among the most abundant mammalian elements in my study collection. However, these elements could not be readily or reliably identified at the species level. As was noted in the review of prior studies in Chapter 2, there is a general lack of attention to inter-species diagnostic criteria for ribs, vertebrae, and phalanges in illustrated osteological guides. It should be noted that due to this it is one of the limitations of prior studies due to a lack of diagnostic features for these specific elements.

Therefore, an alternative approach was developed for them. Having established the potential utility of these size categories, osteometrics were used to operationalize them. Known species from the comparative collection were used to collect metric data for elements from taxa in these size categories.

I used these metrics to establish minimal and maximal thresholds per size category per element, with the goal of providing operationalized size categories of use to other researchers. This effort is detailed below and documented in Table 3.2 and Appendix C. It should be noted that these efforts were made by using Von den Driesch (1976) descriptions and measurement illustrations as a reference.

Live weights of expected fauna (wild and domestic species common in Wisconsin) were tabled to establish whether there were discrete size categories of local fauna and how these were grouped. Table 3.3 provides species names and live weight data for the very large (cow, elk, horse) and large (deer, bear, sheep, goat, pig, wolf) mammal categories that resulted. To assess the relevance of these size categories to the question of differentiated human and nonhuman bone, human data was added. Figure 3.3 provides a visual representation of the size distributions of these taxa and includes humans for comparison.

Table 3.2. Measurement names and descriptions per element, and the equipment used (Von den Driesch 1976:72-96).

Element	Name of Measurement	Description of Measurement	Equipment Used
Rib	Length of rib (LR)	Maximum length from proximal to distal extreme* in the transverse plane in cranial view	Osteometric board
Rib	Rib head to tubercle (RT)	Distance from extreme of rib head to extreme portion of rib tubercle in the transverse plane in cranial view	Sliding caliper
Rib	Width of rib (WR)	Maximum width of rib blade (cranio-caudal dimension; thickest part of blade) in the transverse plane in cranial view	Sliding caliper
Vertebra	Greatest length of vertebra (GLV)	Maximum length (lateral to lateral extremes) of articular surface of the body (centrum) in the transverse plane in cranial view	Sliding caliper
Vertebra	Greatest breadth of vertebra (GBV)	Maximum breadth (height, dorsal to ventral) of the body (centrum) in the transverse plane in cranial view	Sliding caliper
Phalanx	Greatest length of phalanx (GLP)	Greatest length (proximal to distal extreme*) in the transverse plane in cranial view	Sliding caliper
Phalanx	Proximal articular breadth (PAB)	Greatest breadth (height) of the proximal end (articular surface) in the transverse plane in proximal view	Sliding caliper

*the most projecting point

It is important to note that the human weight range, as seen in Figure 3.3, was derived from the 2015-2016 column of Fryar et al. (2018:6) table of mean weights of females and males from a source population of 45,047 individuals of non-Hispanic White, non-Hispanic Black, non-Hispanic Asian, and Hispanic Mexican American ancestry. The lower threshold was taken from the female category in the age ranges 20-60 years old, and the higher threshold was taken from the male category in the age ranges 20-60 years old.

For the ribs, the size categories were operationalized by taking measurements of the smallest and largest rib of all of the species in the very large category (cow, elk, and horse) and the large category (white-tailed deer, black bear, sheep, goat, pig, and wolf) using digital sliding calipers and an osteometric board (see Table 3.4).The type of measurements taken for the ribs were: the minimum and maximum length of the rib (mm), measurement from the rib head to tubercle range (mm), and the minimum and maximum width of the rib body (mm).

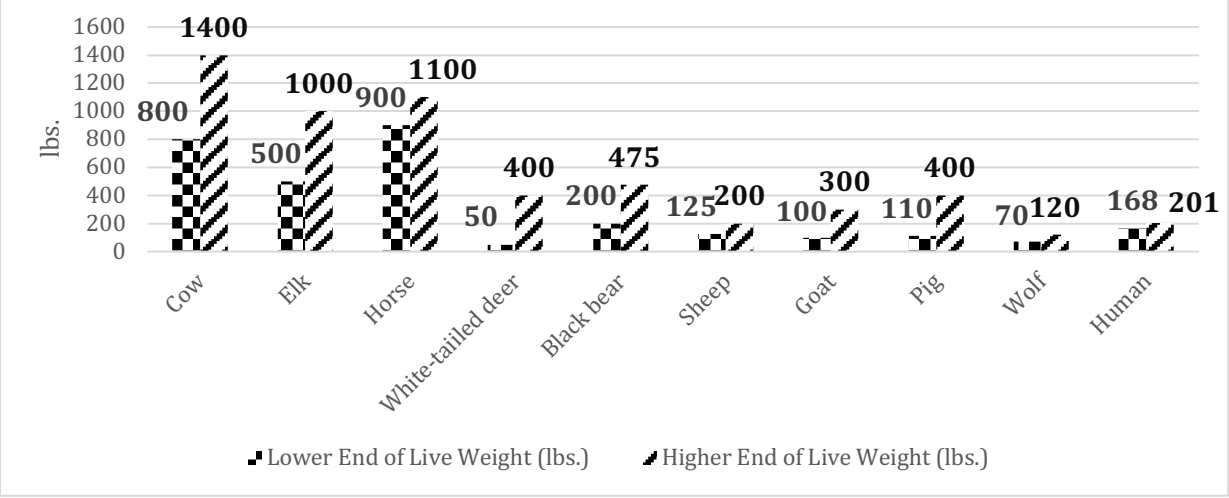

Figure 3.3. Clustered bar chart of the average live weights (lbs) per species and adult human (Burt and Grossenheider 1976:46-227 [Cow, Horse, Bear, Sheep, Goat, Pig], Kurta 1995:338 [Deer, Elk, Wolf], Fryar et al 2018:6 [Human]).

Table 3.3. Live weights (lbs) for size categories (Burt and Grossenheider 1976:46-227, Kurta 1995:338).

Size Category	Common Name	Scientific Name	Live Weight (lbs)
Very Large	Cow	*Bos taurus*	800 – 1,400
	Elk	*Cervus canadensis*	500 – 1,000
	Horse	*Equus ferras*	900 – 1,100
Large	White-tailed deer	*Odocoileus virginianus*	50 – 400
	Black Bear	*Ursus americanus*	200 – 475
	Sheep	*Ovis aries*	125 – 200
	Goat	*Capra hircus*	100 – 300
	Pig	*Sus scrofa*	110 – 400
	Wolf	*Canis lupus*	70 – 120

Table 3.4. Rib measurements per taxa for size categories using UWM comparative specimens*.

Size Category	Common Name	Minimum length of rib (mm)	Maximum length of rib (mm)	Rib head to tubercle (mm)		Minimum width of rib (mm)	Maximum width of rib (mm)
		Smallest	Largest	Smallest	Largest	Smallest	Largest
Very Large	Cow	370	**469**	**27.8**	**51.4**	23.6	44.8
	Elk	207	365	50.7	45.8	36.5	43.8
	Horse	**182**	450	38.8	39.1	**20.9**	**27.9**
Large	White-tailed deer	115	222	29.0	24.6	18.3	12.7
	Black Bear	**81**	229	29.2	**30.3**	14.3	14.4
	Goat	145	**270**	31.5	25.9	15.2	10.8
	Sheep	155	235	25.9	28.1	14.9	**20.9**
	Pig	105	184	20.5	28.3	19.9	20.7
	Wolf	85	132	**18.2**	24.6	**13.4**	18.5

*Minimum and maximum values per metric and size category are highlighted by bolding.

For the vertebrae and phalanges, the size categories were operationalized by taking measurements of the smallest vertebra and phalanx of the very large (elk) and large (wolf) taxa which belonged to the elk, and the smallest vertebra and phalanx among large taxa, which belonged to the wolf. The cow (*Bos taurus*) comparative did not have caudal vertebrae represented; however, it appeared the cow atlas, axis, cervical, thoracic, and lumbar vertebrae

were all larger than the corresponding elements in the elk (*Cervus canadensis*), hence why the elk was chosen as the smallest representative of the very large category and as the threshold metric. Similarly, wolf (*Canis lupus*) was chosen as the smallest of the large category and as the threshold metric for that size category.

The type of measurements taken for the vertebrae were: the greatest length of the vertebral body (centrum) (mm) and the greatest breadth of the vertebral body (centrum) (mm) for the atlas, axis, cervical, thoracic, lumbar, and caudal vertebra. The type of measurements taken for the phalanx were: the measurement of the greatest length from the proximal to distal extreme (mm) and the measurement of the proximal articular breadth (proximal articular surface from medial to lateral) (mm).

These measurements were used as threshold guidelines when placing the Kenosha MEO study collection ribs, vertebrae, and phalanx into their respective size category (see Table 3.6). It is worth noting that additional large or very large species might be encountered in Wisconsin today as a result of small-scale raising of more exotic livestock such as llama (*Lama glama*), or alpaca (*Vicugna pacos*) or bison (*Bison bison*); however, the probability is judged to be small, and they have not been included in this study.

Table 3.5. Vertebra measurements for size categories using UWM comparative specimens. Study collection specimens with parallel metrics equal to or larger than elk were sized as very large. Study collection specimens with parallel metrics equal to or greater than wolf and smaller than elk were sized as large.

Taxa	Specimen #	Type of Vertebra	Length of centrum (mm)	Breadth of centrum (mm)
Elk	7.3.29.1	Atlas	76.3	37.5
		Axis	76.5	48.9
		Cervical	35.8	37.0
		Thoracic	50.4	36.3
		Lumbar	36.5	29.3
Elk	UWZS 21715	Largest Caudal	21.6	16.1
		Smallest Caudal	9.1	8.1
Wolf	UWZS 35928	Atlas	39.1	30.3
		Axis	37.4	17.3
		Cervical	18.2	13.8
		Thoracic	17.1	15.2
		Lumbar	24.6	15.0
		Largest Caudal	8.8	10.2
		Smallest Caudal	6.3	5.9

Table 3.6. Phalanx measurements for size categories using UWM comparative specimens. Study collection specimens with parallel metrics equal to or larger than elk were sized as very large. Study collection specimens with parallel metrics equal to or greater than wolf and smaller than elk were sized as large.

Common Name	Species #	Phalanx	Greatest length in mm (proximal to distal extreme)	Proximal end articular breadth in mm (medial to lateral)
Elk	UWZS 21715	1	55.8	27.7
		2	40.5	26.7
		3	45.3	28.5
Wolf	UWZS 35928	1	35.9	8.3
		2	16.6	7.8
		3	33.2	12.7

3.4 Bird remains

The species used for the taxonomic identifications of the bird remains in the study collection can be found in Appendix A. Due to preservation and diagnostic morphology of the 120 bird elements, only 34 could be identified at a more specific level. In some cases, the identification could be made most confidently at the level of family or order, and in some cases the identification included notes about species that "compare favorably," which meant that the bird elements showed good morphological similarity to the regional species represented in the available comparatives, but other possibilities could not be excluded. For example, some bird vertebrae in the study collection compared well with the sandhill crane (*Grus canadensis*)

comparative, but vertebrae are not easily identified to species, and our comparatives did not include examples of other larger birds with a similar build, such as great egret (*Ardea alba*) and whooping crane (*Grus americana*). Most of the bird identifications are best viewed at the level of family or order. The bird elements identified were: carpometacarpus, coracoid, humerus, scapula, sternum, tarsometatarsus, tibiotarsus, ulna, and vertebra.

It is worth noting that while the comparatives included both wild and domesticated turkey (*Meleagris gallopavo*), an additional resource was consulted for those identifications, *Avian Osteology* by Gilbert (1996). This volume provides morphological keys, shaded line drawings, and tables of metrics. Four bird elements required this resource for identification. It keyed these elements as turkey based on morphology, however, my study collection specimens are larger than the wild turkey illustrations included in the book, and unfortunately the book does not include metrics for domestic turkey. Given that domestic turkeys are raised for meat and can be double the weight of wild turkeys (Dickson 1992:89), it seems likely that at least some of the study collection birds represent domesticated turkeys.

3.5 Summary

This chapter provided an explanation of the procedures used to identify the full collection of nonhuman remains to taxonomic class, element, and according to developmental age, preservation, and surface modification. The use of the UWM vertebrate comparative collection to make more specific taxonomic identifications for a subset of mammal and bird elements was detailed, as was the procedure for creating and operationalizing size categories for ribs, vertebrae, and phalanges. Analytical goals and approaches to comparing this collection with that

published by Pokines (2015), and to documenting preservation, developmental age, and surface modifications were also discussed.

Chapter 4: RESULTS

This chapter presents quantitative results that address six research questions about the nonhuman remains brought into the Kenosha County MEO. The research questions of this thesis are as follows: 1) Which classes of fauna are the most common among the nonhuman bones brought into the ME's office? 2) Which mammal elements are most common? 3) Which species were represented by the most abundant mammal elements? 4) Which bird elements were most abundant? 5) Looking at the bird elements that were complete enough to be identified to taxon, what species were represented? and 6) Do developmental age or particular taphonomic processes contribute to ambiguity in identifying bone as clearly animal versus possibly human?

These questions concern: 1) the most abundant taxonomic class, 2) the most frequently occurring elements, 3) which taxonomic species for the most frequently occurring elements, and 4) size classes represented. Additionally, based on the age representation, poor preservation, and modifications that were discovered on each of the 1,940 nonhuman bones, the findings evaluate whether any of these might be associated with increased ambiguity for a non-specialist. My data and Pokines' (2015) data are compared.

4.1 Taxonomic class

The most common classes of fauna in this collection are mammal (74%, N=1432) and bird (6%, N=120). Approximately 20% of the collection was not differentiated to class due to small fragment size or lack of diagnostic features and was categorized as unidentified (UNID; N=388). No reptile, amphibian, or fish were identified. These data are illustrated in Figure 4.1.

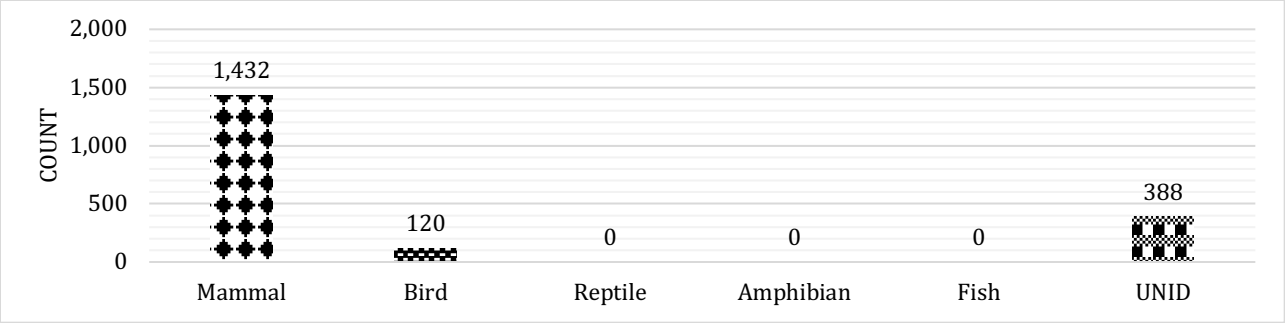

Figure 4.1. Column chart of the NISP per class (N=1,940).

4.2 Mammalian skeletal elements

The most common mammal elements are vertebrae, ribs, femora, tibiae, and phalanges. There were 344 vertebrae, 336 ribs, 107 femora, 100 tibiae, and 79 phalanges. These elements were the top five out of the 24 elements identified for mammals (see Figure 4.2).

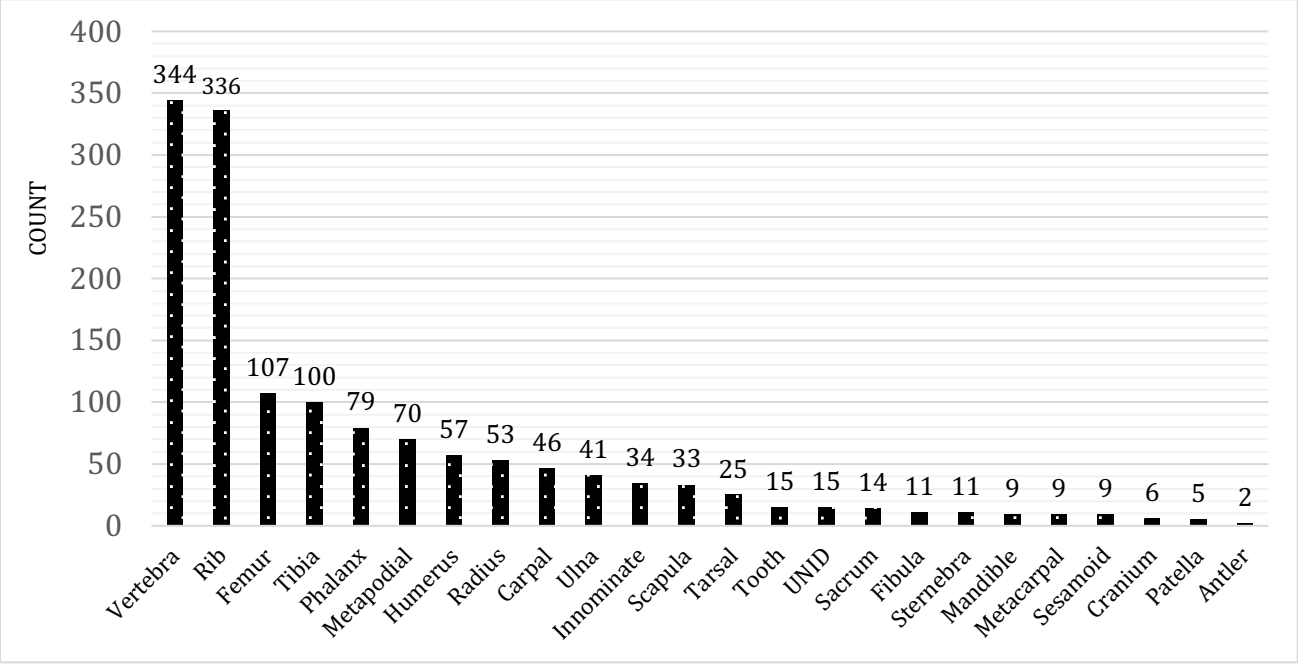

Figure 4.2. Column chart of the mammalian elements (N=1,432).

4.3 Species and family level identifications for mammalian elements

When evaluating the most abundant mammal elements, two of the top five, femur and tibia, were identifiable in many cases to species. As noted in the Methods chapter, these identifications were based on details of size and morphology and relied upon comparison with skeletal elements of known species, using the UWM vertebrate comparative collection. The ranked abundance of species for the femur are white-tailed deer, pig, cow, sheep/goat, artiodactyl, canidae, black bear, elk, horse, and eastern cottontail rabbit. The sheep/goat category were combined since the two species are too similar in relative size and morphology for confident distinction. See Table 4.1 for the scientific nomenclature of the species. The lists of more specific taxa represented by the femur and tibia were the same, and for both elements deer and pig were the best represented, however; the rank order of the other taxa varies, as can be seen in Figure 4.3 and Table 4.1.

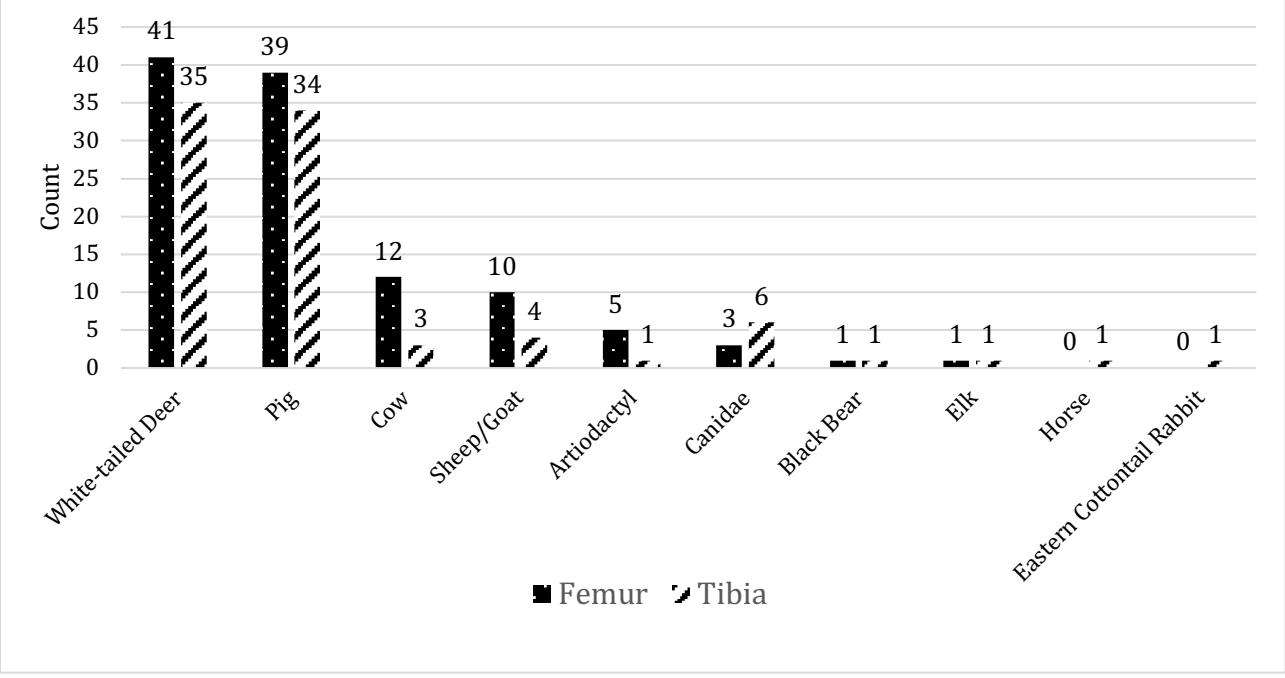

Figure 4.3. Column chart for counts per taxon of femur and tibia (N=199).

Table 4.1. Counts per element per specific taxon for femur and tibia (N=199).

Common Name/Family Name	Scientific Name	Femur (N=111)	Tibia (N=87)
White-tailed Deer	*Odocoileus virginianus*	41	35
Pig	*Sus scrofa*	39	34
Cow	*Bos taurus*	12	3
Sheep/Goat	*Ovis aries/Capra hircus*	10	4
Order Artiodactyla		5	1
Family Canidae		3	6
Black Bear	*Ursus americanus*	1	1
Elk	*Cervus canadensis*	1	1
Horse	*Equus ferras*	0	1
Eastern Cottontail Rabbit	*Sylvilagus floridanus*	0	1

4.4 Size category identifications for mammalian elements

The other most frequently encountered elements, rib, vertebra, and phalanx, were identified according to size categories of mammals rather than to species, as explained in the Methods chapter (see Table 3.2 and Figure 3.3). Very large mammals included those in the size range of horse, cow, and elk. Large mammals included those in the size range of bear, deer, pig,

goat, sheep, and wolf. The size category thresholds were operationalized per skeletal element using metrics. As noted in the Methods chapter, using the body weight thresholds established for this study, humans would fall in the large mammal category.

In the Kenosha MEO collection, the mammal ribs fell into three categories of fragmentation; whole rib, rib head, and blade of rib. The relative frequency of each is presented in Table 4.2 and then summarized in Table 4.3 to show the distribution by mammal size. Rib blades and whole ribs were the most common types of fragments. Large mammal ribs were almost twice as common as those from very large mammals. A small number of ribs (N=7) could not be confidently placed in either of those size categories due to fragmentation.

Table 4.2. Size categories of mammal ribs by fragment type (N=332).

Size Category	Whole Rib	Rib Head	Blade of Rib	Summed
Very Large	10	3	98	111
Large	106	24	24	154
UNID	0	0	7	7
Totals	116	27	129	272

Table 4.3. Size categories and totals of ribs (N=332).

Size Category	Total
Very Large	111
Large	214
UNID	7

For the vertebrae, sizing was done by measuring two threshold species, the elk, as the smallest of the very large group, and the wolf, as the smallest of the large group (see Tables 4.4 – 4.7). Mammal vertebrae were sorted according to their anatomical position (cervical, thoracic, lumbar, and caudal) and then by completeness and then by size. The vertebrae were sorted to type in order to analyze which portion of the vertebral column was most frequently represented in this collection. The most common vertebral type to be represented is thoracic (41%, N=63), and was followed by lumbar (30%, N=46), and the least represented were cervical (16%, N=24) and caudal (13%, N=20). Large mammal vertebrae were almost 12 times more common as those of very large vertebrae. A small number of vertebrae (N=4) could not be confidently placed in either of those size categories due to their relative size, instead they were placed in the size category identified as out of range; however, they were placed in their respective vertebral type categories. These data can be seen in Table 4.4.

Table 4.4. Size categories and counts of complete vertebrae (N=153).

Size Category	Cervical	Thoracic	Lumbar	Caudal	Summed
Very Large	2	0	0	10	12
Large	21	63	43	10	137
Out of Range	1	0	3	0	4
Totals	24	63	46	20	153

Similar data were tabulated for fragmented vertebrae (see Table 4.5). Very large mammal fragmented vertebrae were less common (28%, N=22) than those of large, fragmented vertebrae (72%, N=55). It is important to note that some vertebrae that could not be identified to vertebral

type (N=19). These data can be seen in Table 4.6. Again, very large mammals are less common than large ones. Thus, this was a pattern seen for all vertebrae.

Table 4.5. Size categories and counts of fragmented vertebrae (N=77).

Size Category	Cervical	Thoracic	Lumbar	Caudal
Very Large	14	1	3	4
Large	43	3	7	2

Table 4.6. Size categories and counts of undifferentiated vertebral types (N=19).

Size Category	Counts
Very Large	5
Large	14

For the phalanges, sizing was again done by measuring two threshold species, the elk, as the smallest of the very large group, and the wolf, as the smallest of the large group. The phalanges in the sample (N=79) were not as fragmented as the vertebrae, and therefore, all could

be placed in one of the two size categories. Similarly, to the vertebrae, large phalanges (89%, N=70) were almost eight times more common than very large phalanges (11%, N=9). These data can be seen in Table 4.7.

Table 4.7. Size categories and counts of phalanges (N=79).

Size Category	**Count**
Very Large	9
Large	70

In summary, for this Wisconsin MEO collection, deer and pig were the mammalian species most often represented for the two elements analyzed at the species level, the femur and tibia. In terms of mammalian size classes, elements in the large size category were the most common, suggesting this size category is more easily confused with possible human remains. In terms of mammalian elements represented, vertebrae and ribs contributed the most, followed by femora, tibiae, and phalanges.

4.5 Bird skeletal elements and taxonomic identifications

The most common bird elements are vertebrae, tibiotarsus, UNID, rib, and humerus. There were 32 vertebrae, 21 tibiotarsi, 19 UNID, 12 ribs, and 10 humeri. These elements are the top five out of the 14 elements to be found in the bird class (see Figure 4.4).

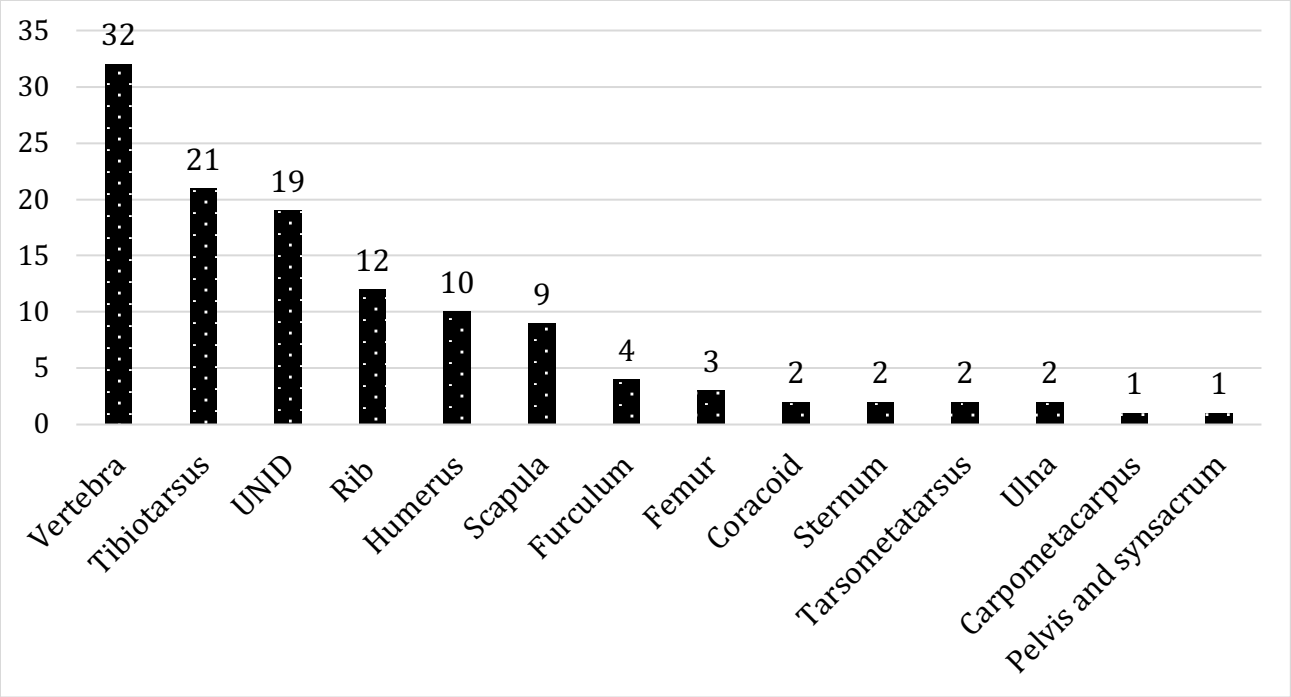

Figure 4.4. Column chart of the bird elements (N=120).

The identifications of the bird elements are most confidently made to the family level, but some likely species identifications are suggested based on morphological comparisons with the limited comparatives available (see Table 4.8). The identified families are Phasianidae (N=17), Anatidae (N=9), and Gruidae (N=8). The Phasianidae include turkeys and chickens, with most of the turkey remains likely representing domesticated turkey based on size, but with at least one likely wild turkey represented. The Anatidae include domestic duck, domestic goose, and Canadian goose. Thus, domestic fowl are well represented (turkey, chicken, duck, and goose), although wild fowl are also present. The Gruidae are represented by eight vertebrae, tentatively identified as sandhill crane. Out of the 120 bird elements, only 34 could be identified to taxon due to poor preservation (see Table 4.8 and Figure 4.5).

Table 4.8. Ranked abundance of bird species and counts (N=34).

Family Name	Scientific Name	Common Name	Count
Phasianidae	*Meleagris gallopavo*	Turkey	14
Phasianidae	*Gallus gallus*	Chicken	3
Gruidae	*Grus canadensis*	Sandhill Crane*	8
Anatidae	*Anas platyrhynchos*	Duck	5
Anatidae	*Answer anser*	Domestic Goose	2
Anatidae	*Branta canadensis lencopareia*	Canadian Goose	2

* tentative identification

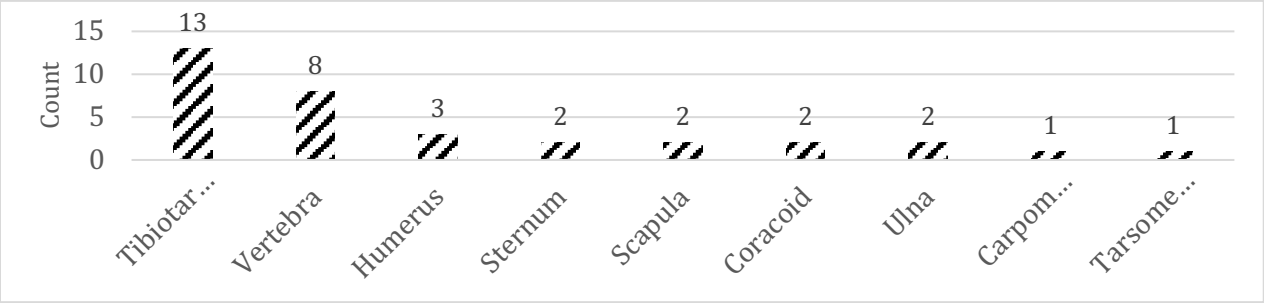

Figure 4.5. Column chart of the bird elements that were identifiable to family or species (N=34).

4.6 Developmental age, preservation, and surface modifications

Based on the premise that developmental age, preservation, and modifications might obscure features key to distinguishing nonhuman and human bone, and thus impact which bones were brought into the MEO, I recorded evidence for the presence of developmental age representation, surface deterioration and taphonomic alterations of weathering, animal activity, and pathologies, surface modifications of butchery, fire damage, and worked bone.

Out of the 1,940 nonhuman bones, most (1,466) could be identified to developmental age. There were 423 adult (29%), 230 subadult (16%), and 811 juvenile (55%) bones. There were 472 bones that were of unknown developmental age due to the element type, such as isolated teeth and limb shaft fragments which did not include the sites of fusion. Thus, for the 1,464 bones that could be aged by epiphyseal fusion, the majority fell in the juvenile category, defined osteologically for the purposes of this thesis as complete lack of fusion, including both unattached epiphyses, and limb shafts and vertebral bodies missing epiphyses. Vertebral centra epiphyses were especially abundant compared to that of shafts without epiphyses. Those data are presented in Table 4.9.

Table 4.9. Percentages of developmental age out of the nonhuman bones that could be classified (N=1,466).

Adult (%)	Subadult (%)	Juvenile (%)
29	16	55

Data on observed evidence for various taphonomic processes are presented in Table 4.10. The processes evaluated were surface deterioration and weathering, animal gnaw marks,

butchery, burning, worked bone, and pathologies. Most of these showed a low frequency of occurrence, suggesting they had little impact on the identifiability of the bone in this collection. The two processes with the largest impact were surface deterioration, observed on 35% of the bones, and butchering, observed on 24% of the bones.

The juvenile age group, surface deterioration, and butchery marks are the analyses that have the largest impacts on the study collection. The majority of the juvenile bones came from specific types of species, such as pig (*Sus scrofa*) and white-tailed deer (*Odocoileus virginianus*). For the femora, the developmental age group juvenile is identified in 36 pig and 25 white-tailed deer. For the tibiae, the developmental age group juvenile is represented 33 times in pig and 16 times in white-tailed deer. Those data are illustrated in Figure 4.6. The top five elements identified as juvenile based off epiphyseal fusion were rib, vertebra, femur, tibia, and phalanx (see Figure 4.7).

Table 4.10. Percentages of preservation and surface modifications out of the overall NISP (N=1,940).

	Percent exhibiting evidence
Surface deterioration	35
Weathering	13
Animal gnaw marks	12
Pathologies	1
Butchery	24
Burning	1
Worked bone	0

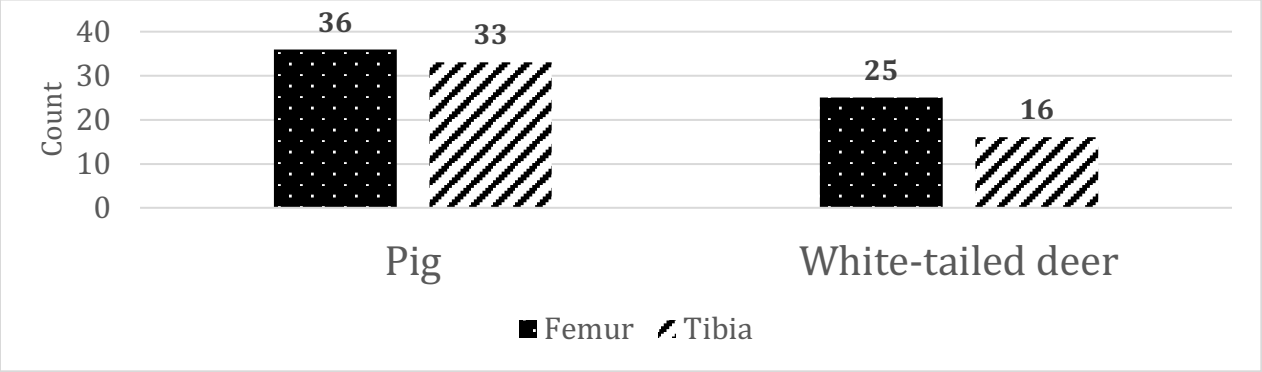

Figure 4.6. Developmental age group juvenile represented in pig and white-tailed deer (N=110).

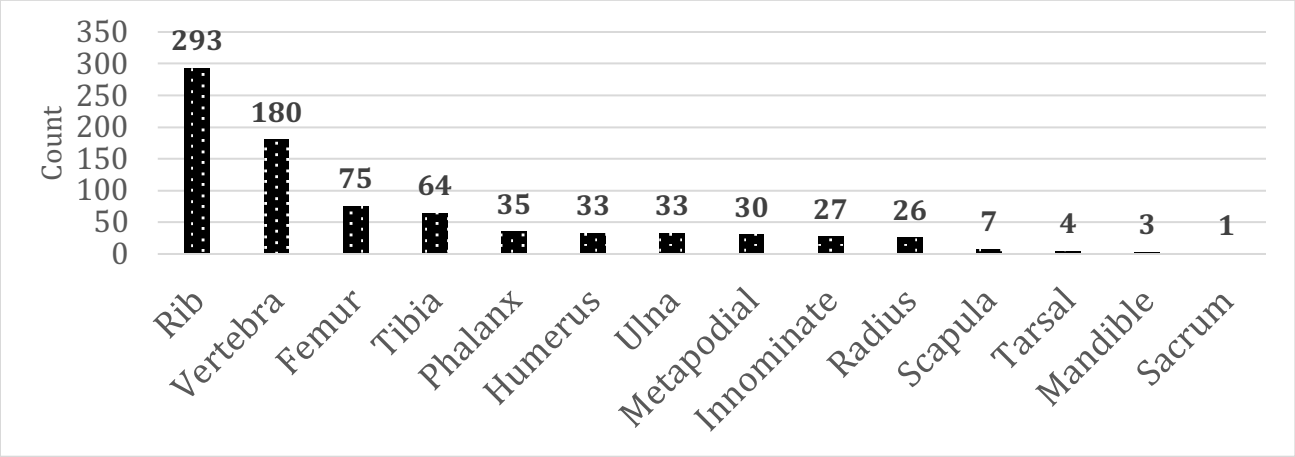

Figure 4.7. Juvenile age representation in mammal and undifferentiated elements (N=811).

Evidence of surface deterioration is present on 35% out of the 1,940 nonhuman bones in this assemblage. Over half the evidence for surface deterioration (392 out of 683) occurs on bone in the UNID category, suggesting it may in fact be associated with increased difficulty in identification of diagnostic features (see Figure 4.8). Butchery marks were observed on 24% of the nonhuman bones in this assemblage. Of these, the largest number occur on ribs (192 out of 466), followed by vertebrae, tibiae, femora, and ulnae (see Figure 4.9).

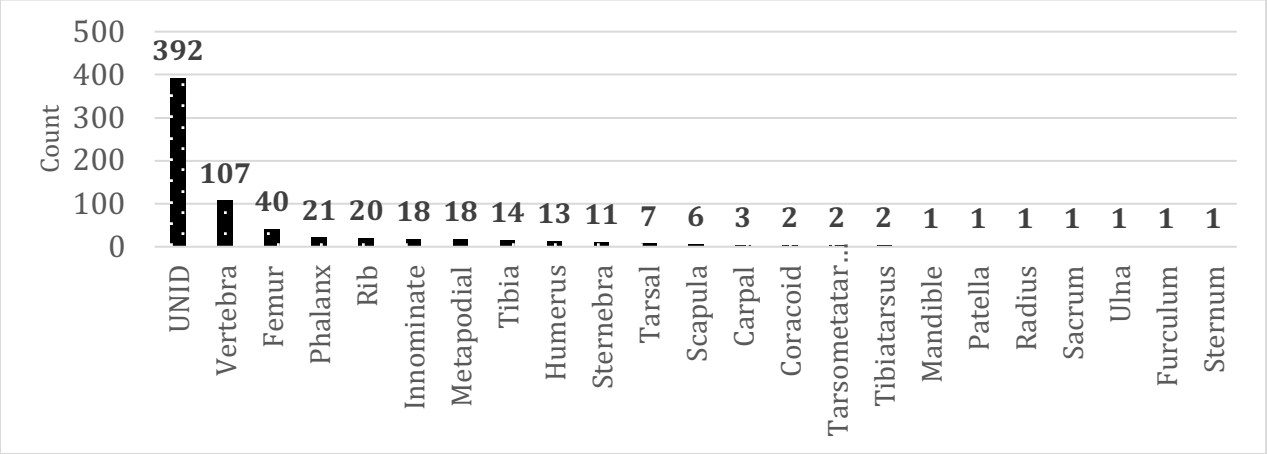

Figure 4.8. Surface deterioration represented in mammal, bird, and undifferentiated elements (N=683).

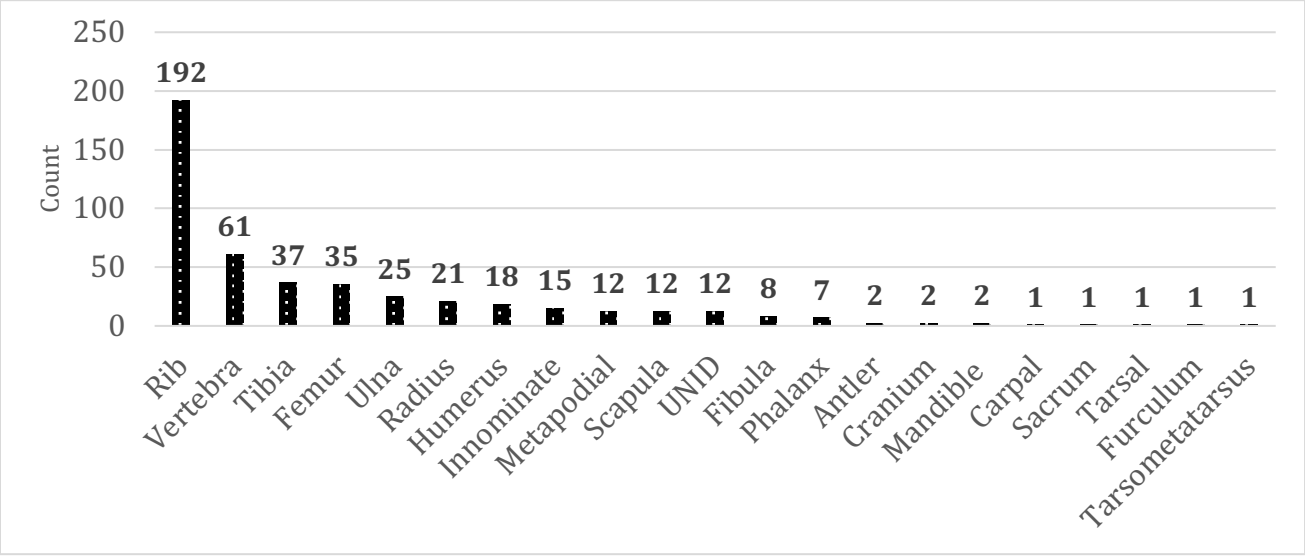

Figure 4.9. Butchery marks represented in mammal, bird, and undifferentiated elements (N=466).

It is important to note that there is a similar pattern of which elements are among the top five for all three of these analyses; developmental age of juvenile, evidence of surface

deterioration, and evidence of butchery marks. This suggests that the vertebrae, femora, tibiae, phalanges, and ribs have a similar, and perhaps interconnected, influence on causing ambiguities for a non-specialist when it comes to recognizing a bone as human or nonhuman.

4.7 Summary

The results of nonhuman remains according to taxonomic class, element, developmental age, preservation, and surface modification were reported in this chapter. Mammals (N=1,432) and birds (N=120) make up the majority of the fauna in this collection, with the remaining 20% (N=388) being undifferentiated. Vertebrae, ribs, femora, tibiae, and phalanges are among the most prevalent elements of mammals. Species-level identifications were made for the femur and tibia. Deer and pig were the best represented species, while the ranking of the other taxa vary. In contrast, the other most common mammalian elements, rib, vertebra, and phalanx, were identified based on mammal size categories. There were roughly twice as many ribs from large mammals as from very large mammals, nearly 12 times as many large mammal vertebrae were found as very large vertebrae, and about eight times as many large phalanges as very large phalanges. This suggests that the majority of the mammal bone, even the juvenile bone, brought into the Kenosha MEO is actually in a body size range that overlaps with that of humans.

Of the bird bone recovered, the vertebrae, tibiotarsus, rib, and humerus are the most typical avian elements; unidentified elements also contribute. In terms of the bird taxa identified, the family Phasianidae is more frequently encountered than the families Anatidae and Gruidae, with turkey and other domestic fowl comprising a large percentage of the identified birds.

In terms of developmental age and taphonomic processes, and their impacts on identifiability of bone, the biggest effects are linked to juvenile-aged bone with unfused

epiphyses, surface deterioration, and butchery. Similar patterns can be seen for developmental age, preservation, and modification. The majority of the 1,464 bones that could be aged by epiphyseal fusion belong to the juvenile group (55%). Among the observed taphonomic processes, 35% of the bone exhibited surface deterioration, and 24% of bone exhibited butchery marks. Weathering was observed on 13% of the bone and animal gnaw marks were observed on 12%.

Chapter 5: DISCUSSION

In this chapter I discuss possible interpretations of my results and how they relate to my original research questions. Additionally, I explore comparisons between my results and those of Pokines (2015). I discuss some of the limitations of this study and suggest some avenues for future research.

5.1 What was learned?

The first research question was: Which classes of fauna are the most common among the nonhuman bones brought into the ME's office? Mammal remains dominated in this collection, comprising 74% of the total sample of 1,940 nonhuman bones. The only other identified class was bird, contributing 6%. The remaining 20% could not be identified to taxonomic class, often due to fragmentation of the element. Most of the nonhuman bones were from mammals. One possible explanation is that because humans are mammals, mammalian osteology is more familiar to the non-specialist, and many elements are recognizable. Another possible explanation is that the discarded remains of wildlife, livestock, and domesticated mammals are more abundant on the landscape and thus more frequently encountered. Adams and Crabtree suggest that due to this "it is quite common for non-human bones to be mistaken for human remains and end up in the medical examiner or coroner system" (2008:4).

One possible explanation for the inclusion of bird bones is that their size and lightness makes the non-specialist who first encounters them consider juvenile humans. The bird bones in this collection fall within the size range of human juveniles; France (2021) makes this argument and provides comparative photos. She states, "a frying chicken is an immature bird, the bones of which often appear in picnics and backyards, the elements of a fryer can often be mistaken for a

human infant" (2021:49). She illustrates an example by stating that an "immature chicken femur can be mistaken for a human infant femur or tibia" and offers a diagnostic hint: "note the prominent condyles on the chicken femur, which are absent on the human infant femur" (France 2021:217). This suggests that immature bird bones are more likely to cause the confusion between human subadult and nonhuman bones. Among the 34 bird bones to be identified to family and species-level in this assemblage, there were two immature chicken bones and four immature turkey bones.

The complete absence of reptile, amphibian, and fish bone in this study collection came as something of a surprise, given the potential confusion of fragments of turtle carapace with mammalian skull, and the proximity of Kenosha to Lake Michigan. Perhaps the lack of these taxonomic classes are due to recovery bias resulting from the general public reviewing reptile, amphibian, and fish bones as too small to be considered as human. Even though Kenosha is close in proximity to Lake Michigan, another possible explanation is that Kenosha is closer to proximity to farmland and other rural land where reptile and amphibian bones would less likely be found. Another possible explanation could be that the MEO discarded the reptile, amphibian, and fish remains more immediately, recognizing them as nonhuman.

The second research question was: Which mammal elements are most common? In this collection vertebra, rib, femur, tibia, and phalanx were the top five most prevalent mammal elements; together, they accounted for 68% of the mammals, and 50% of the total assemblage. A possible explanation is that non-specialists would recognize these elements more readily than others simply due to them being more recognizable as elements that humans have, while the details of their morphology are less well known. France argues that "it is easy to mistake the

floating 12th rib of a human and a chicken scapula" due to mistaking the "glenoid fossa on the blade for a point of vertebral articulation" (2021:14).

The third research question was: Which species were represented by the most abundant mammal elements? Of the five most abundant elements, only the femur and tibia could be successfully identified at the species level. Due to the variation in size and form, vertebrae, ribs, and phalanges could not be brought to species level identifications; however, these elements were classified in size categories corresponding to two groups of regionally relevant species, very large (elk, cow, and horse) and large (bear, deer, pig, sheep, goat, and wolf). The data show that the large size was more common. It should be noted that a large sample of these overlap with the size of human remains and the same can be said with the taxa identifications for the femur and tibia. A next step for future research would be to see if there is a way to exclude these elements from the human size range by producing a new approach.

However, an explanation why vertebrae, ribs, and phalanges were so popular in this collection could be due to the typical number of vertebrae in a nonhuman mammalian skeleton ranging from 26 to 27. Ribs vary in mammalian skeletons, anywhere from 12 (wolf) to 18 (horse) pairs. The same is true for phalanges, horses have 12 and wolves have 48, whereas humans have 56 phalanges. France argues that "the phalanges of birds, reptiles, and mammals can be mistaken for human hand and foot bones, even by those who are somewhat familiar with the human elements" (France 2021:16). France says one way to tell the difference is by looking at "the articular surfaces of nonhuman mammalian phalanges which usually have a ridge running in the anterior-posterior direction in the middle of the distal articular surfaces" (France 2021:16-18).

The species and taxonomic families and orders that were identified for the femur and tibia are white-tailed deer, pig, cow, sheep/goat, artiodactyl, canidae, black bear, elk, horse, and eastern cottontail rabbit. The ranked abundance of the species per element were different, however for both the femora and tibiae, deer and pig were best represented. To estimate the relative contribution of wild and domesticated species as represented in the femora and tibiae, artiodactyla and canidae were excluded, since they include members of both. With this in mind, domesticated species (pig, cow, sheep/goat, and horse) represented 52% of the femora and tibiae, while wild species (elk, deer, bear, and eastern cottontail rabbit) comprised of 41%. However, when looking at white-tailed deer and pig, wild species comprised 51% and domesticated species comprised of 49% of the femora and tibiae. Thus, one might argue that in this MEO collection, the representation of wild and domesticated mammals is roughly equivalent. This suggests that even though Wisconsin is known for its domesticated animals, it has value for hunters because of the wild animals; which could explain the equivalence of domesticated and wild mammals in this collection.

A possible explanation for the importance of deer and pig is that femora and tibiae of these particular taxa are similar in size and shape to those elements in adult humans. However, Adams and Crabtree suggest looking at the "well-developed greater trochanter on the deer femur" and the "well-developed tibial tuberosity on the proximal deer tibia to distinguish human from deer bones" (2008:84-89). In addition, they suggest looking at the "greater trochanter on the pig femur because it will be larger and more developed than humans" and the "distal pig tibia has two parallel concave articular facets for articulation with the astragalus, which is absent in humans" (Adams and Crabtree 2008:103-105).

The fourth research question was: Which bird elements were most abundant? These were determined to be vertebra (34%, N=32), tibiotarsus (22%, N=21), rib (13%, N=12, and humerus (11%, N=10). The remaining 21% could not be identified to element, often due to fragmentation. However, based on the lightness of the bones and the thinness of the cortical bone they were identified to the taxonomic class bird. France argues the reasoning for the loss of identifying features is because bird bones are fragile and are more susceptible to poor preservation due to animal activity (2021:12). She continues and states that "the humerus of birds can be mistaken for a human mandible, particularly if it has been partially scavenged" (France 2021:14). Adams and Crabtree (2008) agree with France (2021) that the lightness of the bird skeleton, due to the adaption for flying, can cause the bones to be more fragile. However, Adams and Crabtree suggest that a "bird humerus can be mistaken for an infant human humerus" and to "note the pneumatic fossa near the proximal end of the bird humerus" (2008:252).

The fifth research question was: Looking at the bird elements that were complete enough to be identified to taxon, what species were represented? Out of the 120 bird elements in the sample, only 34 could be taken to species and family-level identification due to the majority of the bird bones being too poorly preserved to retain diagnostic features. It was found that the ranking of the species to be most prevalent for the bird elements were domestic turkey, sandhill crane, domestic duck, domestic goose, Canadian goose, domestic chicken, and wild turkey. It is important to note some of these more specific bird identifications are tentative, based on comparable morphology with a somewhat limited comparative collection, and the family level identifications are the most secure ones.

While out hiking or hunting in Wisconsin, it is not unusual to come across wild turkey. However, in Wisconsin, domesticated fowl are particularly abundant compared to wild fowl. The

Wisconsin Department of Natural Resources has seen a "35% decrease in the long-term mean" in wild fowl broods (Dhuey 2016). This suggests that domestic fowl may be more common in the contexts where bone is found by the non-specialist. These bones are often discarded in picnics and backyards. There are many different types of wild birds in Wisconsin, yet there was little evidence of this diversity in the MEO collection. The population size of the sandhill crane in Wisconsin is 95,000 compared to 75,000 pheasants and there are about 200,000 to 300,000 Canadian geese in Wisconsin due to their migratory patterns (*Small Game Hunting*, 2022). It is perhaps surprising that they do not contribute more to the MEO nonhuman assemblage.

The sixth research question was: Do developmental age or particular taphonomic processes contribute to ambiguity in identifying bone as clearly animal versus possibly human? Juvenile nonhuman bones with completely unfused epiphyses were especially common in the study collection. As can be seen in the Results chapter, Table 4.9 illustrates that out of the 1,940 nonhuman bones, juvenile bones comprised 55% of the assemblage. The majority of the bones in this assemblage may have resulted from discarding undesired bones from food consumption, such as cow, pig, turkey, and chicken bones. One explanation for this could be that young livestock are slaughtered before the bones have had time to fully develop, thus the intersection of domesticated species and juvenile individuals. This could also account for other factors including the relatively high frequency of butchery marks and surface deterioration evidence in the assemblage.

For instance, a significant portion (35%) of the overall sample had evidence of surface deterioration. One possible explanation may be is people cooking food with the bone in, such as chicken wings, whole turkeys for Thanksgiving, or pig shoulders. The high temperatures used to

cook bone-in meats can make the bones brittle and impact the integrity of the bone, much like they would if they were left out in the environment.

Similarly, butchery marks comprised 24% of the assemblage and one possible explanation could be explained by modern butchery of meats. During this process, a butcher uses hand saws, electric saws, and other tools in order to cut through bone so that the meat may be processed for sale. Even though evidence of burning, evidence of a bone being worked, weathering, and pathologies were the taphonomic alterations that were also evaluated, it should be noted that these did not deem to have noticeable impact on ambiguity.

Therefore, a non-specialist may assume that juvenile bones could be human due to the lack of morphological features. Similarly, surface deterioration can eliminate crucial morphological features that help distinguish between human and nonhuman bones, increasing the challenges of making an accurate field identification. The same is true for bones that have been butchered, as cut marks might result in one half or more of the bone being absent, and the presence of saw marks can prompt a non-specialist to instinctively suspect foul play, such as homicides.

Most forensic cut marks are not butchery marks, there are different types of marks that can be present on bone that could cause a non-specialist to suspect homicides (e.g., hand saw, electric saw, knife marks, etc.). Consequently, it is important to be able to distinguish butchery marks from forensic marks. A person can do so by analyzing the ridges and paths leftover on the bone from the tool used. The different types of tools, which are mentioned above, leave different patterns on the bone.

5.2 Comparison with similar prior studies

This thesis can be compared to Pokines (2015) study of 355 forensic cases collected over three years by the Boston MEO in Massachusetts. By contrasting a Midwest location with a Northeast location in the United States, geographical relevance can be evaluated. Since this thesis relied on counts of bones rather than the total number of cases used by Pokines (2015), it is impossible to say with certainty exactly how the sample size of bones compare between the two assemblages. As a result, comparisons must be done based on internal measures of ranking and relative abundance, tied to bone counts for my sample and cases for his.

Pokines' study found that mammal was the most common taxonomic class, as did I. Cattle, white-tailed deer, and pig were the top three taxa in the Massachusetts collection. They were almost equally important, with cattle making up 29.6% of the sample (N=105), white-tailed deer representing 29.3% (N=104), and pig comprising 26.2% (N=93). White-tailed deer, pig, and cows were also the top three taxa in the Wisconsin collection, although the ranked order of taxa differed. White-tailed deer made up 38.2% of the total, followed by pig (36.7%), and cow (7.5%). Thus, one of the striking differences is the relative low percent contribution by cow in Wisconsin. One explanation of the different representation of cow in the Massachusetts and Wisconsin sample is that although our population is large (>1 million), the cow bones after death are centralized near butchers and slaughterhouses and rendering plants, rather than being discarded in areas where a person out walking might encounter them (Department of Agriculture, Trade and Consumer Production).

The most prevalent bird species in Pokines study was chicken (*Gallus gallus*) and turkey (*Meleagris gallopavo*), with chicken comprising 5.4% (N=19) and turkey comprising 1.1% (N=4) of the 355 cases. In contrast, the Wisconsin assemblage had domestic turkey comprising

27% (N=9) and sandhill crane representing 24% (N=8) of the 34 bird elements that were identified. The Massachusetts collection was slightly smaller, in terms of the number of bird species, than the Wisconsin assemblage and was less diverse. One explanation of this could be that Wisconsin is home to over 300 species of birds (Wisconsin Department of Natural Resources).

However, the Massachusetts assemblage included reptile and fish elements, making it more diverse than the Wisconsin assemblage, which had neither. One explanation of this could be that Massachusetts has a sea coast which added to the natural diversity regional fauna that could be encountered. Wisconsin is in close proximity to Lake Michigan, but there were no fish remains found in the assemblage. This could be due to the Kenosha MEO discarding them, knowing that the elements were too small or fragile to even be fetal remains. For developmental age, Pokines (2015) found that the category named "adult only" had the highest representation of (51%, N=181); this is in striking contrast to the Wisconsin assemblage, where juveniles have the highest representation (55%, N=811).

Some of the differences between the two collections may reflect regional differences in both natural environments and discard and encounter patterns. According to Pokines (2015), "the number of terrestrial mammal species deriving from marine contexts was a surprising finding," and "the remains of domesticated species were likely introduced as human food waste left at the shore or thrown into the ocean, and wild species with no signs of machine butchery were encountered, including white-tailed deer" (2015:18). In contrast, Wisconsin might be expected to have more terrestrial and rural contexts than Massachusetts, a larger deer population, and livestock harvesting patterns that lead to more localized cow and pig butchered and discarded.

5.3 What are the contributions?

If the MEO collection represents the types of bones that people find confusing to distinguish as nonhuman, then the most problematic taxonomic class is mammal, and the most problematic taxa are white-tailed deer, pig, and cow for both this thesis and Pokines (2015) study. The elements that are the most problematic for this thesis are vertebrae, ribs, femora, tibiae, and phalanges, which comprised 67.5% of the 1,432 mammal elements. Pokines restricted his evaluation of elements to the cranial versus post-cranial, lumping all post-cranial elements; he found that the cases with postcranial elements dominated, at 94.1% of the 355 cases. Both studies show that increased knowledge about diagnostic features of common nonhuman mammals is necessary in order to decrease the number of times forensic specialists must visit crime scenes, freeing up their time for more challenging cases involving human remains.

The importance of vertebrae, ribs, and phalanges in this thesis highlights a neglected set of challenging elements, as these elements are not always incorporated into the existing illustrated field guides and lists of diagnostic morphological criteria. As previously stated by France (2021) and Adams and Crabtree (2008) these elements can be mistaken for human bones even by forensic specialists. However, this thesis did provide new metric thresholds that could help others sort these elements into body sizes.

The goal of these osteometrics were to try and establish a way to place a bone that is encountered in the field by archaeologists or, in casework by forensic anthropologists, medical examiners, coroners', law enforcement, or even by non-specialists to have a way to determine whether a rib, vertebra, or phalanx were overlapping in size with adult humans. This would help establish medicolegal significance. However, a next step for these metric thresholds is to take the

same measurements of male and female human skeletons from different populations, and to develop lists of morphologically diagnostic criteria and photographic guides.

The final contribution is a comparison of samples from the Midwest and the Northeast, which showed that despite regional variations, white-tailed deer, pigs, and cows were the top three problematic taxa and that the top problematic taxonomic class was mammals. Variation between the two studies in the exact ranking of taxa as well as the overall diversity of taxa shows how regional characteristics might affect the proportion of a certain taxon in an assemblage, even while the most problematic taxa remain the same.

5.4 Limitations and recommendations for future research

The research presented in this thesis had some limitations. Given the overall scale of work and the large size of the collection, only two mammal elements, femur, and tibia, were evaluated for more specific taxonomic identification. As illustrated in Figure 4.2, these do account for 14.5% of the mammal material, and the two elements produced similar lists of species represented, but it would be useful to expand this effort to include all elements to see if the percentages of the most common taxa change, rather than focusing just on the most abundant ones. This could be an avenue for future research.

A related limitation was the comparative vertebrate collection used to make the species level identifications; while the UWM comparative collection has over 200 specimens representing the fauna of Wisconsin (see Appendix A for those comparatives consulted for this study), it is not as comprehensive as it could be. Some species are represented by a single specimen, and in a few cases individual specimens lack particular elements. This made it difficult, but not impossible to compare and contrast the comparative specimens to the femora

and tibiae to make species-level identifications. This limitation could be addressed by consulting other comparative collections, such as those of the University of Wisconsin Madison Zoology Museum and the Field Museum in Chicago, to name two more comprehensive collections in the region.

Another limitation is the lack of previous comparative studies across mammals and birds to establish diagnostic features for elements such as vertebrae, ribs, and phalanges. One of the intriguing outcomes of this study was how common those three are among the nonhuman bone coming into the local MEO. This suggests a productive line for future research. While the present study creates some metric thresholds for sorting these elements into size categories, and eliminating elements too large to be human, it does not attempt to establish diagnostic criteria to differentiate species, or to expand the photographic coverage of these neglected elements, both of which could be useful efforts.

While this thesis represents a positive complement to Pokines (2015) study, expanding the regional coverage of MEO assemblage to the Midwest, there are many other regions with their own distinct environments and expected fauna yet to be studied. Therefore, another recommendation for future research would be to add another regional sample, such as a Southeastern one.

One last potential future study is worth mentioning. A new, abbreviated field guide could be developed for Wisconsin, aimed specifically at the most represented taxa (deer, pig, cow) and the most represented elements (vertebrae, ribs, femora, tibiae, and phalanges), and illustrating juvenile elements, both their loose epiphyses and the shafts and the vertebral bodies that are missing them. If released in a free, online form, it could be immediately accessible to interested

professionals in law enforcement and other relevant fields, and put to use, potentially saving the MEO a little time later.

REFERENCES

Adams, B. J., Santucci, G., & Crabtree, P. J. (2008). *Comparative skeletal anatomy: A photographic atlas for medical examiners, coroners, forensic anthropologists, and archaeologists*. Humana Press.

Andronowski, J.M., Davis, R.A., & Stephen, H.E. (2019). "Inferring bone attribution to species through micro-computed tomography: A comparison of third metapodials from *Homo sapiens* and *Ursus americanus*." *Journal of Forensic Radiology and Imaging*, 18:11–17.

Blau, S., & Briggs, C.A. (2011). "The role of forensic anthropology in Disaster Victim Identification (DVI)." *Forensic Science International*, 205(1-3); 29-35.

Burt, W.H. & Grossenheider, R.P. (1976). *A field guide to the mammals: Field marks of all North American species found North of Mexico*. *3rd edition*. Houghton Mifflin Company.

Christensen, A.M., Passalacqua, N.V., Schmunk, G.A., Fudenberg, J., Hartnett, K., Mitchell, R.A., Love, J.C., Jong, J., & Petaros, A. (2015). "The value and availability of forensic anthropological consultation in medicolegal death investigations." *Forensic Science, Medicine, and Pathology*, 11:438–441.

Christensen, A.M., & Pokines, J.T. (2020). "Discovery context of skeletal remains received at the Federal Bureau of Investigation Laboratory." *Forensic Anthropology*, 3:59–63.

Cummaudo, M., Cappella, A., Giacomini, F., Raffone, C., Màrquez-Grant, N., & Cattaneo, C. (2019). "Histomorphometric analysis of osteocyte lacunae in human and pig: Exploring its potential for species discrimination." *International Journal of Legal Medicine*, 133:711–718.

Crescimanno, A., & Stout, S.D. (2012). “Differentiating fragmented human and nonhuman long bone using osteon circularity.” *Journal of Forensic Sciences*, 57(2):287–294.

Dewey, J. (2013). “Survey of comparative human and non-human osteology: Common Florida species.” *University of Central Florida*, i-211.

Department of Agriculture, Trade and Consumer Production (DATCP). (n.d.). *Farm center supports diary development*. https://datcp.wi.gov/Pages/AgDevelopment/DairyDevelopment.aspx, accessed October 21, 2022.

Dhuey, B. (2016). “Game bird production falls in 2016 from 2015 levels,” https://dnr.wi.gov/news/weekly/?id=553 - art3, accessed November 4, 2022.

Dickson, J. (1992). *The Wild Turkey: Biology and Management*. Stackpole Books.

Dogăroiu, C., Dermengiu, D., & Viorel, V. (2012). “Forensic comparison between bear hind paw and human feet.” *Romanian Journal of Legal Medicine*, 20:131-134.

Dominguez, V.M., & Crowder, C.M. (2012). “The utility of osteon shape and circularity for differentiating human and non-human Haversian bone.” *American Journal of Physical Anthropology*, 149(1); 84-91.

Driesch, A.v.d (1976). *A Guide to the Measurement of Animal Bones from Archaeological Sites*. Germany: Harvard University Press.

France, D.L. (2009). *Human and nonhuman bone identification: A color atlas. 1st edition*. CRC Press.

France, D.L. (2011) *Human and nonhuman bone identification: A concise field guide. 1st edition*. CRC Press.

France, D.L. (2021) *Comparative bone identification: Human subadult and nonhuman --- A field guide. 1st edition*. CRC Press.

Fryar, C.D., Kruszon-Moran, D., Gu, Q., & Ogden, C.L. (2018) "Mean body weight, height, waist circumference, and body mass index among adults: United States, 1999-2000 through 2015-2016." *National Health Statistics Report*, 122:1-15.

Garvin, H. M., Dunn R., Sholts S.B., Litten M.S., Mohamed M., Kuttickat N., & Skantz N. (2021). "Forensic tools for species identification of skeletal remains: Metrics, statistics, and OsteoID." *Biology*, 11(1):1-19.

Grisbaum, G. A., & Ubelaker, D. H. (2001). *An analysis of forensic anthropology cases submitted to the Smithsonian Institution by the Federal Bureau of Investigation from 1962 to 1994* (No. 45). Smithsonian Institution Press.

Hillier, M. L., & Bell, L. S. (2007). "Differentiating human bone from animal bone: a review of histological methods." *Journal of Forensic Sciences*, 52(2):249-263.

Kurta, A., & Burt, W.H. (1995) *Mammals of the Great Lakes region*. The University of Michigan Press.

Lagacé, F., Schmitt, A., Martrille, L., Benassi, J., & Adalian, P. (2020). “Using histomorphometry for human and nonhuman distinction: A test of four methods on fresh and archaeological fragmented bones.” *Forensic Science International*, 313:110369–110369.

Latham, K., Bartelink, E., & Finnegan., M. (2017). *New perspectives in forensic human skeletal identification*. Academic Press.

Lowenstein, J. M., Reuther, J.D., Hood, D.G., Scheuenstuhl G., Gerlach S.C., & Ubelaker, D.H. (2006). “Identification of animal species by protein radioimmunoassay of bone fragments and bloodstained stone tools.” *Forensic Science International*, 159(2-3):182-188.

McGrath, K., Rowsell, K., St-Pierre, C.G., Tedder, A., Foody, G., Roberts, C., Speller, C., & Collins, M. (2019). “Identifying archaeological bone via non-destructive ZooMS and the materiality of symbolic expression: examples from Iroquoian bone points.” *Scientific Reports*, 9(1):1-10.

Mundorff, E.J., & Mar-Cash, E. (2009). “DNA preservation in skeletal elements from the World Trade Center disaster: Recommendations for mass fatality management.” *Journal of Forensic Sciences*, 54(4):739-745.

Olsen, S. J. (1961). “Problems of mammal skull identification due to age differences in the dentition.” *American Antiquity*, 27(2):231-234.

Orcholl, J. L., & Hudson, J. (2022). “Diagnostic criteria for the comparison of human and American black bear skeletal elements,” 1-19. DOI: 10.1.1.211.1955&rep=rep1&type=pdf, accessed March 11, 2022.

Owsley, D.W., Mann, R.W., Chapman, R.E., Moore, E., & Cox W.A. (1993). "Positive identification in a case of intentional extreme fragmentation." *Journal of Forensic Science*, 38(4):985-996.

Piga, G., Solinas, G., Thompson, T.J.U., Brunetti, A., Malagosa, A., & Enzo, S. (2013). "Is X-ray diffraction able to distinguish between animal and human bones?." *Journal of Archaeological Science*, 40(1):778-785.

Pokines, J. T. (2015). "Identification of nonhuman remains received in a medical examiner setting." *Journal of Forensic Identification*, 65(3):1-24.

Pokines, J.T. (2018). "Differential diagnosis of the taphonomic histories of common types of forensic osseous remains." *Journal of Forensic Identification*, 68(1):1-23.

Pokines, J.T. (2019). The case of the… cases: The flow of the ordinary into a medical examiner's office. Garvin, H.M., Editor & Langley, N.R., Editor (Eds.), *Case Studies in Forensic Anthropology* (pp. 291-302). CRC Press.

Pokines, J.T., Eck, C.J., & Sharpe, M.E. (2017). "Sources of skeletal remains at a chief medical examiner's office: Who finds the bones?." *Journal of Forensic Identification*, 67(2), p.278.

Pokines, J.T., L'Abbé, E.N., & Symes, S.A. (2021). *Manual of forensic taphonomy*. CRC Press.

Pollock, C.R., Pokines, J.T., & Bethard, J.D. (2018). "Organic staining on bone from exposure to wood and other plant materials." *Forensic Science International*, 283;200-210.

Santos, E., Gomez-Olivencia, A., Arlegi, M., & Arsuaga, J.L. (2015). "Cranial morphological differences within *U. deningeri – U. spelaeus* lineage: A double traditional and geometric morphometrics approach." *Quaternary International*, 30:1-16.

Savage, H. G., Gilbert, B. M., Martin, L. D. (1996). *Avian Osteology*. Missouri Archaeological Society.

Sims, M. E. (2007). "Comparison of black bear paws to human hands and feet." *Identification Guides for Wildlife Law Enforcement*, 11(3):1-5.

Wisconsin Department of Natural Resources. (2022). *Small Game Hunting*. https://dnr.wisconsin.gov/topic/hunt/smgame.html, accessed November 18, 2022.

Smart, T. S. (2009). "Carpals and tarsals of mule deer, black bear and human: an osteology guide for the archaeologist." *Western Washington University Journal*, 1-101.

"Standard for Determination of Medicolegal Significance from Skeletal Remains in Forensic Anthropology." *American Academy of Forensic Science*, https://www.aafs.org/sites/default/files/media/documents/150_Std_e1.pdf, accessed December 10, 2022.

Stein, W. T. (1963). "Mammal remains from archaeological sites in the Point of Pines region, Arizona." *American Antiquity*, 29(2):213-220.

Stephen, H. (2018). "Inferring species origin through virtual histology: A comparison of third metapodials from *Homo sapiens* and *Ursus americanus* using Micro-computed Tomography." *The University of Akron Honors Research Projects Journal*, 1-16.

Urbanová, P., & Novotný, V. (2005). “Distinguishing between human and non-human bones: histometric method for forensic anthropology.” *Anthropologie (1962-)*, 43(1):77-86.

Warnasch, Scott. (2016). “Forensic archaeological recovery of a large-scale mass disaster scene: Lessons learned from two complex recovery operations at the World Trade Center site.” *Journal of Forensic Sciences*, 61(3):584-593.

White, T.D., & Folkens P. (2005) *The Human Bone Manual*. Elsevier Inc.

White, T.D., Black, M.T., & Folkens P. (2012) *Human Osteology 3rd edition*. Elsevier Inc.

Wisconsin Department of Natural Resources. (n.d.). *Birding and bird conservation*. https://dnr.wisconsin.gov/topic/wildlifehabitat/birding.html, accessed November 18, 2022.

Woods, K.N., & Pokines, J.T. (Eds.). (2013). *Conference Poster: An analysis of nonhuman skeletal material received in a medical examiner setting*. AAFS Digital Library.

Appendix A

MAMMAL AND BIRD COMPARATIVE SPECIMEN TABLES:

This appendix contains the mammal and bird comparative specimen tables used during the species-level identifications.

Table A.1. Mammal specimens from the University of Wisconsin-Milwaukee comparative collection used for species-level identifications.

Specimen #	Species Name	Common Name	Sex (M = male, F = female, U = unknown)	Age (A = adult, S = subadult, J = juvenile, U = unknown) based on epiphyseal fusion
UWZS 27412	*Odocoileus virginianus*	White-tailed deer	M	S
O.v. - 1	*Odocoileus virginianus*	White-tailed deer	U	J
UWZS 15239	*Ursus americanus*	Black Bear	U	S
UWZS 21715	*Cervus canadensis*	Elk	F	A
7.3.29.1	*Cervus canadensis*	Elk	U	A
UWZS 35928	*Canis lupus*	Wolf	F	A
UWZS 20209	*Canis familiaris*	Domestic Dog	M	A
UWZS 20234	*Ovis aries*	Sheep	U	S
UWZS 23182	*Capra hircus*	Goat	F	A
UWZS 21707	*Sus scrofa*	Pig	M	S
UWZS 23185	*Bos taurus*	Cow	U	A
03.05.05.01	*Equus caballus*	Horse	U	A
04.08.25.01	*Sylvilagus floridanus*	Eastern Cottontail	U	A
Resin replica	*Homo sapien*	Human	M	U

Table A.2. Bird specimens from the University of Wisconsin-Milwaukee comparative collection used for species-level identifications.

Specimen #	Species Name	Common Name	Sex (M = male, F = female, U = unknown)	Age (A = adult, S = subadult, J = juvenile, U = unknown) based on epiphyseal fusion
16.10.25.1	*Grus canadensis*	Sandhill Crane	U	U
18.10.10.1	*Ardea herodias*	Great Blue Heron	U	U
3.10.02.1	*Meleagris gallopavo*	Wild Turkey	U	U
99.12.31.1	*Phasianus colchicus*	Wild Ring-Necked Pheasant	U	U
1.11.7.2	*Anas platyrhynchos*	Wild Mallard	U	U
UWZS 25181	*Branta canadensis lencopareia*	Wild Canadian Goose	F	A
H-54	*Meleagris gallopavo*	Domestic Turkey	U	U
Gilbert (1996) Avian Osteology Key	*Meleagris gallopavo*	Turkey	U	U
R-2	*Anser anser*	Domestic Goose	U	U
R-3	*Anas platyrhynchos domesticus*	Domestic Duck	U	U
Gd-1	*Gallus gallus domesticus*	Domestic Chicken	U	U
R-1	*Gallus gallus domesticus*	Domestic Chicken	U	U
H-56	*Gallus gallus domesticus*	Domestic Chicken	U	U
17.2.28.1	*Gallus gallus domesticus*	Domestic Chicken (Rooster)	M	U

Appendix B

DATABASE:

This appendix contains two links to a pdf file of the original excel database and the species-level identifications where the data collection of the 1,940 nonhuman bones were documented. These data can also be obtained by contacting the author.

Thesis - Data Collectiontab1.ps

Thesis - Data Collectiontab2.ps

Appendix C

OSTEOMETRIC PHOTOS:

This appendix contains photos of the ribs, vertebrae, and phalanges. The photos illustrate the osteometrics taken during the data collection as seen in the Methods chapter, the goal is that these measurements can be operationalized by future researchers.

Figure C.1. Cow (*Bos taurus*) rib illustrating the measurement for the length of rib (LR).

Figure C.2. Cow (*Bos taurus*) rib illustrating the rib head to rib tubercle measurement (RT).

Figure C.3. Cow (*Bos taurus*) rib illustrating the width of rib measurement (WR).

Figure C.4. Elk (*Cervus canadensis*) atlas vertebra illustrating the length of vertebral body (centrum) measurement (GLV) and greatest breadth of vertebral body (centrum) measurement (GBV).

Figure C.5. Elk (*Cervus canadensis*) axis vertebra illustrating the length of vertebral body (centrum) measurement (GLV) and greatest breadth of vertebral body (centrum) measurement (GBV).

Figure C.6. Elk (*Cervus canadensis*) cervical vertebra illustrating the length of vertebral body (centrum) measurement (GLV) and greatest breadth of vertebral body (centrum) measurement (GBV).

Figure C.7. Elk (*Cervus canadensis*) thoracic vertebra illustrating the length of vertebral body (centrum) measurement (GLV) and greatest breadth of vertebral body (centrum) measurement (GBV).

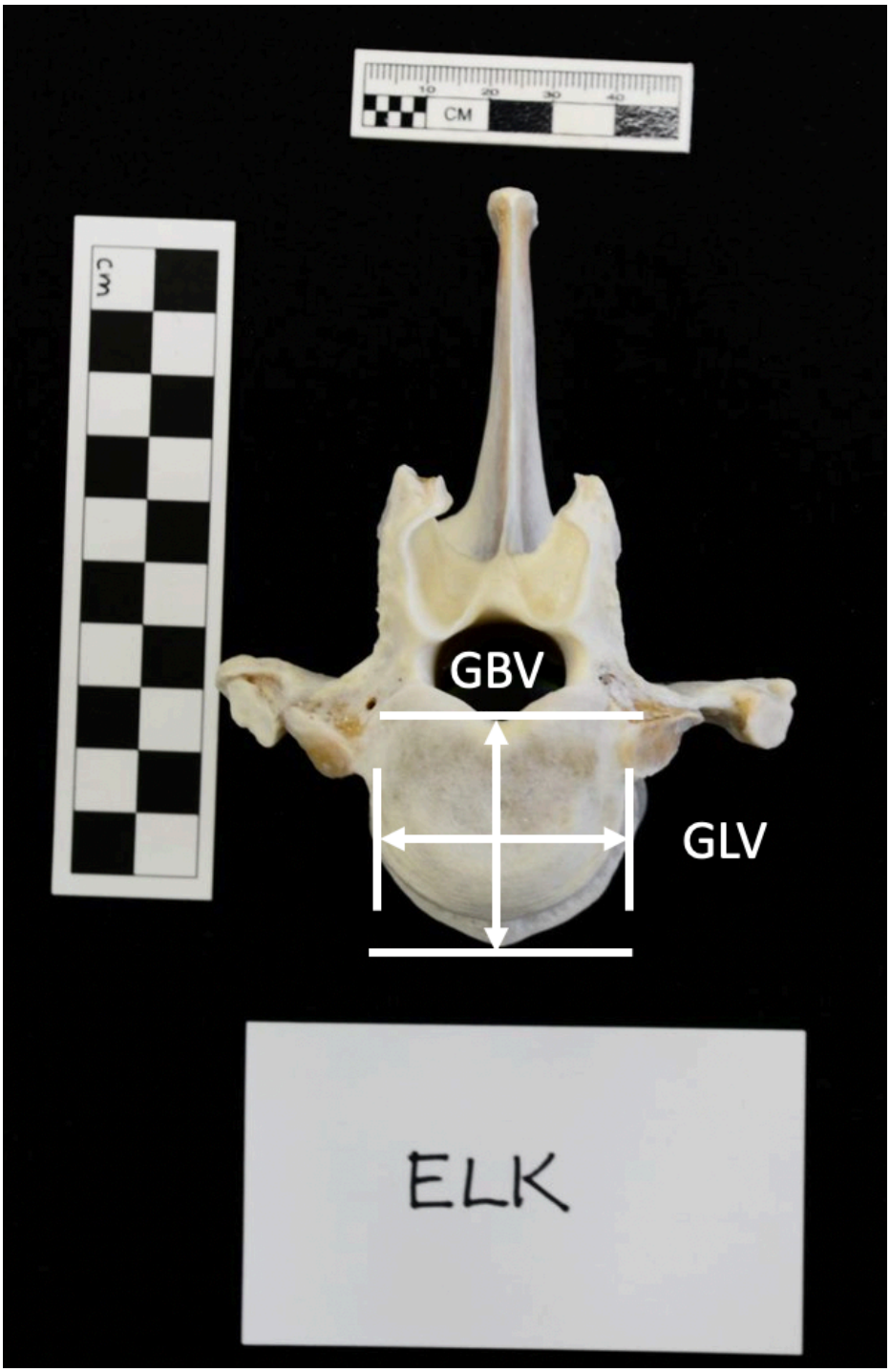

Figure C.8. Elk (*Cervus canadensis*) lumbar vertebra illustrating the length of vertebral body (centrum) measurement (GLV) and greatest breadth of vertebral body (centrum) measurement (GBV).

Figure C.9. Elk (*Cervus canadensis*) largest caudal vertebra illustrating the length of vertebral body (centrum) measurement (GLV) and greatest breadth of vertebral body (centrum) measurement (GBV).

Figure C.10. Elk (*Cervus canadensis*) smallest caudal vertebra illustrating the length of vertebral body (centrum) measurement (GLV) and greatest breadth of vertebral body (centrum) measurement (GBV).

Figure C.11. Elk (*Cervus canadensis*) 3rd phalanx illustrating the greatest length of the phalanx measurement (GLP).

Figure C.12. Elk (*Cervus canadensis*) 2nd phalanx illustrating the greatest length of the phalanx measurement (GLP).

Figure C.13. Elk (*Cervus canadensis*) 1st phalanx illustrating the greatest length of the phalanx measurement (GLP).

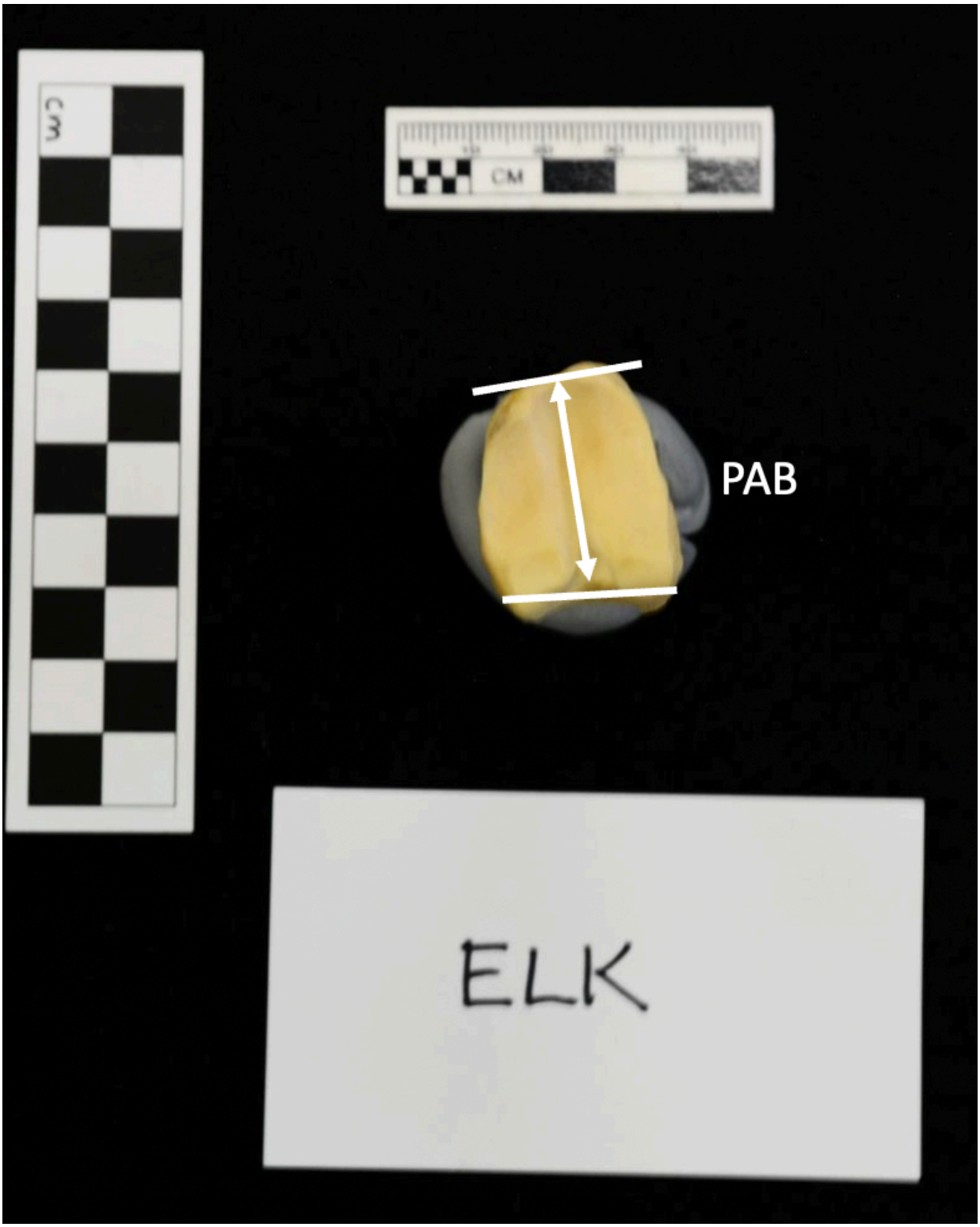

Figure C.14. Elk (*Cervus canadensis*) 3rd phalanx illustrating the measurement of greatest breadth (height) of the proximal end (PAB).

Figure C.15. Elk (*Cervus canadensis*) 2nd phalanx illustrating the measurement of greatest breadth (height) of the proximal end (PAB).

Figure C.16. Elk (*Cervus canadensis*) 1st phalanx illustrating the measurement of greatest breadth (height) of the proximal end (PAB).

Appendix D

DECISION TREE:

This appendix illustrates the decision tree that can be used when a non-specialist is determining the medicolegal significance of a suspected human bone.

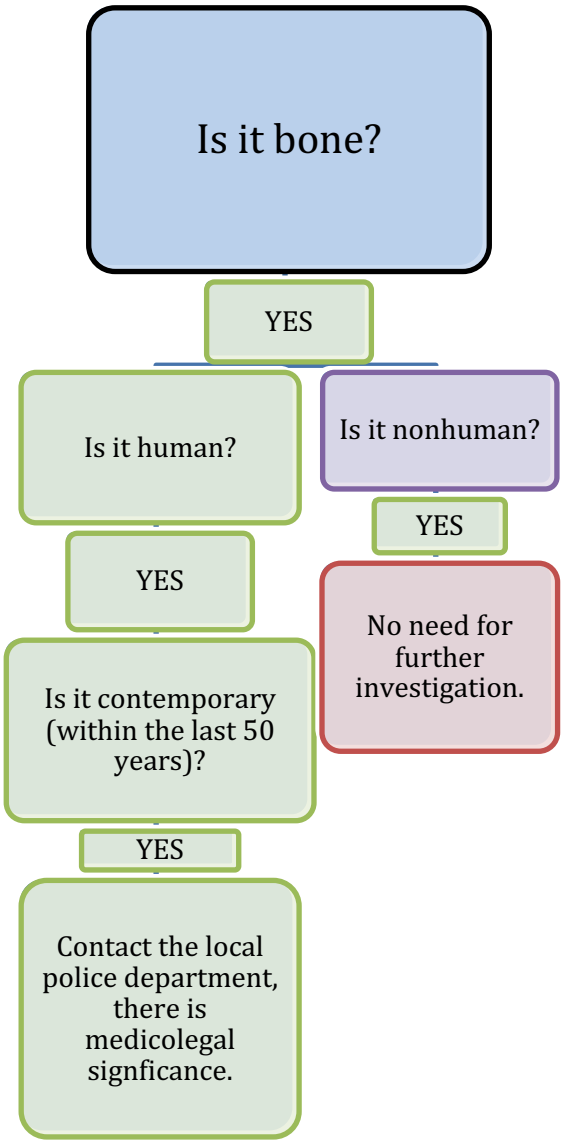

Figure D.1. Decision tree for determining the medicolegal significance of a suspected human bone.