

**Lemur Life Stories: Varying Effects of Captivity as Seen In Skeletal
Remains (*Lemur catta*)**

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Abstract

A 37-year-old Ring-tailed Lemur named Mamu who lived at the Pueblo Zoo in Southern Colorado unintentionally bypassed major species' life milestones by living to such an old age. By studying Mamu and others like her and others who lived shorter lives we can study a curated life history. From analyzing the various specimens, and 3D scanning them we have created a database of these specimens, and analyzed the curated life history that comes from living in a specialized environment such as a zoo as it relates to aging and morphology. Another goal of this project is to create a database that is accessible to those in the field as well as in school to make comparisons of findings and their morphological niches regarding

gerontology in Strepsirrhine primates; such as in captivity being susceptible to dental disease and less overall long bone injury but greater disc degeneration.



Arnold 23yrs enjoying a 'Lemur pellet', Pueblo Zoo 2023 @Autumn Lucas

Introduction

Primate gerontology is a branch of science dedicated to the study of aging in primates, our closest evolutionary relatives. It plays a crucial role in understanding the biological, physiological, and behavioral changes that occur as primates, including humans, grow older. Primates, with their genetic and physiological similarities to humans, provide valuable

insights into the aging process, including factors like longevity, cognitive decline, and age-related diseases (Gilleard, 2023). This research not only contributes to our understanding of the fundamental processes of aging but also informs the development of interventions and therapies to promote healthy aging in both primates and humans. By examining primate gerontology, scientists gain essential knowledge about the challenges and opportunities associated with aging, ultimately contributing to the improvement of the quality of life for elderly individuals and advancing our comprehension of the broader issues of aging. Primates in general have long life spans, primates in captivity are proving to have even longer lifespans (Gilleard, 2023). With these longer lifespans seen in captivity comes the possibility of additional pathologies developing due to aging such as bone disease and tooth loss etc. What allows non-human primates to live longer in captivity is the effect of greater husbandry (human care of animals) and the life stories. In the context of the life history theory of captive primates, "life stories" refer to the detailed, chronological accounts of the individual lives of long-living primates. These stories encompass significant events and milestones such as birth, developmental stages, reproductive history, social interactions, health issues, and aging processes. By documenting and analyzing these life stories, researchers can gain insights into the species' life history strategies, including growth rates, reproductive timing, lifespan, and responses to environmental changes. This information is crucial for understanding the biological and ecological aspects of primate life, especially in managed care settings where these life mile markers are more or less delayed, or non-existent due to human intervention, that develop due to a long lifespan. The opportunity to have a controlled environment changes the life story of a species because many external factors such as food competition, mate competition, seasonal environments, fallback foods, and natural and human-caused habitat loss are removed from the equation of what affects the primate.

In the 21st century, zoos continue to play a crucial role in various aspects of society and conservation efforts. Some reasons highlighting their importance are as follows:

1. Conservation and Education: Zoos serve as essential hubs for educating the public about the world's diverse wildlife. They offer a unique opportunity for people to connect with and learn about animals they might not otherwise encounter. This educational component is instrumental in raising awareness about endangered species, habitat destruction, and the importance of biodiversity (Marcy, n.d.).

2. Conservation Breeding Programs: Many zoos are actively engaged in breeding programs for endangered species (Marcy, n.d.). A recent example is the western lowland gorilla born in February 2024 at the Fort Worth Zoo 4-6 weeks early via cesarean section. Medical professionals at this zoo were able to help this primate enter the “world”, adding her to the number of captive species which can add genetic diversity to the species if they need to be released into the wild in the future. These programs help preserve genetically diverse populations of species on the brink of extinction (Marcy, n.d.). Through these efforts, zoos have played a vital role in preventing the extinction of several species.

3. Research and Science: Zoos provide an ideal environment for scientific research, allowing scientists to closely study animal behavior, physiology, and health. Curated environments such as zoos provide a niche opportunity to closely study a species in a specialized environment, but in zoos scientists have the opportunity to study animals who are already habituated to the presence of humans, changing the life story you can learn from them. In natural research settings, such as a field site, it takes years to habituate the animals you are studying to your presence to be able to study them in a less disruptive way. As those animals will be habituated to specific individuals, when new researchers arrive, that process of trust must begin again. However, in a captive setting such as a zoo those animals are used to seeing many humans every day. They may have their favorite keeper, but observing the

primate will come with more ease because you are removing the initial habituation phase. The knowledge gained from these studies can contribute to both the well-being of animals in captivity and in the wild.

4. Rescue and Rehabilitation: Zoos often collaborate with wildlife rescue and rehabilitation centers. They can provide a temporary or permanent home for animals that have been injured, orphaned, or confiscated from illegal trade, offering these animals a safe and caring environment. (Milberg, 2024)

5. Inspiring Conservation Action: Zoos have the unique ability to inspire and mobilize people to take action in support of conservation efforts. The personal connections formed with animals in zoos can lead to a greater commitment to protecting their natural habitats and ensuring their survival. (Coloradoan, 2024)

6. Habitat Preservation: Many zoos contribute to habitat preservation by funding or actively participating in projects that protect the natural environments of the animals they house. These efforts help combat habitat loss and promote sustainable conservation practices. Most zoos are non-profits that strive to help educate the public about their favorite animals and where they come from. Many use their ticket sales and donations from merchandise purchases to fund projects in the countries that their animals come from to protect their habitats in the wild (*Vietnam - Denver Zoo*, 2024).

7. Crisis Response: Zoos are often equipped to respond to wildlife emergencies and natural disasters, providing a safe refuge for animals displaced by events such as wildfires, hurricanes, or floods. (ZDR3, n.d.)

While zoos have evolved into scientific institutions used to educate the public and researchers significantly over the years, with a growing emphasis on animal welfare,

conservation, and education, they must continue to uphold the highest standards of care for their residents. Responsible zoos work diligently to provide enriching environments for animals, focusing on their well-being, education, and the broader mission of preserving the world's biodiversity. In the 21st century, zoos play a vital role in promoting a harmonious coexistence between humans and the animal kingdom while contributing to the global effort to safeguard our planet's precious wildlife.

It is important to note that zoos have not always been what they are today. Dating back to 2500 BCE wealthy individuals curated menageries to show their power (N/A 2024) and animals were used for pure entertainment purposes. Circuses, “Freak” shows, and Roadside zoos (Lauria, 2021) have all had varying popularity through the centuries even after the founding of scientific zoos. The Hierakonpolis, the capital of Upper Egypt during the Predynastic period, is home to the world's very first zoo (Boissoneault, 2018). Throughout history, zoos have evolved from a source of pure entertainment for humans at the expense of the animals to beautiful displays of husbandry and animal conservation.



Kate, circa 1990, Indianapolis Zoo @ Lynne Villers

Effects of Captivity on Primate Health and Biology

The captivity of primates can have various effects on their physical and mental well-being. It is important to note that primates, including lorises, lemurs, monkeys, and apes, are highly intelligent, cognitively complex, and social animals, and their needs can be challenging to meet in captivity. Potential effects include:

1. ****Behavioral Changes:**** Captive primates may exhibit abnormal behaviors not seen in their wild counterparts. These can include repetitive movements, self-harm, and aggression. The limited space and lack of natural stimuli can contribute to these behavioral changes (Mallapur & Choudhury, 2003).

2. **Social Isolation:** Many primates are highly social and live in complex social groups in the wild. In captivity, they may experience social isolation if kept alone or in small groups. Lack of social interaction can lead to stress and anxiety (Lutz et al., 2013).
3. **Physical Health Issues:** Captive primates may face physical health problems, including obesity (Pontzer, 2023), cardiovascular issues, and musculoskeletal disorders. Limited space for movement and inadequate diets can contribute to these health issues.
4. **Cognitive Impairment:** The lack of mental stimulation and challenges in captivity can result in cognitive impairment for primates. In the wild, they engage in activities like foraging and problem-solving, which are essential for their mental well-being. (*Some Captive Chimpanzees Show Signs of Compromised Mental Health, Research Shows*, 2011)
5. **Reproductive Challenges:** Captive environments may affect the reproductive capabilities of primates. Issues such as disrupted breeding cycles, difficulty breeding in captivity, or challenges in rearing offspring can arise (Small, 1982).
6. **Psychological Stress:** The unnatural conditions of captivity, such as confinement in enclosures, exposure to human spectators, and limited opportunities for natural behaviors, can lead to chronic psychological stress for primates. (Wallace et al., 2019)
7. **Health Risks:** Captive primates may be susceptible to diseases that are uncommon in the wild. Proximity to other animals and humans in captivity can increase the risk of infectious diseases. (Kalter, 1989)

While captivity can have numerous negative effects on primates, it's important to acknowledge that some efforts have been made in certain captive settings to provide environments that aim to enhance the well-being of these animals. It's important to emphasize

the significance of providing proper care, enrichment, and environments that mimic natural conditions when keeping primates in captivity. Many organizations and experts advocate for the ethical treatment and care of captive primates, and there are guidelines and regulations in place in various countries to address these concerns. Zoos play a crucial role in the care of primates by providing environments that aim to meet the physical, mental, and social needs of these highly intelligent and social animals. Modern zoos prioritize ethical and conservation-focused practices to ensure the well-being of primates in captivity (*About AZA Accreditation | Association of Zoos & Aquariums*, n.d.). Zoos often design enclosures that mimic the natural habitats of primates, incorporating features such as climbing structures, vegetation, and enrichment activities to encourage physical activity and mental stimulation. Dedicated zookeepers and animal care professionals closely monitor the health and behavior of primates, implementing veterinary care and dietary plans tailored to each species. Social interaction is also a key focus, with efforts made to house primates in groups that reflect their natural social structures. Conservation and education programs further contribute to the welfare of primates in zoos, raising awareness about the importance of protecting their wild counterparts and their natural habitats. While challenges persist, responsible zoos continue to evolve their practices to provide the best possible care for primates under professional supervision.

It's crucial to note that the positive effects mentioned above are context-dependent, and not all captive settings prioritize the well-being of primates. Ethical considerations, proper care, and adherence to conservation and animal welfare principles are essential to ensuring positive outcomes in captivity. Additionally, there is ongoing debate about the ethical implications of keeping primates in captivity, and efforts are being made to improve the conditions and practices associated with captive settings. (Hosey, 2005)

Primate Gerontology

Primate gerontology refers to the study of aging and the aging process in non-human primates, which include lorises, lemurs, monkeys, and apes (Mattison & Vaughan, 2017). This field of research explores various aspects of primate aging, including physiological changes, cognitive decline, social dynamics, and the impact of aging on overall well-being (Gilleard, 2023). Non-human primates, being close relatives to humans, share similarities in the aging process, making them valuable models for studying age-related conditions.

Researchers in primate gerontology investigate factors such as longevity, reproductive senescence, and the development of age-related diseases. They may study the impact of environmental factors, genetics, and social interactions on the aging process in primate populations. Understanding primate gerontology can provide insights into the evolution of aging mechanisms, as well as potential implications for human aging (Shively et al., 2021).

Observational studies of aging primates in the wild or captivity contribute to our knowledge of how different species cope with aging. The research in primate gerontology not only enhances our understanding of the natural aging process but also informs conservation efforts for endangered primate species. Additionally, findings from primate gerontology research may have implications for developing strategies to promote healthy aging and improve the well-being of aging individuals in both primate and human populations. Applying the study of primate gerontology to captive zoo populations in this research has given us the ability to see the long-term effects of aging on a medium-sized primate (Lemurs), that is experiencing a longer lifespan than what is to be expected in the wild. The effects of a longer life span become evident within the pathologies studied in the control group of specimens provided. As humans, we like to use the centric that everything operates in a similar way to us, including aging. While non-human primates are similar to us in

varying ways and we share a similar life model and have a common ancestor, we are unusual for our size. Our life span has greatly increased over the millions of years that we have existed but alongside that longer life span advancements in luxuries that we can consume have also advanced.

There are numerous patterns seen in primates as they age, many of those patterns are also reflected in humans. Studies show that male primates tend to die before females, similar to the pattern seen in humans. This gap is smaller in primate species with less male-male aggression; this part of the study cannot be duplicated in humans because our parameters for aggression and longevity are different (Bronikowski et al., 2011).

Cognition and age are also linked to shifts in social behavior in primates as they age, this is another similarity to humans. As macaques age the females choose to shrink their social groups, and stay with their natal groups they have developed over time. The macaques become less friendly towards newcomers to the group, and there is evidence of female chimpanzees becoming more dominant as they age. While this connection is harder to make to all humans, some elderly choose to isolate themselves more than before, especially as neurological conditions arise in old age (Machanda et al., 2020).

Menopause is something humans and primates share alike, but it looks different in each species, and doesn't affect some primate females at all. It was found that female chimpanzees spend 20% of their adult life in a state of menopause (Sullivan, 2023), whereas human females spend about 20 years at a minimum in a state of menopause (Alberts et al., 2013). With a greater focus on primate gerontology we may find that more primates also experience menopause. The question of menopause in humans and chimpanzees presents the question of the benefits of ending the reproductive cycle so early in life. While chimpanzees have shorter lifespans compared to humans, menopause might appear to be an evolutionary

disadvantage. However, it may actually serve the purpose of allowing space for our minds and bodies to age and undergo natural processes of decay before death.

Humans are prone to drastic neurological decline, and that makes us very unique. Studies show that all primates have slowly developing brains, some slower than others with body size, life span, and gestational period being taken into account. While all primates have some form of age related neurological decline, humans are the only ones known to have such drastic decline that conditions such as dementia and Alzheimer's develop (Finch & Austad, 2012). By further exploring aging primates in captive settings where they can reach their full potential, we as scientists can explore these conditions further, and really determine what it means to be human when it comes to our old age and the conditions we develop.

Ring-tailed lemurs (*Lemur catta*) is a species of lemurs native to the island of Madagascar. They are easily recognized by their long, bushy, black-and-white striped tails, which are longer than their bodies. Besides their distinctive tails, ring-tailed lemurs have a gray or rosy-brown coat with a white face, black triangular eye patches, and a pinkish-brown nose. They have sharp, grooming claws on their second toes, which they use for maintaining their fur and foraging. Ring-tailed lemurs primarily inhabit the southern and southwestern regions of Madagascar. They are found in a variety of habitats, including deciduous forests, spiny scrub, and rocky areas (Sauther et al. 1999; Gould & Sauther, 2006).

Ring-tailed lemurs are known for their highly social behavior and live in groups called troops. These troops are organized around a dominant female. Troops can range in size from a few individuals to over 20 members. They are omnivores, consuming a varied diet that includes fruits, leaves, flowers, and insects. Ring-tailed lemurs are known for their sunbathing behavior, where they sit with their arms outstretched to absorb sunlight. They use vocalizations, body language, and scent marking to communicate within their groups. The distinctive scent glands on their wrists are used for marking territory. Ring-tailed lemurs are

classified as endangered by the International Union for Conservation of Nature (IUCN) due to habitat loss, hunting, and the illegal pet trade (*Almost a Third of Lemurs and North Atlantic Right Whale Now Critically Endangered - IUCN Red List, 2022*). Conservation efforts are in place to protect their natural habitats and raise awareness about their endangered status.

These lemurs are agile climbers and spend a significant amount of time in trees. Breeding typically occurs during the austral spring; females give birth to one or two offspring. Infants cling to their mother's belly for the first few weeks of life and then transition to riding on her back (*Ring-tailed Lemur - Duke Lemur Center, 2021*).

Ring-tailed lemurs play a crucial role in Madagascar's ecosystem by acting as seed dispersers, helping to maintain the diversity and health of the island's forests. Their foraging behavior contributes to the regeneration of plant species, which supports a variety of other wildlife. Additionally, their social structures and interactions influence the balance of animal populations, making them integral to the overall stability of their environment. Conservation efforts are vital to ensure their survival in the wild. Conservation efforts, including habitat protection and captive breeding programs, are crucial for the survival of ring-tailed lemurs. Zoos and conservation organizations work to raise awareness about their endangered status and implement strategies to preserve both the species and its habitat (Mertl-Millhollen et al., 2011).

The individuals focused on in this examination are captive lemurs who have lived in zoos for most of, if not all their lives. Because of the evolution of the Zoo model; The zoo model serves as a conservation strategy aimed at preserving the genetic diversity of critically endangered species. This approach is crucial for small populations, as it helps mitigate the loss of genetic diversity due to genetic drift, the increased expression of harmful genes, and the restriction of local adaptation. We now have a unique opportunity to study curated life

stories; that is a glimpse into a part of the overall life history of an animal that does not need to undergo the various processes of natural selection to achieve success; such as not needing to compete for food or mates, consistent controlled environment, and lack of predation. Instead, due to the case of captivity, these animals' bones tell part of the story of their lives and what the effects of captivity and a longer life span do to the primate body. For this specific study, I am focusing on captive lemurs that exceed the life expectancy of wild lemurs. I therefore can document patterns of pathology among individuals of various ages as they relate to their own curated life story as a subset of life history theory.

METHODS

The lemur specimens all spent their lives in different zoological environments and thus had different life experiences. I was looking to learn more about these life experiences by studying their pathologies. Mamu lived her life at the Cheyenne Mountain zoo in Colorado Springs and then in the Reid Park Zoo in Pueblo; both zoos are located in Colorado. Sabrina lived at Gladys Porter Zoo in Brownsville and then Cameron Park Zoo in Waco both zoos are located in Texas. Kelly was born at the Gladys Porter Zoo in Brownsville Texas and moved to the Nashville Zoo in Tennessee. Bosley was born at the Potter Park Zoo in Lansing Michigan and moved to the Dickerson Park Zoo in Springfield Missouri. Mick was born at the Indianapolis Zoo and was then moved to the Woodland Park Zoo in Seattle, St Catherines Island, and then back to the Indianapolis Zoo. I was fortunate to interview Mick's keeper Lynne Villers, she was able to provide me with excellent information about him as not only an animal in a zoo but about his unique personality. Upon their death the specimens were provided to Drs. Sauter and Cuozzo were subsequently dissected and prepared by Dr. Julie Thomas and curated into the specimens at the Denver Museum of Nature and Science.

I examined individual elements for pathologies by using presence absence identifying, sometimes using a handheld lens of .5 magnification. I examined fractures, dislocations, joint disease, dental disease, and general signs of non-specific infections active at the time of death. For each pathological lesion, I noted the location, severity as well as the type. For each pathological lesion, I filled out a recording form (see Appendix), skeletal drawings with designated colors, and photographs..

To record joint disease, I filled out a recording form following the standards set by Buikstra and Ubelaker (Temple, 2017). I then examined the individual elements for signs of joint disease; porosity, osteophytes, erosive lesions, and eburnation (see chart) which were then examined a second time by Dr. Julie Thomas. I noted that I was unable to examine a number of the articulated surfaces due to the presence of soft tissue.

Descriptions and Pathologies

To obtain the data, a detailed examination of the specimens was performed from teeth to tail. Assisted by Dr. Michelle Sauther, Dr. Frank Cuzzo, and Dr. Julie Thomas we took an inventory of each bone, its condition, and any pathological findings. I then compiled all of this information into charts.

RESULTS

Table 1. Pathological Dental Findings

Animal Name	Animal Age	Animal Number	Attrition results
Mamu	37	19864	Right p2 Lost Premortem Left p2 Lost Premortem

			Left m2 Lost Premortem Left m3 Lost Premortem Both upper i1s lost Premortem Toothcomb lost Premortem No abscesses Left upper canine lost Premortem
Mick	22	19865	Right Upper Canine Serious wear Apical abscess pulp exposure w/ decay Left p3 agenesis (rare in lemurs) Moderate wear across tooth comb
Kelly	8	19855	Possible calculus
Sabrina	32	19856	Left Upper Canine severe periodontitis w/ porous bone Tooth comb (right 3 teeth and first left tooth lost premortem)
Bosley	10	19860	Left upper incisor agenesis

Studying dentition in modern primates is crucial for understanding their evolutionary history, behavior, and ecological adaptations. The examination of primate teeth provides valuable insights into dietary preferences, feeding strategies, and niche specialization. Different species exhibit distinct dental morphologies adapted to their specific ecological roles, whether folivory, frugivory, or insectivory. Additionally, dental characteristics can explain social structures, as mating systems and group dynamics often influence primate diets. Comparative analysis of dentition across various primate species aids in reconstructing phylogenetic relationships and elucidating the factors that drove evolutionary changes in dental patterns. This knowledge not only enhances our understanding of primate biology but also contributes to broader discussions about the intricate interplay between form and function in the natural world (Berthaume et al., 2020).

The dentition of the study lemurs was assessed in Table 1 above. I have included the results of our findings concerning captive lemurs from the Cameron Park Zoo, Indianapolis Zoo, and the Pueblo Zoo. Mamu from the Pueblo Zoo who passed at age 37 had extensive

damage to her teeth which is especially fascinating because animals at the Indianapolis Zoo received yearly dental cleanings. It seems as if animals at the Pueblo Zoo and Cameron Park Zoo were not receiving these cleanings. Mamu also showed immense bone thickening similar to the other specimens over the age of 22. This bone thickening provides the ability to continuously consume food after they lose teeth, however, you can also see this thickening in the orbits, joints, and long bones of the animal.

Tooth wear across primate species is seen as an age-related phenomenon, you can see it occur during childhood or the juvenile period and again at the elderly stage of life within captivity. In the wild, tooth loss is similar but occurs at an expedited rate due to the fallback foods consumed in the wild (Cuozzo et al., 2014). However, in my specimens tooth wear is dependent on the environment that the lemur was captive in. The Indianapolis Zoo provides yearly dental exams and cleanings for their specimens. By doing this they provide a greater chance that their lemurs maintain healthy teeth even into old age (see chart). In the specimens from the Pueblo Zoo and Cameron Park Zoo, you see increased tooth wear and dental disease as well as the presence of abscesses.

Post Cranial Pathological Findings

These primates share a considerable amount of anatomical and physiological traits with humans, making them suitable models for comparative pathological research. By examining skeletal and soft tissue anomalies in lemurs, researchers can draw parallels to human conditions, uncovering underlying mechanisms and evolutionary perspectives relevant to human health.

One of the key areas where lemur pathology contributes to human medicine is in the study of bone diseases. Ring-tailed lemurs, like humans, can suffer from conditions such as osteoporosis, arthritis, and bone fractures. Detailed analysis of these conditions in lemurs helps to understand the progression and impact of such diseases in a controlled environment.

This can lead to the development of better diagnostic tools and treatments for similar conditions in humans, particularly as lemurs' smaller size and faster life cycles allow for more rapid observation of disease progression and response to treatments.

Soft tissue pathologies in lemurs also offer significant insights. Studies of muscular dystrophies, joint disorders, and ligament injuries in lemurs can provide comparative data that enhance our understanding of these conditions in humans. For instance, the response of lemur tissue to injury and subsequent healing processes can inform medical practices and rehabilitation protocols in human medicine. These findings can be particularly important in the fields of orthopedics and sports medicine, where understanding the mechanics of muscle and joint injuries is crucial. While this study did not focus or have the opportunity due to time restraints the possibility still exists for a number of the specimens as well as future specimens.

Infectious diseases are another critical area where lemur pathology is invaluable. Ring-tailed lemurs are susceptible to various viral, bacterial, and parasitic infections, some of which mirror human diseases (Eschner, 2017). By studying these infections in lemurs, researchers can gain insights into pathogen behavior, transmission modes, and immune responses. This research can inform public health strategies and the development of vaccines and treatments for similar diseases in humans, enhancing our overall ability to manage and prevent infectious diseases.

The study of cancer in lemurs also holds promise for human medicine. Lemurs develop various types of tumors, including those affecting the bone and soft tissues (Hope et al., 2015). By investigating the genetic and environmental factors contributing to cancer in lemurs, scientists can identify potential risk factors and mechanisms that may also be relevant to humans. This comparative approach can lead to the discovery of novel biomarkers for early detection and new targets for therapeutic intervention in human cancers.

Moreover, the impact of environmental and dietary factors on lemur health can offer insights applicable to humans. Lemurs' diet and habitat changes have direct effects on their overall health and the prevalence of certain pathologies. Studying these effects can help elucidate how similar factors influence human health, particularly concerning lifestyle diseases such as diabetes, cardiovascular conditions, and obesity. Understanding these relationships can guide public health policies and personal health choices.

Finally, ethical considerations play a role in the importance of studying lemur pathology. Using ring-tailed lemurs as models allows researchers to conduct studies that would be unethical or impractical in humans, animal testing is immoral but observation is not. This approach enables a deeper understanding of disease processes and potential treatments without compromising human welfare. Consequently, the findings from lemur studies can significantly contribute to advancing medical science and improving human health, demonstrating the critical role of post-cranial pathological findings in these primates.

**Table 2. Post Cranial Pathological Findings
Ages of the Lemurs at their time of death:**

Animal Name	Animal Age	Animal Number
Mamu	37	19864
Mick	22	19865
Kelly	8	19855
Sabrina	32	19856
Bosley	10	19860

Directional terms in anatomy are essential for accurately describing the locations and positions of structures within the body. Anterior (or ventral) refers to the front of the body, while posterior (or dorsal) denotes the back. Superior (or cranial) means toward the head, and inferior (or caudal) indicates toward the feet. Medial refers to structures closer to the midline of the body, whereas lateral describes those farther from the midline. Proximal is used for structures closer to the point of attachment or origin, typically referring to limbs, while distal indicates those farther from the point of attachment. In this survey P and D are used most frequently focusing on proximal and distal.

Name	Spinal 59 or 58 total	Skull 60 total	Upper Limbs 57 total	Lower Limbs 56 total	Total number of pathologies present	Percentage (232*100)/x P/100 = x/232 P = (x/232) * 100 =y
Mick	30/59	1/60	25/57	53/56	109	47%
Mamu	18/58	11/60	7/57	21/56	57	24.5%
Bosley	1/59	0/60	2/57	1/55	4	1.72%
Kelly	4/58	0/60	1/57	1/55	6	2.58%
Sabrina	17/58	4/60	3/57	5/55	29	12.5%

Kelly

Kelly was a young female when she died. Despite reaching out to the zoo I was unable to get details surrounding her life from the zoo in Waco Texas she lived in. As shown from her data, she had mild back problems but nothing that would cause her to have a

decreased quality of life, I would expect to see similar pathologies on lemurs the same age as her in the wild.

Bone: T-4
Side:N/A
Evidence:
Marginal osteophytes:Sharp Ridge <1/3
Surface osteophytes: None
Erosive lesions:none
Porosity:none
Eburnation:none
Location of lesion: Caudal surface of vertebral body
Type of bone formed: osteophyte

Bone: L-5
Side:N/A
Evidence:
Marginal Osteophytes: Sharp ridge, 1/3
Surface Osteophytes:None
Erosive lesions: Cranial surface, clearly present, <1/3 (possible fracture)
Porosity:None
Eburnation: None
Location of lesion: Cranial surface
Type of bone formed: osteophyte

Bone:Caudal 1
Side: N/A
Evidence:
Marginal osteophytes: Barely discernible,<1/3
Surface osteophytes:None
Erosive lesions:None
Porosity:None
Eburnation:None
Location of lesion:Cranial articular surface
Type of bone formed: osteophyte

Bone: Caudal 3
Side:N/A
Evidence:
Marginal osteophytes: Barely discernible,<1/3
Surface osteophytes:None
Erosive lesions:None
Porosity:None
Eburnation:None

Location of lesion: Cranial articular surface

Type of bone formed: osteophyte

Bone: Humerus

Side: Left

Evidence:

Marginal Osteophytes: None

Surface Osteophytes: None

Erosive lesions: None

Porosity: Coalesced <1/3

Location of lesion: Lesser tubercle on the perimeter of the head

Type of bone formed: Clear border around lesion, general porous destruction

Bone: Talus

Side: Left

Evidence:

Marginal Osteophytes: None

Surface Osteophytes: None

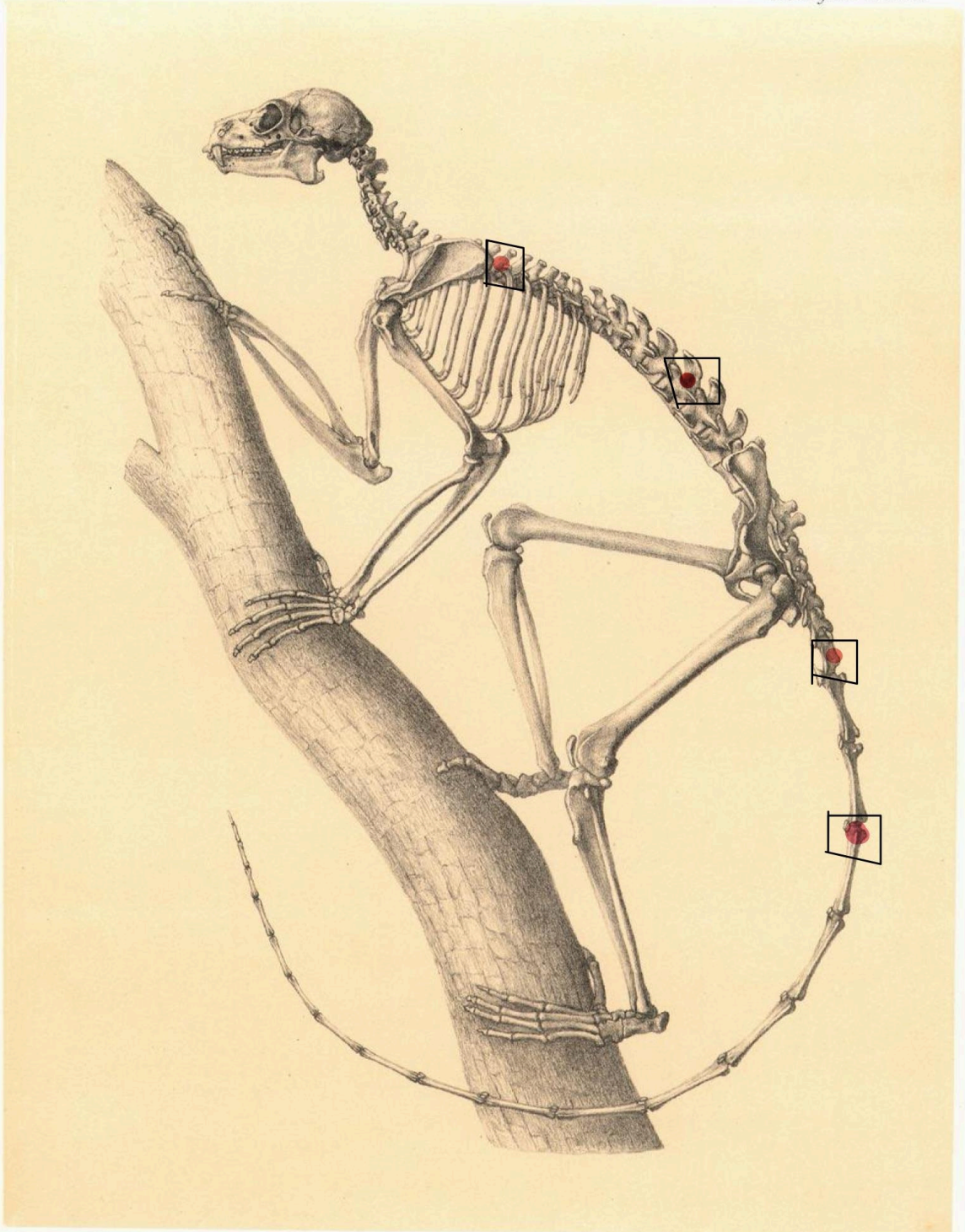
Erosive Lesions: None

Porosity Pinpoint < 1/3

Location of lesion: Calcaneal tuberosity

Type of bone formed: Clear border around lesion, general porous destruction

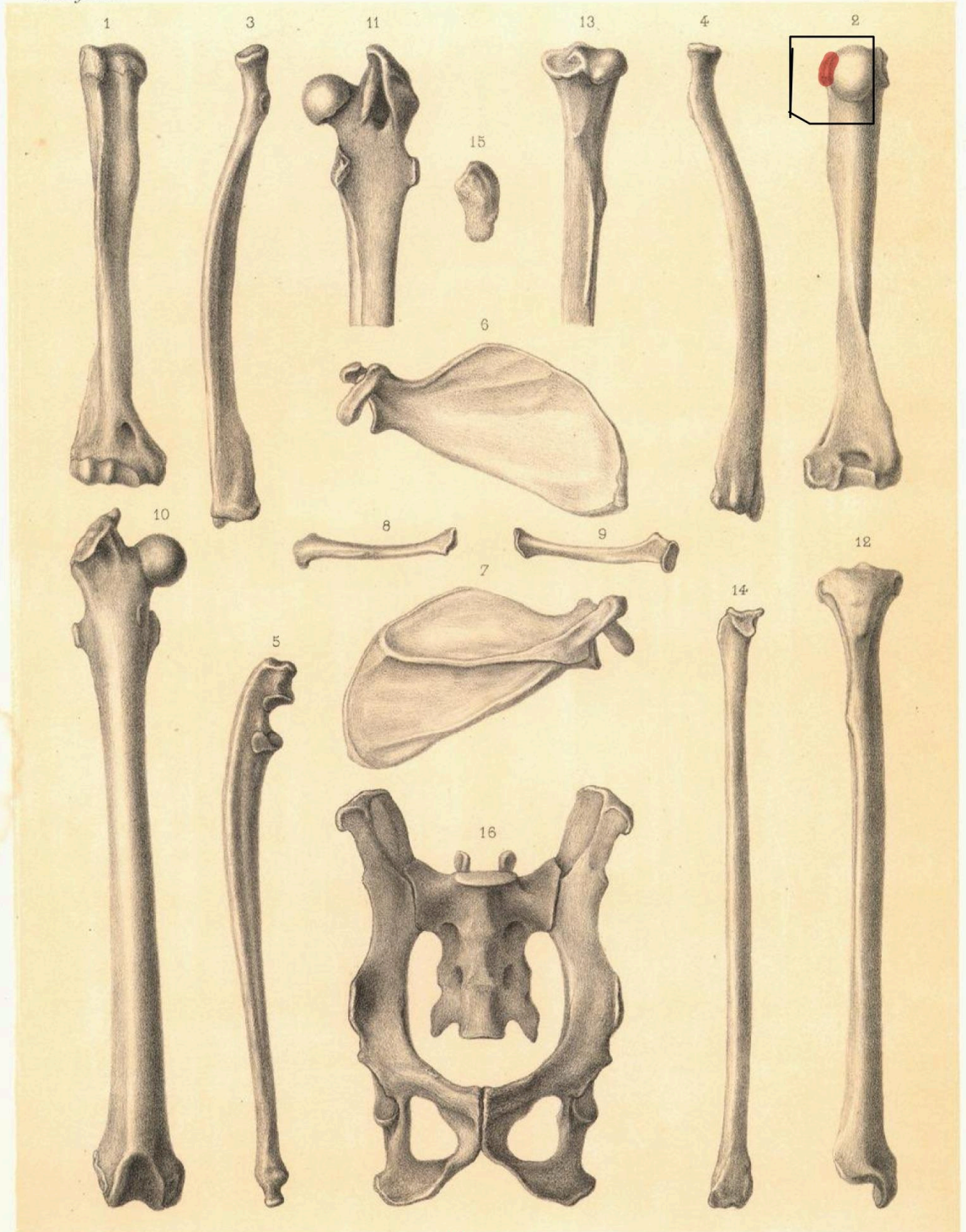
Figure 1. Locations of pathologies on Kelly noted by red circles.



H. Formant del et lith.

Kelly
Lemur catta.

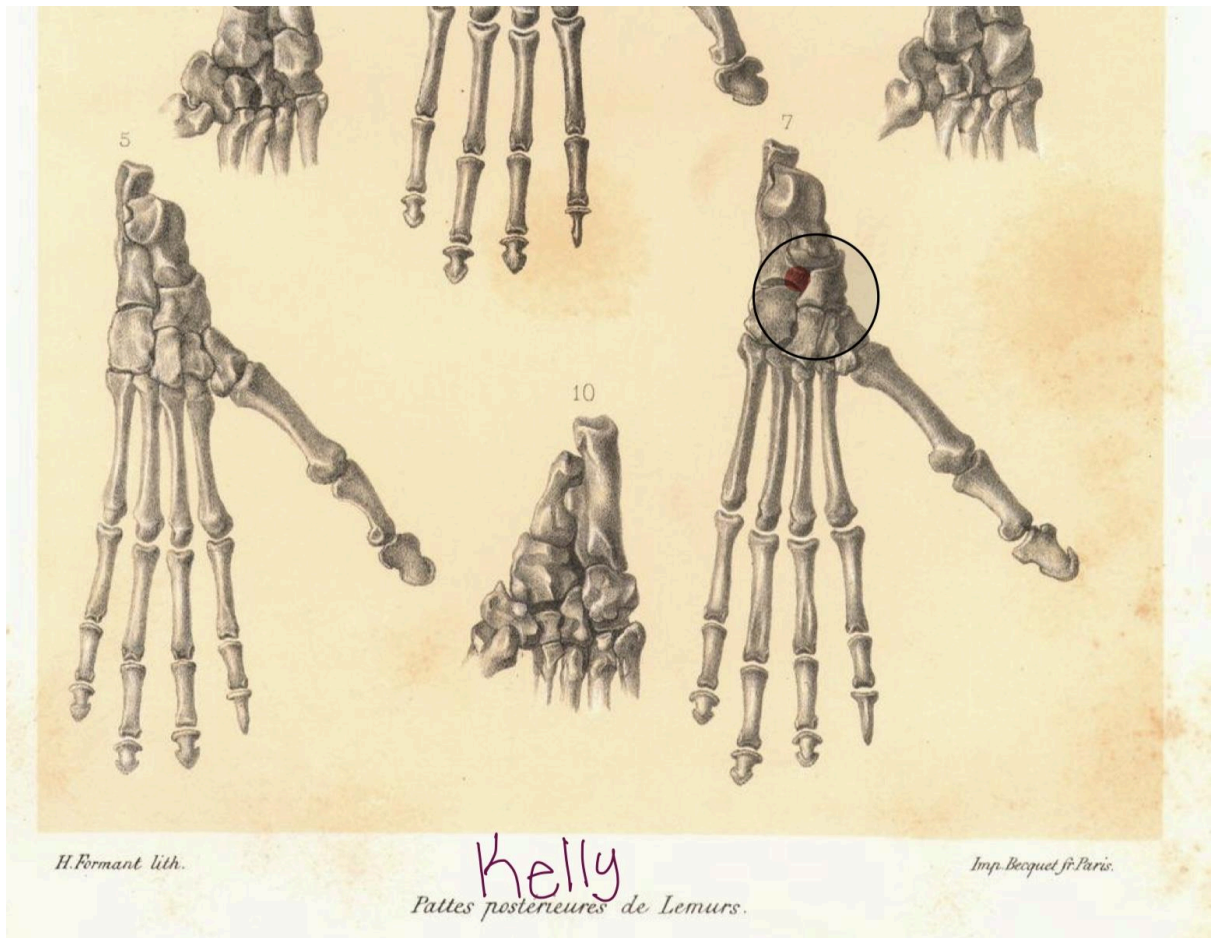
Imp. Becquet fr. Paris



H. Formant lith.

Kelly
Lemur catta.

Imp. Baquet fr. Paris



Bosley

Bosley was also a young lemur when he died and he came from the same zoo as Kelly. Although I was not able to speak to anybody who knew him personally I am able to discern that he and Kelly had some sort of annual dental care as seen by the evidence of most if not all of their teeth being in good to great condition for their age. Bosley as an individual suffered from an abscess that was healing as he died, he had mild back injuries, but more prevalent are injuries to his feet and mild injury to his collarbone. Bosley was a neutered male.

Summary of Pathological Conditions

Bone: Maxilla
 Side: Left
 Evidence:
 Location of lesion:

Type of bone formed: Antemortem tooth loss i2, healing abscess

Bone: T-4

Side: N/A

Evidence:

Marginal osteophytes: Sharp Ridge $< \frac{1}{3}$

Surface osteophytes: None

Erosive lesions: none

Porosity: none

Eburnation: none

Location of lesion: Caudal surface of vertebral body

Type of bone formed: osteophyte

Bone: Acromion

Side: Right

Evidence:

Marginal Osteophytes: extensive, $> \frac{2}{3}$

Surface Osteophytes: Clearly present

Erosive lesions: Clearly present, $> \frac{2}{3}$

Porosity: N/A

Eburnation: N/A

Location of lesion: lateral scapular at the surface of the acromion process

Type of bone formed:

Bone: Clavicle

Side: Right

Evidence:

Marginal Osteophytes: extensive, $> \frac{2}{3}$

Surface Osteophytes: clearly present

Erosive lesions: Clearly present, $> \frac{2}{3}$

Porosity: N/A

Eburnation: N/A

Location of lesion: lateral

Type of bone formed:

Bone: Calcaneus

Side: Left

Evidence:

Marginal Osteophytes: None

Surface Osteophytes: None

Erosive lesions: Clearly present, $< \frac{1}{3}$

Porosity: Coalesced, $< \frac{1}{3}$

Eburnation: None

Location of lesion: Medial process of the calcaneal tuberosity

Type of bone formed: Clear border around lesion, general porous destruction

Bone: L5

Side: N/A

Evidence: Fracture

Location of lesion:

Type of bone formed: Possible post mortem Fracture, no signs of healing

Figure 2: Bosley's left upper incisor agenesis, remarkable amount of teeth even at his young age



Mick

Mick is described as a kind and calm male. He was a loving father and babysitter for all of the infants he shared his habitat with, even those who were not his offspring. He was mild tempered and loved watermelon! Mick spent some time on St. Catherines Island, a semi wild environment in which he had unlimited access to climb and sunbathe but was accounted for and fed. In his time at St. Catherines he suffered a fall that led to a fractured tibia and fibula resulting in surgery to pin the two back together for healing purposes. Due to the extent of pathologies found on Mick I believe that he had to feel uncomfortable in his body, but with no obvious new injuries it would be hard for keepers to spot something like that, especially if he maintained good spirits until the end. Mick lived in the Indianapolis Zoo where he was cared for by Lynne Villers in her time there and Dr. Michelle Sauther along with Dr. Frank Cuozzo was often observed during dental cleanings that happened yearly. In this time any dental problems were addressed, meaning for Mick's old age of 32 he had wonderful teeth even if the rest of his body was fragile and aging poorly.

Summary of Pathological Conditions:

It is without exaggeration that Mick has at least one pathology on each bone, some greater than others.

Bone: Frontal

Side: Left and Right

Evidence:

Marginal Osteophytes: None

Surface Osteophytes: Faintly

Erosive lesions: $< \frac{1}{3}$

Porosity: none

Eburnation: None

Location of lesion: Medial process of the calvaria

Type of bone formed: Clear border around lesion, general porous destruction, possibly from the necropsy

Bone: Maxilla

Side: Left

Evidence:
Marginal Osteophytes: None
Surface Osteophytes: None
Erosive lesions: Clearly present, $\frac{2}{3}$ >
Porosity: Coalesced, $<\frac{1}{3}$
Eburnation: None
Location of lesion: Medial process
Type of bone formed: general porous destruction

Bone: Maxilla
Side: Right
Evidence:
Marginal Osteophytes: None
Surface Osteophytes: None
Erosive lesions: Clearly present, $\frac{2}{3}$ >
Porosity: Coalesced, $<\frac{1}{3}$
Eburnation: None
Location of lesion: Medial process
Type of bone formed: Clear border around lesion, general porous destruction

Bone: C6
Side: N/A
Evidence:
Marginal osteophytes: Sharp Ridge $\frac{2}{3}$ >
Surface osteophytes: None
Erosive lesions: none
Porosity: none
Eburnation: none
Location of lesion: Caudal surface of vertebral body
Type of bone formed: osteophyte

Bone: C7
Side: N/A
Evidence:
Marginal osteophytes: Sharp Ridge $\frac{2}{3}$ >
Surface osteophytes: None
Erosive lesions: none
Porosity: none
Eburnation: none
Location of lesion: Caudal surface of vertebral body
Type of bone formed: osteophyte

Bone: T1
Side: Left
Evidence:
Marginal Osteophytes: None

Surface Osteophytes: None
Erosive lesions: Clearly present, <1/3
Porosity: Coalesced, <1/3
Eburnation: None
Location of lesion: Medial process of the calcaneal tuberosity
Type of bone formed: Clear border around lesion, general porous destruction

Bone: T4
Side: N/A
Evidence:
Marginal osteophytes: Sharp Ridge 2/3>
Surface osteophytes: None
Erosive lesions: none
Porosity: none
Eburnation: none
Location of lesion: Caudal surface of vertebral body
Type of bone formed: osteophyte

Bone: T7
Side: N/A
Evidence:
Marginal osteophytes: Sharp Ridge 2/3>
Surface osteophytes: None
Erosive lesions: none
Porosity: none
Eburnation: none
Location of lesion: Caudal surface of vertebral body
Type of bone formed: osteophyte

Bone: T8
Side: N/A
Evidence:
Marginal osteophytes: Sharp Ridge 2/3>
Surface osteophytes: None
Erosive lesions: none
Porosity: none
Eburnation: none
Location of lesion: Caudal surface of vertebral body
Type of bone formed: osteophyte

Bone: T11
Side: N/A
Evidence:
Marginal osteophytes: Sharp Ridge 2/3>
Surface osteophytes: None
Erosive lesions: none

Porosity:none
Eburnation:none
Location of lesion: Caudal surface of vertebral body
Type of bone formed: osteophyte
n

Bone: L4
Side: N/A
Evidence:
Marginal osteophytes:Sharp Ridge $\frac{2}{3}$ >
Surface osteophytes: None
Erosive lesions:none
Porosity:none
Eburnation:none
Location of lesion: Caudal surface of vertebral body
Type of bone formed: osteophyte

Bone: L5
Side: N/A
Evidence:
Marginal osteophytes:Sharp Ridge $\frac{2}{3}$ >
Surface osteophytes: None
Erosive lesions:none
Porosity:none
Eburnation:none
Location of lesion: Caudal surface of vertebral body
Type of bone formed: osteophyte

Bone: L6
Side: N/A
Evidence:
Marginal osteophytes:Sharp Ridge $\frac{2}{3}$ >
Surface osteophytes: None
Erosive lesions:none
Porosity:none
Eburnation:none
Location of lesion: Caudal surface of vertebral body
Type of bone formed: osteophyte

Bone: L7
Side: N/A
Evidence:
Marginal osteophytes:Sharp Ridge $\frac{2}{3}$ >
Surface osteophytes: None
Erosive lesions:none
Porosity:none
Eburnation:none

Location of lesion: Caudal surface of vertebral body

Type of bone formed: osteophyte

Bone: Sacrum

Side: N/A

Marginal Osteophytes: extensive, $> \frac{2}{3}$

Surface Osteophytes: Clearly present

Erosive lesions: Clearly present, $> \frac{2}{3}$

Porosity: N/A

Eburnation: N/A

Location of lesion: Superior articular process, sacral tuberosity

Type of bone formed: Osteophyte

Bone: Caudal 1

Side: N/A

Evidence:

Marginal osteophytes: extensive, $\frac{2}{3} >$

Surface osteophytes: None

Erosive lesions: None

Porosity: At connecting points

Eburnation: Fully fused

Location of lesion: Cranial articular surface

Type of bone formed: osteophyte

Bone: Caudal 2

Side: N/A

Evidence:

Marginal osteophytes: extensive, $\frac{2}{3} >$

Surface osteophytes: None

Erosive lesions: None

Porosity: At connecting points

Eburnation: Fully fused

Location of lesion: Cranial articular surface

Type of bone formed: osteophyte

Bone: Caudal 3

Side: N/A

Evidence:

Marginal osteophytes: extensive, $\frac{2}{3} >$

Surface osteophytes: None

Erosive lesions: None

Porosity: At connecting points

Eburnation: Fully fused

Location of lesion: Cranial articular surface

Type of bone formed: osteophyte

Bone: Caudal 4

Side: N/A

Evidence:
Marginal osteophytes: Extensive, $\frac{2}{3}$ >
Surface osteophytes:None
Erosive lesions:None
Porosity:None
Eburnation:None
Location of lesion:Cranial articular surface
Type of bone formed: osteophyte

Bone: Caudal 5
Side: N/A
Evidence:
Marginal osteophytes: Extensive, $\frac{2}{3}$ >
Surface osteophytes:None
Erosive lesions:None
Porosity:None
Eburnation:None
Location of lesion:Cranial articular surface
Type of bone formed: osteophyte

Bone: Caudal 6
Side: N/A
Evidence:
Marginal osteophytes: Extensive, $\frac{2}{3}$ >
Surface osteophytes:None
Erosive lesions:None
Porosity:None
Eburnation:None
Location of lesion:Cranial articular surface
Type of bone formed: osteophyte

Bone: Caudal 7
Side: N/A
Evidence:
Marginal osteophytes: Extensive, $\frac{2}{3}$ >
Surface osteophytes:None
Erosive lesions:None
Porosity:None
Eburnation:None
Location of lesion:Cranial articular surface
Type of bone formed: osteophyte

Bone: Caudal 8
Side: N/A
Evidence:
Marginal osteophytes: Extensive, $\frac{2}{3}$ >
Surface osteophytes:None
Erosive lesions:None

Porosity:None
Eburnation:None
Location of lesion:Cranial articular surface
Type of bone formed: osteophyte

Bone: Caudal 9
Side: N/A
Evidence:
Marginal osteophytes: Extensive, $\frac{2}{3}$ >
Surface osteophytes:None
Erosive lesions:None
Porosity:None
Eburnation:None
Location of lesion:Cranial articular surface
Type of bone formed: osteophyte

Bone: Caudal 10
Side: N/A
Evidence:
Marginal osteophytes: Extensive, $\frac{2}{3}$ >
Surface osteophytes:None
Erosive lesions:None
Porosity:None
Eburnation:None
Location of lesion:Cranial articular surface
Type of bone formed: osteophyte

Bone: Caudal 11
Side: N/A
Evidence:
Marginal osteophytes: Extensive, $\frac{2}{3}$ >
Surface osteophytes:None
Erosive lesions:None
Porosity:None
Eburnation:None
Location of lesion:Cranial articular surface
Type of bone formed: osteophyte

Bone: Caudal 12
SSide: N/A
Evidence:
Marginal osteophytes: Extensive, $\frac{2}{3}$ >
Surface osteophytes:None
Erosive lesions:None
Porosity:None
Eburnation:None
Location of lesion:Cranial articular surface
Type of bone formed: osteophyte

Bone: Caudal 13

Side: N/A

Evidence:

Marginal osteophytes: Extensive, $\frac{2}{3}$ >

Surface osteophytes:None

Erosive lesions:None

Porosity:None

Eburnation:None

Location of lesion:Cranial articular surface

Type of bone formed: osteophyte

Type of bone formed: Clear border around lesion, general porous destruction

Bone: Caudal 14

Side: N/A

Evidence:

Marginal osteophytes: Extensive, $\frac{2}{3}$ >

Surface osteophytes:None

Erosive lesions:None

Porosity:None

Eburnation:None

Location of lesion:Cranial articular surface

Type of bone formed: osteophyte

Bone: Caudal 15

Side: N/A

Evidence:

Marginal osteophytes: Extensive, $\frac{2}{3}$ >

Surface osteophytes:None

Erosive lesions:None

Porosity:None

Eburnation:None

Location of lesion:Cranial articular surface

Type of bone formed: osteophyte

Bone: Caudal 16

Side: N/A

Evidence:

Marginal osteophytes: Extensive, $\frac{2}{3}$ >

Surface osteophytes:None

Erosive lesions:None

Porosity:None

Eburnation:None

Location of lesion:Cranial articular surface

Type of bone formed: osteophyte

Bone: Caudal 17

Side: N/A

Evidence:
Marginal osteophytes: Extensive, $\frac{2}{3}$ >
Surface osteophytes:None
Erosive lesions:None
Porosity:None
Eburnation:None
Location of lesion:Cranial articular surface
Type of bone formed: osteophyte

Bone: Caudal 18
Side: N/A
Evidence:
Marginal osteophytes: Barely discernible, $<\frac{1}{3}$
Surface osteophytes:None
Erosive lesions:None
Porosity:None
Eburnation:None
Location of lesion:Cranial articular surface
Type of bone formed: osteophyte

Bone: Sternum Body
Side: N/A
Evidence:
Marginal Osteophytes: None
Surface Osteophytes: Barely discernible $\frac{1}{3}$ <
Erosive lesions: None
Porosity: None
Eburnation: None
Location of lesion: Medial process of the sternum body
Type of bone formed: osteophyte

Bone: Xiphoid Process
Side: N/A
Evidence:
Marginal Osteophytes: Extensive, $\frac{2}{3}$ >
Surface Osteophytes: None
Erosive lesions: Clearly present, $<\frac{1}{3}$
Porosity: Coalesced, $<\frac{1}{3}$
Eburnation: None
Location of lesion: Medial process of the Xiphoid Process
Type of bone formed: Clear border around lesion, general porous destruction, osteophytes

Bone: Scapula
Side: Left
Evidence:
Marginal Osteophytes: None
Surface Osteophytes: None
Erosive lesions: Clearly present, $\frac{2}{3}$ >

Porosity: Coalesced, $\frac{2}{3}$ >

Eburnation: None

Location of lesion: Medial surface of the glenoid fossa, Acromion

Type of bone formed: Clear border around lesion, general porous destruction

Bone: Scapula

Side: Right

Evidence:

Marginal Osteophytes: None

Surface Osteophytes: Clearly present, $\frac{2}{3}$ >

Erosive lesions: Clearly present, $<\frac{1}{3}$

Porosity: Coalesced, $<\frac{1}{3}$

Eburnation: None

Location of lesion: Lateral surface of the Infraspinatus fossa, Proximal surface of the Coracoid process

Type of bone formed: Clear border around lesion, porous destruction creating a hole, osteophytes

Bone: Clavicle

Side: Left

Evidence:

Marginal Osteophytes: None

Surface Osteophytes: Clearly present

Erosive lesions: Clearly present, $<\frac{1}{3}$

Porosity: Coalesced, $<\frac{1}{3}$

Eburnation: None

Location of lesion: Along the trapezoid line near the acromial facet

Type of bone formed: general porous destruction, osteophytes

Bone: Clavicle

Side: Right

Evidence:

Marginal Osteophytes: None

Surface Osteophytes: Clearly present

Erosive lesions: Clearly present, $<\frac{1}{3}$

Porosity: Coalesced, $<\frac{1}{3}$

Eburnation: None

Location of lesion: Along the Subclavian groove, Costal tuberosity

Type of bone formed: Clear border around lesion, general porous destruction, osteophytes

Bone: Left clavicle M

Side: Left

Evidence:

Marginal Osteophytes: None

Surface Osteophytes: None

Erosive lesions: Clearly present, $<\frac{1}{3}$

Porosity: Coalesced, $<\frac{1}{3}$

Eburnation: None

Location of lesion: Medial process of the calcaneal tuberosity
Type of bone formed: Clear border around lesion, general porous destruction

Bone: Left humerus P
Side: Left
Evidence:
Marginal Osteophytes: Clear evidence, $\frac{2}{3}$ >
Surface Osteophytes: Sharp ridges
Erosive lesions: None
Porosity: None
Eburnation: None
Location of lesion: Medial process of the humeral head
Type of bone formed: Osteophytes

Bone: Right humerus D
Side: Right
Evidence:
Marginal Osteophytes: Clear evidence, $\frac{2}{3}$ >
Surface Osteophytes: Sharp ridges
Erosive lesions: None
Porosity: None
Eburnation: None
Location of lesion: Medial epicondyle
Type of bone formed: Osteophytes

Bone: Left radius P
Side: Left
Evidence:
Marginal Osteophytes: Clear evidence, $\frac{2}{3}$ >
Surface Osteophytes: Sharp ridges
Erosive lesions: None
Porosity: None
Eburnation: None
Location of lesion: Medial process of the radial head
Type of bone formed: Osteophytes

Bone: Left radius D
Side: Left
Evidence:
Marginal Osteophytes: Clear evidence, $\frac{2}{3}$ >
Surface Osteophytes: Sharp ridges
Erosive lesions: None
Porosity: None
Eburnation: None
Location of lesion: Articular process for carpals
Type of bone formed: Osteophytes

Bone: Right radius D

Side: Right
Evidence:
Marginal Osteophytes: Clear evidence, $\frac{2}{3}$ >
Surface Osteophytes: Sharp ridges
Erosive lesions: None
Porosity: None
Eburnation: None
Location of lesion: Medial process of the radial head
Type of bone formed: Osteophytes

Bone: Left ulna P
Side: Left
Evidence:
Marginal Osteophytes: Clearly present
Surface Osteophytes: None
Erosive lesions: None
Porosity: Coalesced, $<\frac{1}{3}$
Eburnation: None
Location of lesion: Olecranon.
Type of bone formed: Osteophytes

Bone: Left ulna D
Side: Left
Evidence:
Marginal Osteophytes: Clearly present
Surface Osteophytes: None
Erosive lesions: Clearly present, $<\frac{1}{3}$
Porosity: None
Eburnation: None
Location of lesion: Head of ulna
Type of bone formed: Osteophytes

Bone: Right ulna P
Side: Right
Evidence:
Marginal Osteophytes: Clearly present
Surface Osteophytes: None
Erosive lesions: None
Porosity: Coalesced, $<\frac{1}{3}$
Eburnation: None
Location of lesion: Olecranon, Coronoid process
Type of bone formed: Osteophytes

Bone: Left ulna D
Side: Left
Evidence:
Marginal Osteophytes: Clearly present
Surface Osteophytes: None

Erosive lesions: Clearly present, $< \frac{1}{3}$

Porosity: None

Eburnation: None

Location of lesion: Head of ulna

Type of bone formed: Osteophytes

Bone: Acetabulum

Side: Left

Evidence:

Marginal Osteophytes: Clearly present

Surface Osteophytes: None

Erosive lesions: Clearly present, $< \frac{1}{3}$

Porosity: None

Eburnation: Extensive

Location of lesion: Proximal Ilium

Type of bone formed: Osteophytes

Bone: Acetabulum

Side: Right

Evidence:

Marginal Osteophytes: Clearly present

Surface Osteophytes: None

Erosive lesions: Clearly present, $< \frac{1}{3}$

Porosity: None

Eburnation: Extensive

Location of lesion: Proximal Ilium

Type of bone formed: Osteophytes

Bone: ischial tuberosity

Side: Right

Evidence:

Marginal Osteophytes: Clearly present

Surface Osteophytes: None

Erosive lesions: Clearly present, $< \frac{1}{3}$

Porosity: None

Eburnation: None

Location of lesion: Medial process of ischial tuberosity

Type of bone formed: Osteophytes

Bone: ischial tuberosity

Side: Left

Evidence:

Marginal Osteophytes: Clearly present

Surface Osteophytes: None

Erosive lesions: Clearly present, $< \frac{1}{3}$

Porosity: None

Eburnation: None

Location of lesion: Medial process of ischial tuberosity

Type of bone formed: Osteophytes

Bone: Patella

Side: Left

Evidence:

Marginal Osteophytes: Clearly present

Surface Osteophytes: None

Erosive lesions: None

Porosity: None

Eburnation: None

Location of lesion: Bony growth around all edges of the anterior

Type of bone formed: Osteophytes

Bone: Patella

Side: Right

Evidence:

Marginal Osteophytes: Clearly present

Surface Osteophytes: None

Erosive lesions: None

Porosity: None

Eburnation: None

Location of lesion: Bony growth around all edges of the anterior

Type of bone formed: Osteophytes

Bone: Femur D

Side: Right

Evidence:

Marginal Osteophytes: Clearly present $\frac{2}{3}$ >

Surface Osteophytes: None

Erosive lesions: none

Porosity: None

Eburnation: None

Location of lesion: Patellar surface, Lateral condyle

Type of bone formed: osteophytes

Bone: Femur P

Side: Right

Evidence:

Marginal Osteophytes: Clearly present $\frac{2}{3}$ >

Surface Osteophytes: None

Erosive lesions: none

Porosity: None

Eburnation: Partial fusion

Location of lesion: Femoral head, Greater trochanter, lesser trochanter

Type of bone formed: osteophytes

Bone: Femur D

Side: Left

Evidence:

Marginal Osteophytes: Clearly present $\frac{2}{3}$ >

Surface Osteophytes: None

Erosive lesions: none

Porosity: None

Eburnation: None

Location of lesion: Patellar surface, Lateral condyle

Type of bone formed: osteophytes

Bone: Femur P

Side: Left

Evidence:

Marginal Osteophytes: Clearly present $\frac{2}{3}$ >

Surface Osteophytes: None

Erosive lesions: none

Porosity: None

Eburnation: None

Location of lesion: Femoral head, Greater trochanter

Type of bone formed: osteophytes

Note all bones in hands and feet have osteophytes

Figure 3: 1. Mick's first three caudals fused together compared to Bosleys caudals.



Figure 4 Mick 22yrs (Left) next to wild museum specimen, showing orbital thickening in Mick's skull..



Figure 5. Right os coxae, sacrum, and proximal femur from Mick showing extensive bone growth around the acetabulum, femoral head and greater and lesser trochanters.



Figure 6. Detail of Mick's acetabulum showing evidence of extensive joint disease.



Figure 7 and 8. Pins through fibula and tibia from a fracture premortum.





Sabrina

Born March 22nd 1977 at the Gladys Porter Zoo where she spent most of her life before being moved to the Cameron Park Zoo in Waco Texas in 2002 for breeding purposes, all data indicates that Sabrina lived an average life for a lemur in a zoo. She lived with Kelly and Bosley along with many others but shows much greater dental decay than those who are younger than her, indicating that even with dental care as the lemurs age their teeth will

begin to decay if dental care is not provided from a young age. Sabrina died January 23rd 2009.

Summary of Pathological Conditions:

Bone: C1
Side: N/A
Evidence:
Marginal osteophytes: Sharp Ridge $\frac{2}{3}$ >
Surface osteophytes: None
Erosive lesions: none
Porosity: none
Eburnation: none
Location of lesion: Caudal surface of vertebral body
Type of bone formed: osteophyte

Bone: C2
Side: N/A
Evidence:
Marginal osteophytes: Sharp Ridge $\frac{2}{3}$ >
Surface osteophytes: None
Erosive lesions: none
Porosity: none
Eburnation: none
Location of lesion: Caudal surface of vertebral body
Type of bone formed: osteophyte

Bone: C3
Side: N/A
Evidence:
Marginal osteophytes: Sharp Ridge $\frac{2}{3}$ >
Surface osteophytes: None
Erosive lesions: none
Porosity: none
Eburnation: none
Location of lesion: Caudal surface of vertebral body
Type of bone formed: osteophyte

Bone: C4
Side: N/A
Evidence:
Marginal osteophytes: Sharp Ridge $\frac{2}{3}$ >
Surface osteophytes: None
Erosive lesions: none
Porosity: none
Eburnation: none

Location of lesion: Caudal surface of vertebral body
Type of bone formed: osteophyte

Bone: C5
Side: N/A
Evidence:
Marginal osteophytes: Sharp Ridge $\frac{2}{3}$ >
Surface osteophytes: None
Erosive lesions: none
Porosity: none
Eburnation: none
Location of lesion: Caudal surface of vertebral body
Type of bone formed: osteophyte

Bone: C6
Side: N/A
Evidence:
Marginal osteophytes: Sharp Ridge $\frac{2}{3}$ >
Surface osteophytes: None
Erosive lesions: none
Porosity: none
Eburnation: none
Location of lesion: Caudal surface of vertebral body
Type of bone formed: osteophyte

Bone: C7
Side: N/A
Evidence:
Marginal osteophytes: Sharp Ridge $\frac{2}{3}$ >
Surface osteophytes: None
Erosive lesions: none
Porosity: none
Eburnation: none
Location of lesion: Caudal surface of vertebral body
Type of bone formed: osteophyte

Bone: L6
Side: N/A
Evidence:
Marginal osteophytes: Sharp Ridge $\frac{2}{3}$ >
Surface osteophytes: None
Erosive lesions: none
Porosity: none
Eburnation: none
Location of lesion: Caudal surface of vertebral body
Type of bone formed: osteophyte

Bone: L7
Side: N/A
Evidence:
Marginal osteophytes: Sharp Ridge $\frac{2}{3}$ >
Surface osteophytes: None
Erosive lesions: none
Porosity: none
Eburnation: none
Location of lesion: Caudal surface of vertebral body
Type of bone formed: osteophyte

Bone: Sacrum
Side: N/A
Marginal Osteophytes: extensive, $>\frac{2}{3}$
Surface Osteophytes: Clearly present
Erosive lesions: Clearly present, $>\frac{2}{3}$
Porosity: N/A
Eburnation: N/A
Location of lesion: Superior articular process, sacral tuberosity
Type of bone formed: Osteophyte

Bone: Caudal 1
Side: N/A
Evidence:
Marginal osteophytes: extensive, $\frac{2}{3}$ >
Surface osteophytes: None
Erosive lesions: None
Porosity: At connecting points
Eburnation: Beginning stages
Location of lesion: Cranial articular surface
Type of bone formed: osteophyte

Bone: Caudal 2
Side: N/A
Evidence:
Marginal osteophytes: extensive, $\frac{2}{3}$ >
Surface osteophytes: None
Erosive lesions: None
Porosity: At connecting points
Eburnation: Beginning stages
Location of lesion: Cranial articular surface
Type of bone formed: osteophyte

Bone: Caudal 3
Side: N/A

Evidence:

Marginal osteophytes: extensive, $\frac{2}{3}$ >

Surface osteophytes:None

Erosive lesions:None

Porosity: At connecting points

Eburnation:Beginning stages

Location of lesion:Cranial articular surface

Type of bone formed: osteophyte

Bone: Caudal 4

Side: N/A

Evidence:

Marginal osteophytes: extensive, $\frac{2}{3}$ >

Surface osteophytes:None

Erosive lesions:None

Porosity: At connecting points

Eburnation:Beginning stages

Location of lesion:Cranial articular surface

Type of bone formed: osteophyte

Bone: Caudal 5

Side: N/A

Evidence:

Marginal osteophytes: extensive, $\frac{2}{3}$ >

Surface osteophytes:None

Erosive lesions:None

Porosity: At connecting points

Eburnation:Beginning stages

Location of lesion:Cranial articular surface

Type of bone formed: osteophyte

Bone: Caudal 6

Side: N/A

Evidence:

Marginal osteophytes: extensive, $\frac{2}{3}$ >

Surface osteophytes:None

Erosive lesions:None

Porosity: At connecting points

Eburnation:Beginning stages

Location of lesion:Cranial articular surface

Type of bone formed: osteophyte

Bone: Caudal 7

Side: N/A

Evidence:

Marginal osteophytes: extensive, $\frac{2}{3}$ >

Surface osteophytes:None

Erosive lesions: Clearly present
Porosity: Clearly present $\frac{2}{3}$ >
Eburnation: Beginning stages
Location of lesion: Cranial articular surface
Type of bone formed: osteophyte, Nonspecific infection

Bone: Sternum Body
Side: N/A
Evidence:
Marginal Osteophytes: Extensive $\frac{2}{3}$ >
Surface Osteophytes: Extensive $\frac{1}{3}$ <
Erosive lesions: None
Porosity: None
Eburnation: Fully fused
Location of lesion: Medial process of the sternum body
Type of bone formed: osteophyte

Bone: Scapula
Side: Right
Evidence:
Marginal Osteophytes: None
Surface Osteophytes: Clearly present, $\frac{2}{3}$ >
Erosive lesions: Clearly present, $<\frac{1}{3}$
Porosity: Coalesced, $<\frac{1}{3}$
Eburnation: None
Location of lesion: Lateral surface of the Infraspinatus fossa, Proximal surface of the Coracoid process
Type of bone formed: Clear border around lesion, porous destruction creating a hole, osteophytes

Bone: Scapula
Side: Left
Evidence:
Marginal Osteophytes: None
Surface Osteophytes: Clearly present, $\frac{2}{3}$ >
Erosive lesions: Clearly present, $<\frac{1}{3}$
Porosity: Coalesced, $<\frac{1}{3}$
Eburnation: None
Location of lesion: Lateral surface of the Infraspinatus fossa, Proximal surface of the Coracoid process
Type of bone formed: Clear border around lesion, porous destruction creating a hole, osteophytes

Bone: Left humerus P
Side: Left
Evidence:
Marginal Osteophytes: Clear evidence, $\frac{2}{3}$ >

Surface Osteophytes: Sharp ridges
Erosive lesions: None
Porosity: None
Eburnation: Possible, beginning stages
Location of lesion: Medial process of the humeral head
Type of bone formed: Osteophytes

Bone: Left humerus D
Side: Left
Evidence:
Marginal Osteophytes: Clear evidence, $\frac{2}{3}$ >
Surface Osteophytes: Sharp ridges
Erosive lesions: None
Porosity: None
Eburnation: Possible
Location of lesion: Medial process of the humeral head
Type of bone formed: Osteophytes

Bone: Tibia P
Side: Left
Evidence:
Marginal Osteophytes: Clear evidence, $\frac{2}{3}$ >
Surface Osteophytes: Sharp ridges
Erosive lesions: None
Porosity: None
Eburnation: Possible
Location of lesion: Medial process of the condyle
Type of bone formed: Osteophytes

Bone: Tibia D
Side: Left
Evidence:
Marginal Osteophytes: Clear evidence, $\frac{2}{3}$ >
Surface Osteophytes: Sharp ridges
Erosive lesions: None
Porosity: None
Eburnation: Possible
Location of lesion: Distal process of the medial malleolus
Type of bone formed: Osteophytes

Figure 9. Sabrina's left Upper Canine severe periodontitis w/ porous bone
Tooth comb (right 3 teeth and first left tooth lost premortem).



Figure 10. Abscess present on left maxilla of Sabrina.



Mamu

Mamu, a female born at the Cheyenne Mountain Zoo in Colorado Springs, Colorado was moved to the Pueblo Zoo in 1989 for breeding purposes. She lived out her days in the zoo's "monkey island", an indoor-outdoor exhibit where both sides are viewable to the public. She underwent a second move in her lifetime as the zoo secured funding for their new Islands of Life exhibit, and with that move, she gained two new lemur friends named Bertha and Frack. At the time of her second move she was 36 years old, the oldest captive ring-tailed lemur ("Rare Animal Dies at Ripe Old Age of 37 in Pueblo Zoo," 2007). She celebrated one more birthday after her move before she died at age 37, although a necropsy was performed there was no cause of death reported. I was unable to speak to anybody who knew Mamu as a keeper, but as I was presenting names of these specimens to my class a number of individuals

grew up seeing Mamu at the zoo and they loved her and were devastated when she died.

From dental evidence it seems that Mamu was not given any dental cleanings to maintain her teeth. Due to this neglect she lost all of the teeth in her tooth comb, one of the most important features of a strepsirrhine primate. Socially ring-tailed lemurs use their tooth combs to groom each other as well as themselves, and with Mamu no longer having one she would've had to depend on her daughters to groom her without being able to return the favor in the same manner.

Summary of Pathological Conditions:

Photographs: 1. Right p2 Lost Premortem

Left p2 Lost Premortem

Left m2 Lost Premortem

Left m3 Lost Premortem

Both upper i1s lost Premortem

Toothcomb lost Premortem

No abscesses

Bone: C6

Side: N/A

Evidence:

Marginal osteophytes: Sharp Ridge $\frac{2}{3}$ >

Surface osteophytes: None

Erosive lesions: none

Porosity: none

Eburnation: none

Location of lesion: Caudal surface of vertebral body

Type of bone formed: osteophyte

Bone: T3

Side: N/A

Evidence:

Marginal osteophytes: Sharp Ridge $\frac{2}{3}$ >

Surface osteophytes: None

Erosive lesions: none

Porosity: none

Eburnation:none
Location of lesion: Caudal surface of vertebral body
Type of bone formed: osteophyte

Bone: T4
Side: N/A
Evidence:
Marginal osteophytes:Sharp Ridge $\frac{2}{3}$ >
Surface osteophytes: None
Erosive lesions:none
Porosity:none
Eburnation:none
Location of lesion: Caudal surface of vertebral body
Type of bone formed: osteophyte

Bone: T5
Side: N/A
Evidence:
Marginal osteophytes:Sharp Ridge $\frac{2}{3}$ >
Surface osteophytes: None
Erosive lesions:none
Porosity:none
Eburnation:none
Location of lesion: Caudal surface of vertebral body
Type of bone formed: osteophyte

Bone: T6
Side: N/A
Evidence:
Marginal osteophytes:Sharp Ridge $\frac{2}{3}$ >
Surface osteophytes: None
Erosive lesions:none
Porosity:none
Eburnation:none
Location of lesion: Caudal surface of vertebral body
Type of bone formed: osteophyte

Bone: T7
Side: N/A
Evidence:
Marginal osteophytes:Sharp Ridge $\frac{2}{3}$ >
Surface osteophytes: None
Erosive lesions:none
Porosity:none

Eburnation:none
Location of lesion: Caudal surface of vertebral body
Type of bone formed: osteophyte

Bone: T8
Side: N/A
Evidence:
Marginal osteophytes:Sharp Ridge $\frac{2}{3}$ >
Surface osteophytes: None
Erosive lesions:none
Porosity:none
Eburnation:none
Location of lesion: Caudal surface of vertebral body
Type of bone formed: osteophyte

Bone: T9
Side: N/A
Evidence:
Marginal osteophytes:Sharp Ridge $\frac{2}{3}$ >
Surface osteophytes: None
Erosive lesions:none
Porosity:none
Eburnation:none
Location of lesion: Caudal surface of vertebral body
Type of bone formed: osteophyte

Bone: T10
Side: N/A
Evidence:
Marginal osteophytes:Sharp Ridge $\frac{2}{3}$ >
Surface osteophytes: None
Erosive lesions:none
Porosity:none
Eburnation:none
Location of lesion: Caudal surface of vertebral body
Type of bone formed: osteophyte

Bone: T11
Side: N/A
Evidence:
Marginal osteophytes:Sharp Ridge $\frac{2}{3}$ >
Surface osteophytes: None
Erosive lesions:none
Porosity:none

Eburnation:none
Location of lesion: Caudal surface of vertebral body
Type of bone formed: osteophyte

Bone: L1
Side: N/A
Evidence:
Marginal osteophytes:Sharp Ridge $\frac{2}{3}$ >
Surface osteophytes: None
Erosive lesions:none
Porosity:none
Eburnation:none
Location of lesion: Caudal surface of vertebral body
Type of bone formed: osteophyte

Bone: Sacrum
Side: N/A
Marginal Osteophytes: extensive, $>\frac{2}{3}$
Surface Osteophytes: Clearly present
Erosive lesions: Clearly present, $>\frac{2}{3}$
Porosity: N/A
Eburnation: N/A
Location of lesion: Superior articular process, sacral tuberosity
Type of bone formed:Osteophyte

Bone: Caudal 1
Side: N/A
Evidence:
Marginal osteophytes: extensive, $\frac{2}{3}$ >
Surface osteophytes:None
Erosive lesions:None
Porosity: At connecting points
Eburnation: Beginning stages
Location of lesion:Cranial articular surface
Type of bone formed: osteophyte

Bone: Caudal 2
Side: N/A
Evidence:
Marginal osteophytes: extensive, $\frac{2}{3}$ >
Surface osteophytes:None
Erosive lesions:None
Porosity: At connecting points
Eburnation: Beginning stages
Location of lesion:Cranial articular surface
Type of bone formed: osteophyte

Bone: Caudal 3
Side: N/A
Evidence:
Marginal osteophytes: extensive, $\frac{2}{3}$ >
Surface osteophytes:None
Erosive lesions:None
Porosity: At connecting points
Eburnation: Beginning stages
Location of lesion:Cranial articular surface
Type of bone formed: osteophyte

Bone: Caudal 4
Side: N/A
Evidence:
Marginal osteophytes: extensive, $\frac{2}{3}$ >
Surface osteophytes:None
Erosive lesions:None
Porosity: At connecting points
Eburnation: Beginning stages
Location of lesion:Cranial articular surface
Type of bone formed: osteophyte

Bone: Sternum Body
Side: N/A
Evidence:
Marginal Osteophytes: None
Surface Osteophytes: Barely discernible $\frac{1}{3}$ <
Erosive lesions: None
Porosity: None
Eburnation: None
Location of lesion: Medial process of the sternum body
Type of bone formed: osteophyte

Bone: Scapula
Side: Right
Evidence:
Marginal Osteophytes: None
Surface Osteophytes: Clearly present, $\frac{2}{3}$ >
Erosive lesions: Clearly present, $<\frac{1}{3}$
Porosity: Coalesced, $<\frac{1}{3}$
Eburnation: None
Location of lesion: Proximal surface of the Coracoid process
Type of bone formed: Clear border around lesion, porous destruction, osteophytes

Bone: Scapula
Side: Left

Evidence:

Marginal Osteophytes: None

Surface Osteophytes: Clearly present, $\frac{2}{3}$ >

Erosive lesions: Clearly present, $<\frac{1}{3}$

Porosity: Coalesced, $<\frac{1}{3}$

Eburnation: None

Location of lesion: Lateral surface of the Infraspinatus fossa, Proximal surface of the Coracoid process

Type of bone formed: Clear border around lesion, porous destruction, osteophytes

Bone: Left humerus P

Side: Left

Evidence:

Marginal Osteophytes: Clear evidence, $\frac{2}{3}$ >

Surface Osteophytes: Sharp ridges

Erosive lesions: None

Porosity: None

Eburnation: None

Location of lesion: Medial process of the humeral head

Type of bone formed: Osteophytes

Bone: Left humerus D

Side: Left

Evidence:

Marginal Osteophytes: Clear evidence, $\frac{2}{3}$ >

Surface Osteophytes: Sharp ridges

Erosive lesions: None

Porosity: None

Eburnation: None

Location of lesion: Capitulum

Type of bone formed: Osteophytes

Bone: humerus D

Side: Right

Evidence:

Marginal Osteophytes: Clear evidence, $\frac{2}{3}$ >

Surface Osteophytes: Sharp ridges

Erosive lesions: None

Porosity: None

Eburnation: None

Location of lesion: Medial supracondylar ridge

Type of bone formed: Osteophytes

Bone: humerus P

Side: Right

Evidence:

Marginal Osteophytes: Clear evidence, $\frac{2}{3}$ >

Surface Osteophytes: Sharp ridges

Erosive lesions: None
Porosity: None
Eburnation: None
Location of lesion: Greater Tubercle
Type of bone formed: Osteophytes

Bone: Right radius P
Side: Right
Evidence:
Marginal Osteophytes: Clear evidence, $\frac{2}{3}$ >
Surface Osteophytes: Sharp ridges
Erosive lesions: None
Porosity: None
Eburnation: None
Location of lesion: Radial tuberosity
Type of bone formed: Osteophytes

Bone: Left ulna P
Side: Left
Evidence:
Marginal Osteophytes: Clearly present
Surface Osteophytes: None
Erosive lesions: Clearly present, $<\frac{1}{3}$
Porosity: None
Eburnation: None
Location of lesion: Olecranon process
Type of bone formed: Osteophytes

Bone: Left ulna D
Side: Left
Evidence:
Marginal Osteophytes: Clearly present
Surface Osteophytes: None
Erosive lesions: Clearly present, $<\frac{1}{3}$
Porosity: None
Eburnation: None
Location of lesion: Head of ulna
Type of bone formed: Osteophytes

Bone: Right ulna D
Side: Right
Evidence:
Marginal Osteophytes: Clearly present
Surface Osteophytes: None
Erosive lesions: Clearly present, $<\frac{1}{3}$
Porosity: None

Eburnation: None
Location of lesion: Head of ulna
Type of bone formed: Osteophytes

Bone: Right ulna P
Side: Right
Evidence:
Marginal Osteophytes: Clearly present
Surface Osteophytes: None
Erosive lesions: Clearly present, <1/3
Porosity: None
Eburnation: None
Location of lesion: Coronoid process
Type of bone formed: Osteophytes

Bone: Acetabulum
Side: Left
Evidence:
Marginal Osteophytes: Clearly present
Surface Osteophytes: None
Erosive lesions: Clearly present, <1/3
Porosity: None
Eburnation: Extensive
Location of lesion: Proximal Ilium
Type of bone formed: Osteophytes

Bone: Acetabulum
Side: Right
Evidence:
Marginal Osteophytes: Clearly present
Surface Osteophytes: None
Erosive lesions: Clearly present, <1/3
Porosity: None
Eburnation: Extensive
Location of lesion: Proximal Ilium
Type of bone formed: Osteophytes

Bone: ischial tuberosity
Side: Right
Evidence:
Marginal Osteophytes: Clearly present
Surface Osteophytes: None
Erosive lesions: Clearly present, <1/3
Porosity: None
Eburnation: None
Location of lesion: Medial process of ischial tuberosity
Type of bone formed: Osteophytes

Bone: ischial tuberosity
Side: Left
Evidence:
Marginal Osteophytes: Clearly present
Surface Osteophytes: None
Erosive lesions: Clearly present, $< \frac{1}{3}$
Porosity: None
Eburnation: None
Location of lesion: Medial process of ischial tuberosity
Type of bone formed: Osteophytes

Bone: Patella
Side: Right
Evidence:
Marginal Osteophytes: Clearly present
Surface Osteophytes: None
Erosive lesions: None
Porosity: None
Eburnation: None
Location of lesion: Bony growth around all edges of the anterior
Type of bone formed: Osteophytes

Bone: Patella
Side: Left
Evidence:
Marginal Osteophytes: Clearly present
Surface Osteophytes: None
Erosive lesions: None
Porosity: None
Eburnation: None
Location of lesion: Bony growth around all edges of the anterior
Type of bone formed: Osteophytes

Bone: Femur
Side: Right
Evidence:
Marginal Osteophytes: None
Surface Osteophytes: None
Erosive lesions: none
Porosity: None
Eburnation: None
Location of lesion: Complete fracture of the shaft Primary callus formation is woven
Type of bone formed: N/A fracture happened too close to death

Bone: Femur D
Side: Right
Evidence:
Marginal Osteophytes: Clearly present $\frac{2}{3}$ >

Surface Osteophytes: None

Erosive lesions: none

Porosity: None

Eburnation: None

Location of lesion: Patellar surface, Lateral condyle

Type of bone formed: osteophytes

Note all bones in hand and foot have osteophytes

Figure 11. Mamu's left upper canine lost Premortem. Note also her missing tooth comb.



Figure 12. Front photo showing orbital thickening on Mamu's skull.



Findings

The results of this pathological examination indicate that captive lemurs are especially susceptible to dental disease but with early intervention in the form of yearly dental cleanings and exams can help to dramatically reduce this issue. I also found that captive lemurs that reach an older age have overall thicker cranial measurements, especially the orbital thickness.

At first as a team we considered infection of the bone due to one of the specimens having an abscess that showed signs of osteomyelitis; upon further study of all the specimens we found that the orbital thickness varied, but was still present even in those without signs of infection. This leads us to believe that a combination of consistent tough “Monkey pellets” provided by zoos as the main source of nutrition along with supplemental diet fillers to add variation cause the mastication muscles to pull at the orbital bones causing them to thicken. This in combination with long term use that you don't see in wild lemurs which may create this difference.

Captive skeletal remains such as the lemurs used for this study can be especially useful in understanding primate patterns of aging across both wild and captive environments. By having access to this kind of data for a variety of species, it would be easier to identify the age of remains in the field, as well as be able to notice movement patterns of older living primates who may be suffering from some of these pathologies.

Images of Lemurs in their homes



Figure 13. Mick sunbathing on a rock as an adult, visible foot deformities from osteophytes
@ Lynne Villers



Figure 14. Juvenile Mick hanging from his Fathers tail during playtime @ Lynne Villers Indianapolis Zoo



Figure 14. Mamu 2006 @ The Denver Post

Why do these lemurs matter?

The emotional connection between zoo keepers and the animals they care for is profound and multifaceted. Keepers spend significant amounts of time with the animals, developing a deep understanding of their behaviors, needs, and personalities. This daily interaction fosters a bond that goes beyond mere caretaker duties; it becomes a relationship built on trust and mutual recognition. Keepers often describe their role as more than just a job; it's a calling that involves emotional investment and a commitment to the well-being of the animals. This bond can be seen in the way keepers talk about their charges, often with affection and concern akin to that of a family member.

The connection between keepers and animals is not one-sided; animals, too, recognize and respond to their keepers. Many animals in zoos form attachments to their caregivers, showing visible signs of excitement and comfort in their presence. This relationship is crucial for the animals' psychological well-being, providing a sense of stability and security in a captive environment. The trust built between keepers and animals facilitates better care, as animals are more likely to cooperate during medical treatments and routine health checks, reducing stress and promoting better health outcomes.

The emotional bond between keepers and animals often extends to the public who visit zoos. Visitors, especially children, develop a sense of connection and empathy towards the animals they see. This connection is nurtured through educational programs, interactive exhibits, and storytelling by the keepers. When the public learns about the individual stories of the animals, such as their rescue, rehabilitation, or unique behaviors, it humanizes the animals and creates a personal connection. This emotional engagement can inspire a deeper appreciation for wildlife and a commitment to conservation efforts.

Public emotional connections to zoo animals are also reinforced through repeated visits and personal experiences. Families who visit zoos regularly often form attachments to specific animals, considering them as part of their lives. These connections can be especially poignant when animals give birth, reach significant milestones, or face health challenges. The shared experiences of joy, wonder, and concern foster a community spirit among zoo visitors, united by their affection for the animals.

Social media has amplified the emotional connections between the public and zoo animals. Zoos frequently share updates, photos, and videos of their animals on platforms like Instagram, Facebook, and X (Twitter). These posts allow the public to follow the lives of the animals, celebrate their milestones, and even participate in naming contests. The ability to engage with the animals' stories online extends the emotional connection beyond the zoo's

physical boundaries, reaching a global audience and fostering a broader sense of empathy and support for wildlife.

The emotional connections formed in zoos play a significant role in wildlife conservation. When people feel emotionally connected to animals, they are more likely to support conservation initiatives and contribute to efforts aimed at protecting endangered species and their habitats. Zoos often leverage these connections to raise awareness and funds for conservation projects, highlighting the direct impact of public support on preserving wildlife. Emotional bonds with zoo animals thus translate into tangible benefits for conservation, bridging the gap between human compassion and action.

Ultimately, the emotional connections formed between keepers, the public, and zoo animals underscore the importance of zoos as places of education, conservation, and emotional enrichment. These bonds remind us of our shared responsibility to protect and care for the natural world. By fostering empathy and understanding, zoos play a crucial role in cultivating a generation of wildlife advocates committed to the well-being of animals both in captivity and in the wild. The emotional connections nurtured within zoo environments have the power to inspire meaningful change and ensure a sustainable future for all species.

Why Zoos?

The controversy surrounding the presence of primates in zoos stems from ethical, environmental, and welfare concerns. Primates, including not only great apes but also monkeys and other species, are highly intelligent, social animals with complex behaviors and emotional needs. Critics argue that even the best zoos cannot fully replicate the natural environments and social structures these animals require, leading to potential psychological distress and abnormal behaviors such as stereotypy, where animals engage in repetitive,

unvarying behaviors (Rose et al., 2017). This ethical dilemma questions the morality of keeping such sentient beings in captivity, regardless of the quality of their enclosures.

One of the primary arguments against keeping primates in zoos is their cognitive and emotional complexity. Primates exhibit behaviors such as tool use, social bonding, and problem-solving, indicating high levels of intelligence and emotional depth. Confining these animals to zoo environments can limit their opportunities for mental stimulation and natural behaviors, leading to boredom, frustration, and mental health issues. The inability to engage in normal social interactions and complex activities found in the wild further exacerbates these problems, raising serious welfare concerns (Brune et al., 2006).

Another point of contention is the impact of captivity on the physical health of primates. In the wild, primates have large territories and varied diets that are difficult to replicate in zoos. The lack of space and diversity in their environment can lead to obesity, cardiovascular issues, and other health problems. Furthermore, the confinement of primates can also contribute to the spread of diseases within zoo populations, posing risks to both the animals and their human caregivers. These health concerns highlight the potential drawbacks of keeping primates in captivity from a purely biological standpoint.

However, proponents of keeping primates in zoos argue that these institutions play a crucial role in conservation efforts. Many primate species are threatened or endangered due to habitat destruction, poaching, and other human activities. Zoos provide a safe haven for these animals, offering protection from these threats and contributing to the preservation of species that might otherwise face extinction. Breeding programs in zoos can help maintain genetic diversity and, in some cases, reintroduce individuals back into the wild, supporting broader conservation initiatives.

Educational opportunities presented by zoos are another significant benefit. Zoos serve as living classrooms where visitors can learn about primates and the challenges they face in the wild. These educational programs can foster a greater appreciation for primates and inspire visitors to support conservation efforts. By providing firsthand experiences with primates, zoos can bridge the gap between humans and wildlife, promoting empathy and a deeper understanding of the natural world. This educational mission is vital in an increasingly urbanized world where direct encounters with wildlife are rare (Conway, 1969)

Modern zoos have made significant strides in improving the welfare of primates through better enclosure designs and enrichment programs. These efforts aim to create environments that simulate the complexities of the wild, offering physical and mental stimulation to the animals. Enrichment activities, such as puzzle feeders and social groupings, encourage natural behaviors and provide opportunities for problem-solving and social interaction. While these improvements do not entirely replace the natural habitat, they represent a significant advancement in addressing the welfare needs of captive primates.

Moreover, zoos are increasingly involved in scientific research that benefits both captive and wild primate populations. Studies conducted in zoos can provide valuable insights into primate behavior, health, and genetics that are difficult to obtain in the wild. This research can inform conservation strategies, improve captive care practices, and enhance our understanding of primate biology. Zoos thus serve as important centers for scientific inquiry, contributing to the broader goal of primate conservation and welfare.

In conclusion, the debate over keeping primates in zoos is complex and multifaceted, balancing ethical concerns with practical benefits. While the challenges of providing adequate care for such intelligent and social animals in captivity are significant, zoos also play a crucial role in conservation, education, and research. The ongoing improvements in zoo practices and the dedication to enhancing the welfare of primates indicate a commitment

to addressing these challenges. In the modern world, where primate habitats are increasingly threatened, zoos may offer a vital lifeline for the survival and understanding of these remarkable animals.

Why Lemurs?

Lemurs deserve to be focused on as much as any of the great apes due to their unique evolutionary history and ecological significance. Native to Madagascar, lemurs represent a distinct branch of the primate family tree, having evolved in isolation for millions of years. This isolation has led to a remarkable diversity of species, each adapted to different ecological niches. Studying lemurs provides valuable insights into primate evolution and the adaptive strategies that have enabled their survival in various environments. Their unique evolutionary path makes them crucial for understanding the broader picture of primate and mammalian evolution.

Another reason lemurs warrant significant attention is their critical role in maintaining the ecological balance of Madagascar's forests. As primary seed dispersers and pollinators, lemurs are integral to the health and regeneration of their habitats. The decline or extinction of lemur populations can lead to cascading effects on forest ecosystems, disrupting plant reproduction and altering the structure and function of the forest. This ecological role highlights the importance of conserving lemurs, not only for their intrinsic value but also for the broader health of Madagascar's unique biodiversity (Wright, 1999).

Lemurs are also facing extreme conservation challenges that rival those of the great apes. Madagascar's forests are being rapidly destroyed due to deforestation, agriculture, and mining, leading to significant habitat loss for lemurs. Additionally, lemurs are threatened by hunting and the illegal pet trade. Many lemur species are now critically endangered, with some teetering on the brink of extinction. The urgent need to address these threats

underscores the importance of focusing conservation efforts on lemurs to prevent their loss and preserve the biodiversity of Madagascar (Lemur Conservation Network, 2021).

In terms of research and scientific interest, lemurs offer unique opportunities for studying primate behavior, cognition, and social structures. Their diverse species exhibit a wide range of social organizations, from solitary to complex multi-female groups, providing comparative data that enrich our understanding of social evolution in primates. Research on lemur cognition and communication can also shed light on the development of these traits in other primates, including humans. This scientific interest makes lemurs valuable subjects for advancing knowledge in primatology and anthropology.

Public awareness and education about lemurs are also essential for their conservation. Lemurs, with their distinctive appearances and behaviors, can captivate the public's imagination and foster a connection to Madagascar's unique wildlife. By focusing on lemurs in educational programs and media, conservation organizations can raise awareness about the critical issues facing these animals and the broader environmental challenges in Madagascar. Engaging the public in lemur conservation can lead to increased support for preservation efforts and funding for research and habitat protection.

Finally, lemurs hold significant cultural and intrinsic value. They are iconic symbols of Madagascar and are deeply intertwined with the island's natural heritage. The loss of lemurs would not only represent a biological tragedy but also a cultural one, as these animals are an integral part of the identity of Madagascar. Protecting lemurs is a matter of preserving a unique and irreplaceable part of the world's natural and cultural legacy. Their importance to both the environment and human culture warrants a level of focus and attention comparable to that given to the great apes.

Concluding Remarks

The study of primate gerontology is a vital anthropological discipline that offers profound insights into the aging process, health, and longevity of both non-human primates and humans. By examining the aging patterns and life histories of primates, particularly through the lens of the zoo model and the specific example of ring-tailed lemurs, we gain a deeper understanding of the biological, environmental, and social factors that influence aging. The zoo model provides a controlled environment for longitudinal studies, allowing researchers to monitor and analyze the health and behavior of primates over their lifetimes, thereby contributing valuable data that can inform both primate and human gerontology.

Ring-tailed lemurs, with their unique evolutionary background and ecological significance, serve as an exceptional model for studying aging. Their relatively small body size and quicker life cycles, yet prolonged lifespans in captivity, offer a unique opportunity to observe aging processes in a compressed time frame. This can reflect broader trends and potential future scenarios for human aging, given the similarities in physiological and behavioral aspects shared between primates and humans. The insights gained from studying lemurs' gerontology can help predict and address the challenges of human aging, such as the development of age-related diseases, the maintenance of cognitive functions, and the overall quality of life in advanced age.

Furthermore, understanding the intricate balance of care, enrichment, and medical intervention provided within the zoo model emphasizes the importance of optimal living conditions in promoting longevity and health in aging populations. This perspective can be applied to human societies, where improving the quality of life for the elderly requires a comprehensive approach that includes social, environmental, and medical considerations. The interdisciplinary nature of primate gerontology, combining elements of anthropology,

biology, and veterinary science, underscores the importance of a holistic approach to studying and addressing the complexities of aging.

To summarize, the study of primate gerontology, exemplified through the zoo model and the specific case of ring-tailed lemurs, is crucial for advancing our understanding of aging processes and improving the health and longevity of both primates and humans. The accelerated life cycles of smaller primates like lemurs provide a unique window into the future of human aging, offering valuable lessons and potential strategies for promoting healthy aging in our own species. By continuing to invest in this interdisciplinary field, we can unlock new knowledge that will enhance the quality of life for aging populations and contribute to the broader goal of understanding the biological and social dimensions of aging across species.

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APPENDIX

Skeletal Recording Form KELLY

Summary Sheet

Captive Location: Cameron Park Zoo

Skeleton

Number: Stud Book Number:2589

DMNS ID:19865

CUA-1008

DZTM: 7998

Date: February 14th, 2024

Recorded By:

Autumn Lucas

Age/Class: 8/Adult

Sex: Female

Preservation: Good

Necropsied by a Vet, kept in storage for 20 years. Soft tissue still connects cervical vertebrae C2-C6,

Left carpals are still articulated,

Left metacarpals are still articulated

Sternal bodies and xiphoid process connected with tissue

Photographs: No remarkable finds to photograph, instead highlighted on illustrated drawings

3D Scans:

3D prints:

Summary of Pathological Conditions:

Skull	Present	Absent	Fragmentary	Pathology
Frontal	Skull cap detached			No
Occipital	Skull Cap detached	Some		No
Sphenoid	Yes			No
Ethmoid	Yes			No
Vomer	Yes			No
Hyoid	Yes			No
Left mandible	Yes			No
Right mandible	Yes			No
Left maxilla	Yes			No
Right maxilla	Yes			No
Left parietal	Skull cap detached			No
Right parietal	Skull cap detached			No
Left temporal	Yes			No
Right temporal	Yes			No
Left nasal	Yes			No
Right nasal	Yes			No
Left zygomatic	Yes			No
Right zygomatic	Yes			No

Left lacrimal	Yes			No
Right lacrimal	Yes			No
Left palate	Yes			No
Right palate	Yes			No
Left inf. nas.con	Yes			No
Right inf.nas.con	Yes			No
Malleus I/r	Yes			No
Incus I/r	Yes			No
Stapes I/r	Yes			No

TEETH

PTooth	Pres.	Absent	Frag.	DTooth	Pres.	Absent	Frag.
LEFT MAND				LEFT MAND			
I¹				I¹			
I²				I²			
C				C			
PM¹				PM¹			
PM²				PM²			
PM³				PM³			

M ¹				M ¹			
M ²				M ²			
M ³				M ³			
LEFT MAX				LEFT MAX			
I ¹				I ¹			
I ²		No		I ²			
C				C			
PM ¹				PM ¹			
PM ²				PM ²			
PM ³				PM ³			
M ¹				M ¹			
M ²				M ²			
M ³				M ³			
RIGHT MAND				RIGHT MAND			
I ¹				I ¹			
I ²				I ²			
C				C			
PM ¹				PM ¹			
PM ²				PM ²			
PM ³				PM ³			
M ¹				M ¹			
M ²				M ²			

M³				M³			
RIGHT MAX				RIGHT MAX			
I¹				I¹			
I²				I²			
C				C			
PM¹				PM¹			
PM²				PM²			
PM³				PM³			
M¹				M¹			
M²				M²			
M³				M³			

POST-CRANIAL

	Present	Absent	Fragmentary	Pathology
Cervical 1	Yes			No
Cervical 2	Yes			None Visible
Cervical 3	Yes			None Visible
Cervical 4	Yes			None Visible
Cervical 5	Yes			None Visible
Cervical 6	Yes			None Visible
Cervical 7	Yes			No
Thoracic 1	Yes			No
Thoracic 2	Yes			No

Thoracic 3	Yes			No
Thoracic 4	Yes			Yes
Thoracic 5	Yes			No
Thoracic 6	Yes			No
Thoracic 7	Yes			No
Thoracic 8	Yes			No
Thoracic 9	Yes			No
Thoracic 10	Yes			No
Thoracic 11	Yes			No
Thoracic 12	Yes			No
Lumbar 1	Yes			No
Lumbar 2	Yes			No
Lumbar 3	Yes			No
Lumbar 4	Yes			No
Lumbar 5	Yes			Yes
Lumbar 6	Yes			No
Lumbar 7	Yes			No
Sacrum	3 bodies Yes			No
Caudal 1	Yes			Yes
Caudal 2	Yes			No
Caudal 3	Yes			Yes
Caudal 4	Yes			None Visible

Caudal 5	Yes			None Visible
Caudal 6	Yes			None Visible
Caudal 7	Yes			No
Caudal 8	Yes			No
Caudal 9	Yes			No
Caudal 10	Yes			No
Caudal 11	Yes			No
Caudal 12	Yes			No
Caudal 13	Yes			No
Caudal 14	Yes			No
Caudal 15	Yes			No
Caudal 16	Yes			No
Caudal 17	Yes			No
Caudal 18	Yes			No
Caudal 18	Yes			No
Caudal 19	Yes			No
Caudal 20	Yes			No
Caudal 21	Yes			No
Caudal 22	Yes			No
Caudal 23	Yes			N/A
Caudal 24	N/A			N/A
Caudal 25	N/A			N/A
Sternum	4			No

Body	Yes			
Manubrium	Yes			No
Xiphoid process	Yes			
	Head end	Shaft	Sternal end	
Left ribs	12			None
Right ribs	12			None
?left/right	0	11		

	Present	Absent	Fragmentary	Pathology
Left scapula	Yes			No
Right scapula	Yes			No
Left scap.glen.	Yes			No
Right scap.glen.	Yes			No
Left clavicle	Yes			Cut post mortem No
Right clavicle	Yes			Cut post mortem No
Left clavicle M	Yes			No
Left clavicle D	Yes			No
Right clavicle M	Yes			No
Right clavicle D	Yes			No
Left humerus P	Yes			Yes
Left humerus D	Yes			No
Right humerus P	Yes			No

Right humerus D	Yes			No
Left radius P	Yes			No
Left radius D	Yes			No
Right radius P	Yes			No
Right radius D	Yes			No
Left ulna P	Yes			No
Left ulna D	Yes			No
Baculum	Yes			No
Right ulna P	Yes			No
Left ulna D	Yes			No
Left innom	Yes			No
Right innom	Yes			No
Left acetabulum	Yes			No
Right acetabulum	Yes			No
Left pub.symph.	Yes			No
Right pub.symph.	Yes			No
Left ischial tub.	Yes			No
Right ischial tub .	Yes			No
Left patella	Yes			No
Right patella	Yes			No
Left femur P	Yes			No
Left femur D	Yes			No
Right femur P	Yes			No

Right femur D	Yes			No
Left tibia P	Yes			No
Left tibia D	Yes			No
Right tibia P	Yes			No
Right tibia D	Yes			No
Left fibula P	Yes			No
Left fibula D	Yes			No
Right fibula P	Yes			No
Left fibula D	Yes			No

HAND left	Present	Absent	Fragmentary	Pathology
Scaphoid	Yes			None Visible
Lunate	Yes			None Visible
Triquetral	Yes			None Visible
Pisiform	Yes			None Visible
Trapezium	Yes			None Visible
Trapezoid	Yes			None Visible
Capitate	Yes			None Visible
Hamate	Yes			None Visible
Metacarpal 1	Yes			No
Metacarpal 2	Yes			No
Metacarpal 3	Yes			No
Metacarpal 4	Yes			No

Metacarpal 5	Yes			No
Prox. phals (No.)	5 Yes			No

Mid phals (No.)	5 Yes			No
Distal phals (No.)	5 Yes			No
Nails attached?	5 Yes			N/A
HAND right	Present	Absent	Fragmentary	Pathology
Scaphoid		Yes		N/A With Study Skin
Lunate		Yes		N/A With Study Skin
Triquetral		Yes		N/A With Study Skin
Pisiform		Yes		N/A With Study Skin
Trapezium		Yes		N/A With Study Skin
Trapezoid		Yes		N/A With Study Skin
Capitate		Yes		N/A With Study Skin
Hamate		Yes		N/A With Study Skin
Metacarpal 1	Yes			N/A

				With Study Skin
Metacarpal 2	Yes			N/A With Study Skin
Metacarpal 3	Yes			N/A With Study Skin
Metacarpal 4	Yes			N/A With Study Skin
Metacarpal 5	Yes			N/A With Study Skin
Prox. phals (No.)		N/A With Study Skin		N/A With Study Skin
Mid phals (No.)		N/A With Study Skin		N/A With Study Skin
Distal phals (No.)		N/A With Study Skin		N/A With Study Skin
Nails attached?		N/A With Study Skin		N/A With Study Skin
Sesamoid bones?		N/A With Study Skin		N/A With Study Skin

FOOT left	Present	Absent	Fragmentary	Pathology
Talus	Yes			Yes
Calcaneus	Yes			No
Navicular	Yes			No

Cuboid	Yes			No
Medial cuneiform	Yes			No
Internal cun.	Yes			No
Lateral cun.	Yes			No
Metatarsal 1	Yes			None Visible
Metatarsal 2	Yes			None Visible
Metatarsal 3	Yes			None Visible
Metatarsal 4	Yes			None Visible
Metatarsal 5	Yes			None Visible
Prox phals (No.)	5 Yes			None Visible
Prox. phals (No.)	5 Yes			None Visible

Mid phals (No.)	5 Yes			None Visible
Distal phals (No.)	No			N/A
Nails attached?	No			N/A
FOOT right	Present	Absent	Fragmentary	Pathology
Talus		Yes		N/A With Study Skin
Calcaneus		Yes		N/A With Study Skin
Navicular		Yes		N/A With Study Skin
Cuboid		Yes		N/A With Study Skin

Medial cuneiform		Yes		N/A With Study Skin
Internal cun.		Yes		N/A With Study Skin
Lateral cun.		Yes		N/A With Study Skin
Metatarsal 1		Yes		N/A With Study Skin
Metatarsal 2		Yes		N/A With Study Skin
Metatarsal 3		Yes		N/A With Study Skin
Metatarsal 4		Yes		N/A With Study Skin
Metatarsal 5		Yes		N/A With Study Skin
Prox phals (No.)		Yes		N/A With Study Skin
Prox. phals (No.)		Yes		N/A With Study Skin
Mid phals (No.)		Yes		N/A With Study Skin
Distal phals (No.)		Yes		N/A With Study Skin
Nails Attached?		Yes		N/A With Study Skin
Sesamoid bones?		Yes		N/A With Study Skin
Cranial Measurements (mm)- Brothwell, 1981	Left	Right		
Basion-Prosthion length	37.56mm			

Orbital Breadth	16.21mm			
Orbital Thickness	1.78mm			
Mandibular length	64.20mm			

Skeletal Recording Form BOSLEY

Summary Sheet

Captive Location: Cameron Park Zoo
Number: Stud Book Number:2308
DMNS ID:19860
CUA-1005:M01702
DZTM: 7991

Skeleton

Date: January 31, 2024
Autumn Lucas, Julie Thomas

Recorded By:

Age/Class: 10, Adult
Sex: Male

Preservation: Good
Necropsied by a Vet, kept in storage for 20 years. Soft tissue still connects cervical vertebrae C2-C6, T1-T3, T6-T8, T11-12
Left carpals are still articulated,
Left metacarpals are still articulated
Sternal bodies and xiphoid process connected with tissue

3D Scans:
3D prints:

Summary of Pathological Conditions:

Skull	Present	Absent	Fragmentary	Pathology
Frontal	Skull cap detached			No
Occipital	Skull Cap detached	Some		No
Sphenoid	Yes			No
Ethmoid	Yes			No
Vomer	Yes			No
Hyoid	Yes			No
Left mandible	Yes			No
Right mandible	Yes			No
Left maxilla	Yes			Yes
Right maxilla	Yes			No
Left parietal	Skull cap detached			No
Right parietal	Skull cap detached			No
Left temporal	Yes			No
Right temporal	Yes			No
Left nasal	Yes			No
Right nasal	Yes			No
Left zygomatic	Yes			No

Right zygomatic	Yes			No
Left lacrimal	Yes			No
Right lacrimal	Yes			No
Left palate	Yes			No
Right palate	Yes			No
Left inf. nas.con	Yes			No
Right inf.nas.co n	Yes			No
Malleus I/r	Yes			No
Incus I/r	Yes			No
Stapes I/r	Yes			No

PTooth	Pres.	Absent	Frag.	DTooth	Pres.	Absent	Frag.
LEFT MAND				LEFT MAND			
I¹				I¹			
I²				I²			
C				C			
PM¹				PM¹			
PM²				PM²			

PM ³				PM ³			
M ¹				M ¹			
M ²				M ²			
M ³				M ³			
LEFT MAX				LEFT MAX			
I ¹				I ¹			
I ²		No		I ²			
C				C			
PM ¹				PM ¹			
PM ²				PM ²			
PM ³				PM ³			
M ¹				M ¹			
M ²				M ²			
M ³				M ³			
RIGHT MAND				RIGHT MAND			
I ¹				I ¹			
I ²				I ²			
C				C			
PM ¹				PM ¹			
PM ²				PM ²			
PM ³				PM ³			
M ¹				M ¹			

M ²				M ²			
M ³				M ³			
RIGHT MAX				RIGHT MAX			
I ¹				I ¹			
I ²				I ²			
C				C			
PM ¹				PM ¹			
PM ²				PM ²			
PM ³				PM ³			
M ¹				M ¹			
M ²				M ²			
M ³				M ³			

TEETH

	Present	Absent	Fragmentary	Pathology
Cervical 1	Yes			None Visible
Cervical 2	Yes			None Visible
Cervical 3	Yes			None Visible
Cervical 4	Yes			None Visible
Cervical 5	Yes			None Visible
Cervical 6	Yes			None Visible
Cervical 7	Yes			None Visible
Thoracic 1	Yes			None Visible

Thoracic 2	Yes			None Visible
Thoracic 3	Yes			None Visible
Thoracic 4	Yes			None Visible
Thoracic 5	Yes			None Visible
Thoracic 6	Yes			None Visible
Thoracic 7	Yes			None Visible
Thoracic 8	Yes			None Visible
Thoracic 9	Yes			None Visible
Thoracic 10	Yes			None Visible
Thoracic 11	Yes			None Visible
Thoracic 12	Yes			None Visible
Lumbar 1	Yes			No
Lumbar 2	Yes			No
Lumbar 3	Yes			No
Lumbar 4	Yes			No
Lumbar 5	Yes			Yes
Lumbar 6	Yes			No
Lumbar 7	Yes			No
Sacrum	3 bodies Yes			No
Caudal 1	Yes			No
Caudal 2	Yes			No
Caudal 3	Yes			No

Caudal 4	Yes			No
Caudal 5	Yes			No
Caudal 6	Yes			No
Caudal 7	Yes			No
Caudal 8	Yes			No
Caudal 9	Yes			No
Caudal 10	Yes			No
Caudal 11	Yes			No
Caudal 12	Yes			No
Caudal 13	Yes			No
Caudal 14	Yes			No
Caudal 15	Yes			No
Caudal 16	Yes			No
Caudal 17	Yes			No
Caudal 18	Yes			No
Caudal 18	Yes			No
Caudal 19	Yes			No
Caudal 20	Yes			No
Caudal 21	Yes			No
Caudal 22	Yes			No
Caudal 23	Yes			No
Caudal 24	N/A			
Caudal 25	N/A			

Sternum Body	4 Yes			
Manubrium	Yes			
Xiphoid process	Yes			
	Head end	Shaft	Sternal end	
Left ribs	12		9	
Right ribs	12		12	
?left/right	0	11		

POST-CRANIAL

	Present	Absent	Fragmentary	Pathology
Left scapula	Yes			No
Right scapula	Yes			Yes
Left scap.glen.	Yes			No
Right scap.glen.	Yes			No
Left clavicle	Yes			No
Right clavicle	Yes			Yes
Left clavicle M	Yes			No
Left clavicle D	Yes			No
Right clavicle M	Yes			No
Right clavicle D	Yes			No
Left humerus P	Yes			No
Left humerus D	Yes			No
Right humerus P	Yes			No

Right humerus D	Yes			No
Left radius P	Yes			No
Left radius D	Yes			No
Right radius P	Yes			No
Right radius D	Yes			No
Left ulna P	Yes			No
Left ulna D	Yes			No
Baculum	Yes			No
Right ulna P	Yes			No
Left ulna D	Yes			No
Left innom	Yes			No
Right innom	Yes			No
Left acetabulum	Yes			No
Right acetabulum	Yes			No
Left pub.symph.	Yes			No
Right pub.symph.	Yes			No
Left ischial tub.	Yes			No
Right ischial tub .	Yes			No
Left patella	Yes			No
Right patella	Yes			No
Left femur P	Yes			Possible extra muscle attachment
Left femur D	Yes			No

Right femur P	Yes			No
Right femur D	Yes			No
Left tibia P	Yes			No
Left tibia D	Yes			No
Right tibia P	Yes			No
Right tibia D	Yes			No
Left fibula P	Yes			No
Left fibula D	Yes			No
Right fibula P	Yes			No
Left fibula D	Yes			No

HAND left	Present	Absent	Fragmentary	Pathology
Scaphoid	Yes			None Visible
Lunate	Yes			None Visible
Triquetral	Yes			None Visible
Pisiform	Yes			None Visible
Trapezium	Yes			None Visible
Trapezoid	Yes			None Visible
Capitate	Yes			None Visible
Hamate	Yes			No
Metacarpal 1	Yes			No
Metacarpal 2	Yes			No
Metacarpal 3	Yes			No

Metacarpal 4	Yes			No
Metacarpal 5	Yes			No
Prox. phals (No.)	5 Yes			

Mid phals (No.)	5 Yes			
Distal phals (No.)	5 Yes			
Nails attached?	5 Yes			
HAND right	Present	Absent	Fragmentary	Pathology
Scaphoid		Yes		N/A
Lunate		Yes		N/A
Triquetral		Yes		N/A
Pisiform		Yes		N/A
Trapezium		Yes		N/A
Trapezoid		Yes		N/A
Capitate		Yes		N/A
Hamate		Yes		N/A
Metacarpal 1	Yes			No
Metacarpal 2	Yes			No
Metacarpal 3	Yes			No
Metacarpal 4	Yes			No
Metacarpal 5	Yes			No

Prox. phals (No.)		Yes		
Mid phals (No.)		Yes		
Distal phals (No.)		Yes		
Nails attached?		Yes		
Sesamoid bones?		Yes		

FOOT left	Present	Absent	Fragmentary	Present
Talus	Yes			Possible pathology
Calcaneus	Yes			Yes
Navicular	Yes			No
Cuboid	Yes			No
Medial cuneiform	Yes			No
Internal cun.	Yes			No
Lateral cun.	Yes			No
Metatarsal 1	Yes			No
Metatarsal 2	Yes			No
Metatarsal 3	Yes			No
Metatarsal 4	Yes			No
Metatarsal 5	Yes			No
Prox phals (No.)	5 Yes			N/A
Prox. phals (No.)	5 Yes			N/A

Mid phals (No.)	5 Yes			
Distal phals (No.)	5 Yes			
Nails attached?	5 Yes			
FOOT right	Present	Absent	Fragmentary	Pathology
Talus		Yes		N/A
Calcaneus		Yes		N/A
Navicular		Yes		N/A
Cuboid		Yes		N/A
Medial cuneiform		Yes		N/A
Internal cun.		Yes		N/A
Lateral cun.		Yes		N/A
Metatarsal 1		Yes		N/A
Metatarsal 2		Yes		N/A
Metatarsal 3		Yes		N/A
Metatarsal 4		Yes		N/A
Metatarsal 5		Yes		N/A
Prox phals (No.)		Yes		N/A
Prox. phals (No.)		Yes		
Mid phals (No.)		Yes		
Distal phals (No.)		Yes		

Nails Attached?		Yes		
Sesamoid bones?		Yes		
Cranial Measurements (mm)- Brothwell, 1981	Left	Right		
Basion-Prosthion length	39.37mm			
Orbital Breadth	17.39mm			
Orbital Thickness	0.21mm			
Mandibular length	66.75mm			

Skeletal Recording Form MICK

Summary Sheet

Captive Location: Indianapolis Zoo
Book Number:1733
DMNS ID:19869
CUA-1001
DZTM:7986

Skeleton Number: Stud

Date: February 14th, 2024
Autumn Lucas, Julie Thomas

Recorded By:

Age/Class: 22 Adult
Sex: Male

Preservation: Good

Necropsied by a Vet, and kept in storage for 20 years. Soft tissue still connects cervical vertebrae C3-C6 T1-T3 T4-T7 T8-T9 L1-LT L4-L5

Pins holding together Left Tibia and Fibula

Left proximal carpals are still articulated

Left distal carpals are still articulated

Left metacarpals are still articulated

Right proximal carpals are still articulated

Right distal carpals are still articulated

Right Metacarpals are still articulated

Sternal bodies and xiphoid process connected with tissue

Manubrium connected

Sacrum and right innominate connected

3D Scans:

3D prints:

Summary of Pathological Conditions:

Skull	Present	Absent	Fragmentary	Pathology
Frontal	Skull cap detached			Possible
Occipital	Skull Cap detached	Some		No
Sphenoid	Yes			No
Ethmoid	Yes			No
Vomer	Yes			No
Hyoid	Yes			No
Left mandible	Yes			
Right mandible	Yes			
Left maxilla	Yes			Possible
Right maxilla	Yes			Possible

Left parietal	Skull cap detached			No
Right parietal	Skull cap detached			No
Left temporal	Yes			No
Right temporal	Yes			No
Left nasal	Yes			No
Right nasal	Yes			No
Left zygomatic	Yes			No
Right zygomatic	Yes			No
Left lacrimal	Yes			Possible
Right lacrimal	Yes			Possible
Left palate	Yes			No
Right palate	Yes			No
Left inf. nas.con	Yes			No
Right inf.nas.con	Yes			No
Malleus I/r	Yes			No
Incus I/r	Yes			No

Stapes I/r	Yes			No
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PTooth	Pres.	Absent	Frag.	DTooth	Pres.	Absent	Frag.
LEFT MAND				LEFT MAND			
I ¹				I ¹			
I ²				I ²			
C				C			
PM ¹				PM ¹			
PM ²				PM ²			
PM ³				PM ³			
M ¹				M ¹			
M ²				M ²			
M ³				M ³			
LEFT MAX				LEFT MAX			
I ¹				I ¹			
I ²		No		I ²			
C				C			
PM ¹				PM ¹			
PM ²				PM ²			
PM ³				PM ³			
M ¹				M ¹			
M ²				M ²			

M³				M³			
RIGHT MAND				RIGHT MAND			
I¹				I¹			
I²				I²			
C				C			
PM¹				PM¹			
PM²				PM²			
PM³				PM³			
M¹				M¹			
M²				M²			
M³				M³			
RIGHT MAX				RIGHT MAX			
I¹				I¹			
I²				I²			
C				C			
PM¹				PM¹			
PM²				PM²			
PM³				PM³			
M¹				M¹			
M²				M²			
M³				M³			

TEETH

	Present	Absent	Fragmentary	Pathology
Cervical 1	Yes			No
Cervical 2	Yes			No
Cervical 3	Yes			None visible
Cervical 4	Yes			None visible
Cervical 5	Yes			None visible
Cervical 6	Yes			Yes
Cervical 7	Yes			Yes
Thoracic 1	Yes			Yes
Thoracic 2	Yes			Not visible
Thoracic 3	Yes			Not Visible
Thoracic 4	Yes			Yes
Thoracic 5	Yes			No
Thoracic 6	Yes			None Visible
Thoracic 7	Yes			Yes
Thoracic 8	Yes			Yes
Thoracic 9	Yes			No
Thoracic 10	Yes			No
Thoracic 11	Yes			Yes
Thoracic 12	Yes			No
Lumbar 1	Yes			No
Lumbar 2	Yes			None Visible

Lumbar 3	Yes			None Visible
Lumbar 4	Yes			Yes
Lumbar 5	Yes			Yes
Lumbar 6	Yes			Yes
Lumbar 7	Yes			Yes
Sacrum	3 bodies Yes			Yes
Caudal 1	Yes			Yes
Caudal 2	Yes			Yes
Caudal 3	Yes			Yes
Caudal 4	Yes			Yes
Caudal 5	Yes			Yes
Caudal 6	Yes			Yes
Caudal 7	Yes			Yes
Caudal 8	Yes			Yes
Caudal 9	Yes			Yes
Caudal 10	Yes			Yes
Caudal 11	Yes			Yes
Caudal 12	Yes			Yes
Caudal 13	Yes			Yes
Caudal 14	Yes			Yes
Caudal 15	Yes			Yes
Caudal 16	Yes			Yes

Caudal 17	Yes			Yes
Caudal 18	Yes			Yes
Caudal 18	Yes			Yes
Caudal 19	Yes			Yes
Caudal 20	N/A			N/A
Caudal 21	N/A			N/A
Caudal 22	N/A			N/A
Caudal 23	N/A			N/A
Caudal 24	N/A			N/A
Caudal 25	N/A			N/A
Sternum Body	4 Yes			Yes
Manubrium	Yes			Yes
Xiphoid process	Yes			Yes
	Head end	Shaft	Sternal end	
Left ribs	12		9	
Right ribs	12		12	
?left/right	26		20	

POST-CRANIAL

	Present	Absent	Fragmentary	Pathology
Left scapula	Yes			Yes
Right scapula	Yes			Yes
Left scap.glen.	Yes			Yes

Right scap.glen.	Yes			No
Left clavicle	Yes			Yes
Right clavicle	Yes			Yes
Left clavicle M	Yes			Yes
Left clavicle D	Yes			Yes
Right clavicle M	Yes			Yes
Right clavicle D	Yes			Yes
Left humerus P	Yes			Yes
Left humerus D	Yes			Yes
Right humerus P	Yes			Yes
Right humerus D	Yes			Yes
Left radius P	Yes			Yes
Left radius D	Yes			Yes
Right radius P	Yes			Yes
Right radius D	Yes			Yes
Left ulna P	Yes			Yes
Left ulna D	Yes			Yes
Baculum		Yes		N/A
Right ulna P	Yes			Yes
Left ulna D	Yes			Yes
Left innom	Yes			Yes
Right innom	Yes			Yes
Left acetabulum	Yes			Yes

Right acetabulum	Yes			Yes
Left pub.symph.	Yes			Yes
Right pub.symph.	Yes			Yes
Left ischial tub.	Yes			Yes
Right ischial tub .	Yes			Yes
Left patella	Yes			Yes
Right patella	Yes			Yes
Left femur P	Yes			Yes
Left femur D	Yes			Yes
Right femur P	Yes			Yes
Right femur D	Yes			Yes
Left tibia P	Yes Pinned			Yes
Left tibia D	Yes Pinned			Yes
Right tibia P	Yes			Yes
Right tibia D	Yes			Yes
Left fibula P	Yes Pinned			Yes
Left fibula D	Yes Pinned			Yes
Right fibula P	Yes			Yes
Left fibula D	Yes			Yes

HAND left	Present	Absent	Fragmentary	Pathology
Scaphoid	Yes			Yes

Lunate	Yes			Yes
Triquetral	Yes			Yes
Pisiform	Yes			Yes
Trapezium	Yes			Yes
Trapezoid	Yes			Yes
Capitate	Yes			Yes
Hamate	Yes			None Visible
Metacarpal 1	Yes			None Visible
Metacarpal 2	Yes			None Visible
Metacarpal 3	Yes			None Visible
Metacarpal 4	Yes			None Visible
Metacarpal 5	Yes			None Visible
Prox. phals (No.)	5 Yes			

Mid phals (No.)	5 Yes			
Distal phals (No.)	5 Yes			
Nails attached?	5 Yes			
HAND right	Present	Absent	Fragmentary	Pathology
Scaphoid	Yes			Yes
Lunate	Yes			Yes
Triquetral	Yes			Yes

Pisiform	Yes			Yes
Trapezium	Yes			Yes
Trapezoid	Yes			Yes
Capitate	Yes			Yes
Hamate	Yes			Yes
Metacarpal 1	Yes			No
Metacarpal 2	Yes			No
Metacarpal 3	Yes			No
Metacarpal 4	Yes			No
Metacarpal 5	Yes			No
Prox. phals (No.)	Yes 5			
Mid phals (No.)	Yes 5			
Distal phals (No.)	Yes 5			
Nails attached?	Yes			
Sesamoid bones?	Yes			

FOOT left	Present	Absent	Fragmentary	Pathology
Talus	Yes			Yes
Calcaneus	Yes			Yes
Navicular	Yes			Yes
Cuboid	Yes			Yes

Medial cuneiform	Yes			
Internal cun.	Yes			
Lateral cun.	Yes			
Metatarsal 1	Yes			
Metatarsal 2	Yes			
Metatarsal 3	Yes			
Metatarsal 4	Yes			
Metatarsal 5	Yes			
Prox phals (No.)	5 Yes			
Prox. phals (No.)	5 Yes			

Mid phals (No.)	5 Yes			
Distal phals (No.)	5 Yes			
Nails attached?	5 Yes			
FOOT right	Present	Absent	Fragmentary	Pathology
Talus	Yes			
Calcaneus	Yes			
Navicular	Yes			
Cuboid	Yes			
Medial cuneiform	Yes			

Internal cun.	Yes			
Lateral cun.	Yes			
Metatarsal 1	Yes			
Metatarsal 2	Yes			
Metatarsal 3	Yes			
Metatarsal 4	Yes			
Metatarsal 5	Yes			
Prox phals (No.)	Yes			
Prox. phals (No.)	Yes			
Mid phals (No.)	Yes			
Distal phals (No.)	Yes			
Nails Attached?	No			
Sesamoid bones?	Yes			
Cranial Measurements (mm)- Brothwell, 1981	Left	Right		
Basion-Prosthion length	39.17mm			
Orbital Breadth	18.41mm			
Orbital Thickness	4.02mm			
Mandibular length	59.01mm			

Skeletal Recording Form SABRINA

Summary Sheet

Captive Location: Indianapolis Zoo
Stud Book Number:607
DMNS ID:19856
CUA-1000
DZTM: 7987

Skeleton Number:

Date: February 6th, 2024
Autumn Lucas

Recorded By:

Age/Class: 32, Adult
Sex: Female

Preservation: Good
Necropsied by a Vet, kept in storage for 20 years. Soft tissue still connects cervical vertebrae C2-C6, T1-T11, T13-T15,L6-L7, L8-L10
Left carpals are still articulated,
Left metacarpals are still articulated
Sternal bodies and xiphoid process connected with tissue
3D Scans:

Summary of Pathological Conditions:

Skull	Present	Absent	Fragmentary
Frontal	Skull cap detached		
Occipital	Skull Cap detached	Some	
Sphenoid	Yes		
Ethmoid	Yes		
Vomer	Yes		
Hyoid	Yes		
Left mandible	Yes		
Right mandible	Yes		

Left maxilla	Yes		
Right maxilla	Yes		
Left parietal	Skull cap detached		
Right parietal	Skull cap detached		
Left temporal	Yes		
Right temporal	Yes		
Left nasal	Yes		
Right nasal	Yes		
Left zygomatic	Yes		
Right zygomatic	Yes		
Left lacrimal	Yes		
Right lacrimal	Yes		
Left palate	Yes		
Right palate	Yes		
Left inf. nas.con	Yes		
Right inf.nas.con	Yes		

Malleus I/r	Yes		
Incus I/r	Yes		
Stapes I/r	Yes		

3D prints: TEETH

PTooth	Pres.	Absent	Frag.	DTooth	Pres.	Absent	Frag.
LEFT MAND				LEFT MAND			
I¹				I¹			
I²				I²			
C				C			
PM¹				PM¹			
PM²				PM²			
PM³				PM³			
M¹				M¹			
M²				M²			
M³				M³			
LEFT MAX				LEFT MAX			
I¹				I¹			
I²		No		I²			
C				C			

PM ¹				PM ¹			
PM ²				PM ²			
PM ³				PM ³			
M ¹				M ¹			
M ²				M ²			
M ³				M ³			
RIGH T MAN D				RIGHT MAND			
I ¹				I ¹			
I ²				I ²			
C				C			
PM ¹				PM ¹			
PM ²				PM ²			
PM ³				PM ³			
M ¹				M ¹			
M ²				M ²			
M ³				M ³			
RIGH T MAX				RIGHT MAX			
I ¹				I ¹			
I ²				I ²			
C				C			
PM ¹				PM ¹			

PM²				PM²			
PM³				PM³			
M¹				M¹			
M²				M²			
M³				M³			

	Present	Absent	Fragmentary	Pathology
Cervical 1	Yes			Yes
Cervical 2	Yes			Yes
Cervical 3	Yes			Yes
Cervical 4	Yes			Yes
Cervical 5	Yes			Yes
Cervical 6	Yes			Yes
Cervical 7	Yes			Yes
Thoracic 1	Yes			Yes
Thoracic 2	Yes			None Visible
Thoracic 3	Yes			None Visible
Thoracic 4	Yes			None Visible
Thoracic 5	Yes			None Visible
Thoracic 6	Yes			None Visible
Thoracic 7	Yes			None Visible
Thoracic 8	Yes			
Thoracic 9	Yes			

Thoracic 10	Yes			
Thoracic 11	Yes			
Thoracic 12	Yes			
Lumbar 1	Yes			
Lumbar 2	Yes			
Lumbar 3	Yes			
Lumbar 4	Yes			
Lumbar 5	Yes			No
Lumbar 6	Yes			Yes Over $\frac{2}{3}$ caudal surface
Lumbar 7	Yes			Yes Over $\frac{2}{3}$ caudal surface
Sacrum	3 bodies Yes			Yes
Caudal 1	Yes			$\frac{1}{3}$ - $\frac{2}{3}$ 1-7
Caudal 2	Yes			
Caudal 3	Yes			
Caudal 4	Yes			
Caudal 5	Yes			
Caudal 6	Yes			
Caudal 7	Yes			Non specific infection
Caudal 8	Yes			
Caudal 9	Yes			
Caudal 10	Yes			

Caudal 11	Yes			
Caudal 12	Yes			
Caudal 13	Yes			
Caudal 14	Yes			
Caudal 15	Yes			
Caudal 16	Yes			
Caudal 17	N/A			
Caudal 18	N/A			
Caudal 18	N/A			
Caudal 19	N/A			
Caudal 20	N/A			
Caudal 21	N/A			
Caudal 22	N/A			
Caudal 23	N/A			
Caudal 24	N/A			
Caudal 25	N/A			
Sternum Body	4 Yes			Starting to fuse
Manubrium	Yes			No obvious signs
Xiphoid process	Yes			No
	Head end	Shaft	Sternal end	
Left ribs	12		9	
Right ribs	11		12	

?left/right	0	10		
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	Present	Absent	Fragmentary	
Left scapula	Yes			2/3
Right scapula	Yes			2/3
Left scap.glen.	Yes			
Right scap.glen.	Yes			
Left clavicle	Yes			
Right clavicle	Yes			
Left clavicle M	Yes			
Left clavicle D	Yes			
Right clavicle M	Yes			
Right clavicle D	Yes			
Left humerus P	Yes			Possible eburnation
Left humerus D	Yes			Possible eburnation -2/3
Right humerus P	Yes			
Right humerus D	Yes			
Left radius P	Yes			
Left radius D	Yes			
Right radius P	Yes			
Right radius D	Yes			
Left ulna P	Yes			

Left ulna D	Yes			
Baculum				
Right ulna P	Yes			
Left ulna D	Yes			
Left innom	Yes			
Right innom	Yes			
Left acetabulum	Yes			
Right acetabulum	Yes			
Left pub.symph.	Yes			
Right pub.symph.	Yes			
Left ischial tub.	Yes			
Right ischial tub .	Yes			
Left patella	Yes			
Right patella	Yes			
Left femur P	Yes			
Left femur D	Yes			
Right femur P	Yes			
Right femur D	Yes			
Left tibia P	Yes			$\frac{1}{2}$ - $\frac{2}{3}$
Left tibia D	Yes			
Right tibia P	Yes			
Right tibia D	Yes			
Left fibula P	Yes			over $\frac{2}{3}$

Left fibula D	Yes			less than 1/3
Right fibula P	Yes			
Left fibula D	Yes			

POST-CRANIAL

HAND left	Present	Absent	Fragmentary
Scaphoid	Yes		
Lunate	Yes		
Triquetral	Yes		
Pisiform	Yes		
Trapezium	Yes		
Trapezoid	Yes		
Capitate	Yes		
Hamate	Yes		
Metacarpal 1	Yes		
Metacarpal 2	Yes		
Metacarpal 3	Yes		
Metacarpal 4	Yes		
Metacarpal 5	Yes		
Prox. phals (No.)	5 Yes		

Mid phals (No.)	5 Yes		
Distal phals (No.)	5		

	Yes		
Nails attached?	5 Yes		
HAND right	Present	Absent	Fragmentary
Scaphoid		Yes	
Lunate		Yes	
Triquetral		Yes	
Pisiform		Yes	
Trapezium		Yes	
Trapezoid		Yes	
Capitate		Yes	
Hamate		Yes	
Metacarpal 1	Yes		
Metacarpal 2	Yes		
Metacarpal 3	Yes		
Metacarpal 4	Yes		
Metacarpal 5	Yes		
Prox. phals (No.)		Yes	
Mid phals (No.)		Yes	
Distal phals (No.)		Yes	
Nails attached?		Yes	
Sesamoid bones?		Yes	

FOOT left	Present	Absent	Fragmentary
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Talus	Yes		
Calcaneus	Yes		
Navicular	Yes		
Cuboid	Yes		
Medial cuneiform	Yes		
Internal cun.	Yes		
Lateral cun.	Yes		
Metatarsal 1	Yes		
Metatarsal 2	Yes		
Metatarsal 3	Yes		
Metatarsal 4	Yes		
Metatarsal 5	Yes		
Prox phals (No.)	5 Yes		
Prox. phals (No.)	5 Yes		

Mid phals (No.)	5 Yes		
Distal phals (No.)	5 Yes		
Nails attached?	5 Yes		
FOOT right	Present	Absent	Fragmentary
Talus		Yes	
Calcaneus		Yes	

Navicular		Yes	
Cuboid		Yes	
Medial cuneiform		Yes	
Internal cun.		Yes	
Lateral cun.		Yes	
Metatarsal 1		Yes	
Metatarsal 2		Yes	
Metatarsal 3		Yes	
Metatarsal 4		Yes	
Metatarsal 5		Yes	
Prox phals (No.)		Yes	
Prox. phals (No.)		Yes	
Mid phals (No.)		Yes	
Distal phals (No.)		Yes	
Nails Attached?		Yes	
Sesamoid bones?		Yes	
Cranial Measurements (mm)- Brothwell, 1981	Left	Right	
Basion-Prosthion length	36.13mm		
Orbital Breadth	17.17mm		
Orbital Thickness	3.26mm		

Mandibular length	55.85mm		
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Skeletal Recording Form MAMU

Summary Sheet

Captive Location: Pueblo Zoo
Book Number:309
DMNS ID:19864
CUA-1010
DZTM: 7997

Skeleton Number: Stud

Date: February 6th, 2024
Autumn Lucas

Recorded By:

Age/Class: 37, Adult

Sex: Female

Preservation: Good

Necropsied by a Vet, kept in storage for 20 years. Soft tissue still connects cervical vertebrae C2-C6, T1-T3, T6-T8, T11-12

Left carpals are still articulated,

Left metacarpals are still articulated

Sternal bodies and xiphoid process connected with tissue

Photographs: 1. Right p2 Lost Premortem

Left p2 Lost Premortem

Left m2 Lost Premortem

Left m3 Lost Premortem

Both upper i1s lost Premortem

Toothcomb lost Premortem

No abscesses

3D Scans:

3D prints:

Summary of Pathological Conditions:

TEETH

Skull	Present	Absent	Fragmentary	Pathology
Frontal	Skull cap detached			No

Occipital	Skull Cap detached	Some		No
Sphenoid	Yes			No
Ethmoid	Yes			No
Vomer	Yes			No
Hyoid	Yes			No
Left mandible	Yes			Yes
Right mandible	Yes			Yes
Left maxilla	Yes			No
Right maxilla	Yes			No
Left parietal	Skull cap detached			No
Right parietal	Skull cap detached			No
Left temporal	Yes			No
Right temporal	Yes			No
Left nasal	Yes			No
Right nasal	Yes			No
Left zygomatic	Yes			No
Right zygomatic	Yes			No
Left lacrimal	Yes			No
Right lacrimal	Yes			No

Left palate	Yes			No
Right palate	Yes			No
Left inf. nas.con	Yes			No
Right inf.nas.con	Yes			No
Malleus I/r	Yes			No
Incus I/r	Yes			No
Stapes I/r	Yes			No

PTooth	Pres.	Absent	Frag.	DTooth	Pres.	Absent	Frag.
LEFT MAND				LEFT MAND			
I¹				I¹			
I²				I²			
C				C			
PM¹				PM¹			
PM²				PM²			
PM³				PM³			
M¹				M¹			
M²				M²			

M ³				M ³			
LEFT MAX				LEFT MAX			
I ¹				I ¹			
I ²		No		I ²			
C				C			
PM ¹				PM ¹			
PM ²				PM ²			
PM ³				PM ³			
M ¹				M ¹			
M ²				M ²			
M ³				M ³			
RIGHT MAND				RIGHT MAND			
I ¹				I ¹			
I ²				I ²			
C				C			
PM ¹				PM ¹			
PM ²				PM ²			
PM ³				PM ³			
M ¹				M ¹			
M ²				M ²			
M ³				M ³			
RIGHT MAX				RIGHT MAX			

I ¹				I ¹			
I ²				I ²			
C				C			
PM ¹				PM ¹			
PM ²				PM ²			
PM ³				PM ³			
M ¹				M ¹			
M ²				M ²			
M ³				M ³			

	Present	Absent	Fragmentary	Pathology
Cervical 1	Yes			None Visible
Cervical 2	Yes			None Visible
Cervical 3	Yes			None Visible
Cervical 4	Yes			None Visible
Cervical 5	Yes			None Visible
Cervical 6	Yes			Yes
Cervical 7	Yes			None Visible
Thoracic 1	Yes			None Visible
Thoracic 2	Yes			No
Thoracic 3	Yes			Yes
Thoracic 4	Yes			Yes
Thoracic 5	Yes			Yes

Thoracic 6	Yes			Yes
Thoracic 7	Yes			Yes
Thoracic 8	Yes			Yes
Thoracic 9	Yes			Yes
Thoracic 10	Yes			Yes
Thoracic 11	Yes			Yes
Thoracic 12	Yes			None Visible
Lumbar 1	Yes			Yes
Lumbar 2	Yes			None Visible
Lumbar 3	Yes			No
Lumbar 4	Yes			No
Lumbar 5	Yes			None Visible
Lumbar 6	Yes			No
Lumbar 7	Yes			No
Sacrum	3 bodies Yes			Yes
Caudal 1	Yes			Yes
Caudal 2	Yes			Yes
Caudal 3	Yes			Yes
Caudal 4	Yes			Yes
Caudal 5	Yes			None Visible
Caudal 6	Yes			No
Caudal 7	Yes			No

Caudal 8	Yes			No
Caudal 9	Yes			No
Caudal 10	Yes			No
Caudal 11	Yes			No
Caudal 12	Yes			No
Caudal 13	Yes			No
Caudal 14	Yes			None Visible
Caudal 15	Yes			None Visible
Caudal 16	Yes			None Visible
Caudal 17	Yes			None Visible
Caudal 18	Yes			None Visible
Caudal 18	Yes			None Visible
Caudal 19	Yes			None Visible
Caudal 20	Yes			None Visible
Caudal 21	Yes			None Visible
Caudal 22	Yes			None Visible
Caudal 23	Yes			None Visible
Caudal 24	N/A			N/A
Caudal 25	N/A			N/A
Sternum Body	4 Yes			Yes
Manubrium	Yes			No
Xiphoid process	Yes			No

	Head end	Shaft	Sternal end	
Left ribs	12			
Right ribs	12		12	
?left/right	0	11		

	Present	Absent	Fragmentary	Pathology
Left scapula	Yes			No
Right scapula	Yes			Yes
Left scap.glen.	Yes			Yes
Right scap.glen.	Yes			Yes
Left clavicle	Yes			No
Right clavicle	Yes			No
Left clavicle M	Yes			No
Left clavicle D	Yes			No
Right clavicle M	Yes			No
Right clavicle D	Yes			No
Left humerus P	Yes			Yes
Left humerus D	Yes			Yes
Right humerus P	Yes			Yes
Right humerus D	Yes			Yes
Left radius P	Yes			No
Left radius D	Yes			No
Right radius P	Yes			Yes

Right radius D	Yes			No
Left ulna P	Yes			Yes
Left ulna D	Yes			Yes
Baculum	N/A			N/A
Right ulna P	Yes			Yes
Left ulna D	Yes			Yes
Left innom	Yes			No
Right innom	Yes			No
Left acetabulum	Yes			Yes
Right acetabulum	Yes			Yes
Left pub.symph.	Yes			No
Right pub.symph.	Yes			No
Left ischial tub.	Yes			Yes
Right ischial tub .	Yes			Yes
Left patella	Yes			Yes
Right patella	Yes			Yes
Left femur P				No
Left femur D				No
Right femur P	Yes		Yes Complete fracture of the shaft Callus Primary callus formation is woven	
Right femur D	Yes		Yes	

Left tibia P	Yes			Yes
Left tibia D	Yes			Yes
Right tibia P	Yes			Yes
Right tibia D	Yes			Yes
Left fibula P	Yes			Yes
Left fibula D	Yes			Yes
Right fibula P	Yes			Yes
Left fibula D	Yes			Yes

POST-CRANIAL

HAND left	Present	Absent	Fragmentary	Pathology
Scaphoid	Yes			No
Lunate	Yes			No
Triquetral	Yes			No
Pisiform	Yes			No
Trapezium	Yes			No
Trapezoid	Yes			No
Capitate	Yes			No
Hamate	Yes			Yes
Metacarpal 1	Yes			No
Metacarpal 2	Yes			No
Metacarpal 3	Yes			No
Metacarpal 4	Yes			No
Metacarpal 5	Yes			No

Prox. phals (No.)	5 Yes			
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Mid phals (No.)	5 Yes			No
Distal phals (No.)	5 Yes			No
Nails attached?	5 Yes			No
HAND right	Present	Absent	Fragmentary	Pathology
Scaphoid		Yes		N/A
Lunate		Yes		N/A
Triquetral		Yes		N/A
Pisiform		Yes		N/A
Trapezium		Yes		N/A
Trapezoid		Yes		N/A
Capitate		Yes		N/A
Hamate		Yes		N/A
Metacarpal 1		Yes		N/A
Metacarpal 2		Yes		N/A
Metacarpal 3		Yes		N/A
Metacarpal 4		Yes		N/A
Metacarpal 5		Yes		N/A
Prox. phals (No.)		Yes		N/A
Mid phals		Yes		N/A

(No.)				
Distal phals (No.)		Yes		N/A
Nails attached?		Yes		
Sesamoid bones?		Yes		

FOOT left	Present	Absent	Fragmentary	Pathology
Talus	Yes			Yes
Calcaneus	Yes			Yes
Navicular	Yes			Yes
Cuboid	Yes			Yes
Medial cuneiform	Yes			Yes
Internal cun.	Yes			Yes
Lateral cun.	Yes			Yes
Metatarsal 1	Yes			Yes
Metatarsal 2	Yes			Yes
Metatarsal 3	Yes			Yes
Metatarsal 4	Yes			Yes
Metatarsal 5	Yes			Yes
Prox phals (No.)	5 Yes			
Prox. phals (No.)	5 Yes			

Mid phals (No.)	5 Yes		
Distal phals (No.)	5 Yes		
Nails attached?	5 Yes		
FOOT right	Present	Absent	Fragmentary
Talus		Yes	
Calcaneus		Yes	
Navicular		Yes	
Cuboid		Yes	
Medial cuneiform		Yes	
Internal cun.		Yes	
Lateral cun.		Yes	
Metatarsal 1		Yes	
Metatarsal 2		Yes	
Metatarsal 3		Yes	
Metatarsal 4		Yes	
Metatarsal 5		Yes	
Prox phals (No.)		Yes	
Prox. phals (No.)		Yes	
Mid phals (No.)		Yes	
Distal phals (No.)		Yes	
Nails Attached?		Yes	
Sesamoid bones?		Yes	

Cranial Measurements (mm)- Brothwell, 1981	Left	Right	
Basion-Prosthion length	38.70mm		
Orbital Breadth	19.07mm		
Orbital Thickness	2.59mm		
Mandibular length	53.70mm		