

POSTCRANIAL METRICS OF TWO *SYLVILAGUS* SPECIES AND THEIR OCCURRENCE

AT KATHY'S ROCKSHELTER, NORTHERN CALIFORNIA

A Thesis

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by

Jennifer Lalenia Farrell

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Abstract  
of  
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Leporids were a commonly exploited food resource represented in pre-contact zooarchaeological assemblages across western North America. Identification of specimens to species from dated archaeological contexts can provide information used in paleoenvironment reconstruction, for establishing the biogeography of the species, and to reconstruct human behavior.

The first goal of this thesis aimed to develop identification measures to discriminate postcranial skeletal remains of *Sylvilagus bachmani* and *S. audubonii*, expanding upon previous methods of leporid identification. The present research found that *S. bachmani* and *S. audubonii* may be generally distinguished using metric data, although the sample size was less than optimal.

The second objective of this thesis is to use the resulting morphometrics to discriminate *S. audubonii* and *S. bachmani* to evaluate whether the relative abundance of the two taxa shift through time at CA-BUT-301 (Kathy's Rockshelter) in the northern Sierra Nevada foothills, California. The presented research found no statistical change in the relative frequencies of *S. audubonii* to *S. bachmani*, although the former does appear

in deposits dating to the Medieval Climatic Anomaly. The lack of observed change suggests foraging efficiency, rather than local environmental trends associated with climate change, may have resulted in an overall increase in *Sylvilagus* over time.

Future research should add to the metric data of modern specimens and apply the distinguishing metrics to other archaeological contexts to better understand the prehistoric distribution of the two species in California.

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## Chapter 1

### INTRODUCTION

Leporid faunal remains are a common resource represented in prehistoric archaeological assemblages across western North America. Although small in size compared to larger terrestrial faunas, rabbits and hares were often an important resource exploited by prehistoric populations for subsistence and utilitarian products (e.g., Anderson and Rosenthal 2015; Christenson 1990; Dixon 1905; Fisher 2012; Reinhard et al., 2006). Leporid remains from archaeological contexts can provide valuable information such as subsistence practices, shifting diets, mobility, and land use among human populations, while also providing critical data of past environments or ecosystems. In regard to the latter, if two leporid species have unique habitat requirements, temporal shifts in their relative abundance in archaeological assemblages may reflect changes in local environment (e.g., Fisher 2012; Szuter and Bayham 1989).

Paleoenvironment reconstruction of a region or area surrounding an archaeological site provides important data to build upon for addressing archaeological research questions and hypotheses. Understanding past environments in which humans lived can provide a broader understanding of the relationship between environmental and climatic variation, human behavior, and human influence and interactions within the landscape. A wide variety of available environmental proxy data has benefited California archaeological research due to the potential to reconstruct regional paleoenvironments in regional areas of human occupation from the Late Pleistocene through Holocene. Reconstructing

paleoenvironments provides a better understanding of past vegetation zones and climate conditions through time. These data are derived from pollen records, dendrochronology, fire-scar data, sedimentology, and other similar data sources that reflect environmental and climatic conditions of past landscapes (e.g., Stine 1998). While providing valuable paleoenvironmental information, it is often challenging to link such data to localized areas containing archaeological assemblages under investigation. In addition, both climatic and archaeological data are expressed in various chronological scales that are often difficult to correlate. Archaeologists may turn to archaeofaunal data as a proxy to fill in gaps and supplement the existing environmental record for areas where such data is not available or may not capture the chronological periods of interest. Integrating the use of both archaeofaunal and existing environmental proxy data will provide a better interpretation of the local environment and conditions in which humans interacted. Such endeavors typically require identification of archaeofaunal remains to the species level since many species inhabit a smaller geographic range, or illustrate a higher ecological fidelity, compared to their genus (Lyman 2017).

The present study will evaluate the relative abundances of leporid species temporally in an effort to gain a better understanding of the distribution of each species in relation to paleoenvironmental, archaeological, and ethnographic data. *Sylvilagus* species are closely tied to their specific habitat and often demonstrate a distinct parapatric behavior (Ramos 1999). In California, *S. bachmani* (brush rabbit) and *S. audubonii* (desert cottontail) have contrasting preferential habitats (closed versus semi-open environment, respectively) and a geographic distribution that does not overlap within certain areas of the

state, making them a habitat-diagnostic species (Chapman 1971, 1974; Ingles 1947). *S. audubonii* is typically associated with areas of open grasslands and woodlands and is affected by habitat changes due to climatic and biotic conditions or anthropogenic processes. In contrast, *S. bachmani* prefers the dense brush habitat of chaparral. Shifts in the relative abundance of the species in archaeological samples may reflect changes in the local environment, while simultaneously informing wildlife managers and conservation biologists on the historical ecology of the species (e.g., Butler and Delacorte 2004; Grayson 2001; Lyman 1991, 2004, 2006).

It is expected that *S. audubonii* would expand its distribution when periods of warm and dry climatic conditions (e.g., Medieval Climatic Anomaly) resulted in a more open vegetation structure, and retract when cooler and wetter conditions resulted in a denser shrub canopy and closed structure (e.g., Little Ice Age). Further, *S. audubonii* may be present during periods of cooler climatic trends if vegetation structure was not solely the result of climatic conditions but also a product documented anthropogenic land use practices such as small-scale burning (*sensu lato* Klimaszewski-Patterson and Mensing 2016).

Distinguishing leporid remains to species level from archaeological deposits is challenging due to fragmentation of skeletal elements, lack of adequate reference samples, and osteological morphometric and skeletal size similarities between species (Dalquest et al., 1989; Neusius and Flint 1985). In regions where the geographic range of multiple species overlap, researchers often identify specimens to a genus level only. Currently, available publications for leporid species identification rely on maxillae and dentary

elements and their morphological characteristics such as mandibular measurements, tooth morphology, and enamel patterns (Delquest et al., 1989; Neuisus and Flint 1985; Ramos 1999). Implementation of these methods have been successful but are limited to cranial features. Archaeofaunal assemblages often contain a variety of fragmented postcranial elements that could potentially be used to identify taxon to a species level. Therefore, a need to develop postcranial identification measures to discriminate between the two species could provide a better understanding of both human interactions with the environment and paleoenvironmental conditions. This thesis expands on previous methods of leporid identification by using a variety of postcranial skeletal elements. Reference samples were measured from zooarchaeological museum specimens of known species to establish a set of replicable diagnostic morphometrics to discriminate between of *S. audubonii* and *S. bachmani*. Application of this approach to both paleontological and archaeological faunal remains would provide another identification method that could be used in conjunction with previous criteria, would allow for a larger sample of fragmentary skeletal remains to be identified to species level, and could supplement and contribute to existing data used for a broader understanding of human ecology, environment, and paleoclimate data.

The second goal of this research is focused on the efficacy of the devised morphometric method for discriminating between *S. audubonii* and *S. bachmani* skeletal remains from an archaeological context. To test the species identification method, this thesis will evaluate whether changes in the relative abundance of the two taxa shift through time through an examination and analysis of the leporid archaeofaunal assemblage from

CA-BUT-301 (Kathy's Rockshelter) located in the Dry Creek Valley of the northern Sierra Nevada foothills, California.

CA-BUT-301 is within the range of two rabbit species that have differential habitat preferences. It is expected that an open environment would reflect an abundance of *S. audubonii*, and a closed environment would reflect an abundance of *S. bachmani*. The relative abundance of each species across time is expected to reflect changes in the local environment. Such changes in abundance can be compared with independent paleoenvironmental and climatic data to determine whether fluctuations are due to climatic or anthropogenic-driven biotic changes to the landscape.

Following this chapter, Chapter 2 provides the environmental, zoological, and archaeological and ethnographic background for the research area. The chapter includes a discussion of the environment, a review of the systematics and biogeography of *S. bachmani* and *S. audubonii*, the cultural history for the northwestern Sierra Mountain foothills, and the California Native American ethnographic background. Chapter 3 reviews existing methods used for taxonomic Leporid skeletal identification. In addition, the metric and quantitative method used in this study are described and applied to the leporid reference sample, and statistical results are presented and discussed. Chapter 4 provides the site background information and characterization of the assemblage of the archaeological test case Kathy's Rockshelter (CA-BUT-301), and the results of the applied zooarchaeological analysis are presented and discussed for CA-BUT-301. Lastly, conclusions and further research possibilities are contemplated.

## Chapter 2

### ENVIRONMENTAL AND ARCHAEOLOGICAL CONTEXT

The study area for the present research is within the northwestern foothills of the Sierra Nevada Mountains, California. Environmental proxy data for the region suggests that towards the end of the Late Holocene, the climate shifted between warm and dry to a cooler and wet period that influenced periodic altitudinal changes in vegetation structure from open to closed forest systems. Although a broader cultural history is provided for the northwestern Sierra Mountain foothills, this study aims to focus on the period during the Late Holocene, a period associated with climatic variability and shifting cultural occupation of the area.

#### **Environmental Context**

The following sections provide background information on the modern and paleoenvironment of the research area, and the biogeography of Leporidae in northern California.

#### *Modern Environment*

The current research area is within the edge of the northeastern region of the Sacramento Valley of the Great Valley geomorphic province and the foothills of the northwestern slopes of the Sierra Nevada geomorphic province (Norris and Webb 1990). The northwestern foothills are drained primarily by the Feather River and associated tributaries, along with several other smaller streams and creeks (e.g., Butte Creek, Little

Dry Creek) that feed directly into the valley. The topography is characterized by gradual slopes that rise eastward from the lowlands of the Sacramento Valley to elevations of 2,438 m asl atop ridges within the northern Sierra mountain range. As the elevation increases from west to east, the vegetation life zones transition from lowland California Prairie grasslands to blue oak (*Quercus douglasii*) woodland, chaparral, and gray pine (*Pinus sabiniana*) forest within the upland foothills (Davis et al., 2016; Hull 2007). The oak woodland is at an elevation from the valley floor to 460 m asl, consisting of sparse *Quercus* spp. and perennial grasses such as *Stipa*, *Poa* and *Aristida* spp. that have been encroached upon and dominated by invasive non-native species (e.g., *Bromus* spp.) (Koehler and Anderson 1993). Within the Sierra foothills and canyons at approximately 460 – 1070 m asl is a broad chaparral belt of chamise (*Adenstoma fasciculatum*), mountain mahogany (*Cercocarpus betuloides*), buckthorn (*Ceanothus* spp.), and manzanita (*Arctostaphylos* spp.) (Koehler and Anderson 1993). Rising above the foothills is the Sierra montane vegetation structure of *Pinus* spp.

The climate is typically described as Mediterranean with cool wet and mild winters and dry hot summers. Precipitation predominately falls between December and March, with variation in precipitation occurring during periodic El Nino and La Nina climate oscillations (Davis et al., 2016). The various climatic cycles in combination with slope, elevation, and latitude create a biotic community that supports a diverse array of floral and faunal resources. The structure of vegetation communities within the Sierra foothills has also been influenced by both past and modern human activities on the land. The current status of the biotic structure (e.g., vegetation, water flow, faunal distribution) has emerged

due to modern fire suppression practices, historic mining and logging activities, modern settlement and development, water diversion, agricultural and grazing activities, invasive non-native species, and global warming (Hull 2007; Millar 1996).

### *Paleoenvironment*

Diverse types of environmental proxy records for a region or localized area can provide information about past climatic fluctuations and be used to reconstruct past distribution of species, biodiversity, hydrology, and vegetation zones. A broad spectrum of environmental proxy data exists from archives such as pollen, insects, and isotopic data from lake sediments, tree ring data, mammal middens with associated macrofossil and microfossil pollen remains, faunal studies, and geomorphological studies.

Based on Great Basin pollen analysis and varved clay count data from Northern Europe and North America, a large-scale Holocene chronological climatic sequence was developed (Antevs 1955; Aschmann 1958). Although the sequence has been revised based on updated methods and varies regionally, the general schematic includes the Anathermal (approximately 10,000 to 7,000 years BP) characterized as post-glacial rising temperatures, Altithermal (approximately 7,000 to 4,000 years BP) defined as much warmer and dryer conditions than today, and Medithermal (approximately 4,000 BP to AD 1850s) with oscillations of cooler and wetter and warmer and dryer conditions.

In the Sierra Nevada and adjacent Sacramento Valley, climate oscillations of cooler and warmer episodes and instability has occurred at various degrees during the Last Glacial Maximum (LGM) of the late Pleistocene and throughout the Holocene. These changes have

been identified to millennial, century, decade, and annual scales. Climatic warming began to occur during the late Pleistocene to Holocene transition as glaciers retreated and vegetation structures began to change in the Sierra-Cascade mountain ranges from an open subalpine forest to a more closed pine and fir forest (Porinchu et al., 2003; West et al., 2007). However, Chironomid (midge-fly) and stratigraphic evidence provided by sediment cores from Greenstone Lake (central Sierra Nevada) illustrate a period of extreme cooling that occurred during the Younger Dryas (12,900 to 11,700 BP), temporarily reversing the vegetation structure (Porinchu et al., 2003). The vegetation in the uplands diversified and pine (*Pinus* sp.), cedar (*Cedrus* sp.), Douglas fir (*Pseudotsuga menziesii*), oaks (*Quercus* spp.), and tanoak (*Notholithocarpus densiflorus*) forest began to appear as temperatures warmed during the end of the Younger Dryas with the xerothermic climate of the early Holocene in the western Sierras (Millar and Woolfenden 2016; Porinchu et al., 2003). Although the warming trend continued into the middle Holocene (Altithermal, about 7,000 to 4,000 BP) in many regions, the environmental data (pollen, macrofossil) for the western Sierra both supports and contradicts this pattern suggesting interludes of cool and moist variability and both open (oaks) and closed (conifer) vegetation structures (Anderson 1990; Moratto et al., 1978; West et al., 2007). The Late Holocene (Medithermal, 4000 BP – AD 1850s) shifts to a cooler and moister climate with decade- to century-level intervals of drier and warmer temperatures with variations of increased precipitation eventually led to the development of modern vegetation zones (Millar and Woolfenden 2016).

Climatic variation of interest over the past two millennia include two episodes of prolonged drought and warmer conditions between A.D. 800 and 1350, referred to as the

Medieval Climatic Anomaly (MCA) (Jones et al., 1999; Stine 1998), followed by a period of cooler and wetter conditions known as the Little Ice Age (LIA) from AD 1400 to 1700. Paleoclimatic reconstructions (tree rings, deep sea core samples) suggest two intervals of extreme drought in the Sierra Nevada during AD 1020 to 1070 and AD 1250 to 1330 that were separated by periods of less severity (Graumlich 1993;; Kennett et al., 2007; Stine 1998). A dendrohydrological reconstruction (tree rings) for flows of the Sacramento River suggests severe droughts occurred around AD 950 and AD 1300 (Meko et al., 2001). Tree ring evidence from Giant Sequoia groves and Bristlecone pine suggest the Sierra Nevada experienced high fire frequency and intensity during the MCA (Swetnam 1996; Swetnam and Baisan 2003). The climatic variability of the MCA is considered potentially influenced by external climatic factors (e.g., volcanic ash, solar events) that had direct effects on both ecosystems (exploitable food and water) and the people that relied upon such habitats for subsistence (Graumlich 1993; Jones et al., 1999).

The LIA is considered the most recent and last period of wetter and cooler temperatures with the increase of snowfall and decrease in temperature resulting in the expansion of glaciers (Stine 1996). Due to lower temperatures, Swetnam (1993) suggest the LIA also witnessed a lower frequency of fires based on Giant Sequoia and bristlecone pine dendroclimatological data. The vegetation structure exhibited a downward slope shift of *Abies magnifica*, *Pinus* spp., incense cedar (*Calocedrus decurrens*), and *Quercus* spp. Forest, creating a more closed environment at lower elevations (Anderson 1990). In the Klamath Mountain region (north-northwest of this study), anomalies within pollen and charcoal proxy record trends are inconsistent with the expected fire cycle and vegetative

structure and illustrate both a closed and open forest based on the presence of both shade tolerant (e.g., *Pseudotsuga*) and shade intolerant (*Quercus*) pollen (Crawford et al., 2015). Crawford and colleagues (2015) suggest the increase in *Quercus* pollen during the LIA may be attributed to both increases in human populations and anthropogenic burning as an intensification strategy to maintain open oak woodlands for acorn-based economies. A similar study conducted by Klimaszewski-Patterson and Mensing (2016) in central and southern Sierra Nevada foothills observed a consistent presence of shade-intolerant/fire-adapted taxa during the LIA and suggest an open canopy was maintained during this cooler period by local Native Americans implementing frequent low-intensity fires.

In view of past environmental variations throughout the Late Holocene as observed in regional proxy data, it is reasonable to expect that changes in local habitat vegetation structure would affect the distribution of various animal resources that rely upon specific ecological conditions, which in turn affects what resources would have been available to human foragers at a given location.

### **Biogeography of Leporidae in Northern California**

Brush and desert cottontail rabbits are two species of rabbit native to California that have varying habitats and ecological requirements. Both species have been established in California since the Pleistocene; in the Sacramento Valley, brush rabbits are found largely on the perimeter of the valley in the foothills while desert cottontail rabbits are restricted to the valley floor (Figure 1). Their prehistoric distribution may have differed due to habitat shifts associated with climatic variability and human modifications to the landscape.

*Brush Rabbit (Sylvilagus bachmani)*

*Sylvilagus bachmani* (*Conejo matorralero* in Spanish) is one of the smallest cottontails, generally weighing up to 1000 g, with small ears, short legs and small feet, and a short-tucked tail. *S. bachmani* has a modern geographic range that extends along the Pacific coast from the Columbia River near the Oregon-Washington border south to the southern tip of Baja California, and from the Pacific Ocean to the western Sierra Nevada Mountain range to the east (Chapman 1974; Chapman and Ceballos 1990; Hall 1951; Ingles 1947). In California, *S. bachmani* range does not extend into the lower elevations of the Great Central Valley or east of the Cascade-Sierra mountain range (Hall 1951; Ingles 1947). Fossil specimens of *S. bachmani* are documented in Pleistocene deposits from Pacheco (near the San Francisco Bay Area) and Rancho La Brea (Los Angeles area) in California (Chapman 1974, Fox et al., 2019; Ramos 1998, Smith et al., 2018). Its elevational range is from sea level to approximately 2070 m asl (Chapman 1974).

An exception to the species range occurs with a very small population of riparian brush rabbit (*S. bachmani riparius*: a subspecies of brush rabbit) that occupies a range contrary to other brush rabbits, and are endemic to the dense riparian habitat along the lower portions of the Old, Stanislaus, Tuolumne, and San Joaquin Rivers (south Delta) along the valley floor in southern San Joaquin County and northern Stanislaus County (Williams and Basey 1986; US Fish and Wildlife Service 2020). The population was first documented by Orr (1935, 1940) as a distinct subspecies that inhabited the lower San Joaquin River and its historic geographic range is currently unknown. By the mid-nineteenth century, anthropogenic habitat alteration such as water diversion and urban and

agricultural development caused a substantial loss of riparian and upland habitat in the San Joaquin Valley (approximately 70 percent). Wildlife biologists and other researchers posit this reduction in quality habitat in combination with periodic flooding, drought, and wildfires, reduced the riparian brush rabbits historic range and resulted in fragmentation and decline of the population in the Central Valley (Matocq et al. 2017; Williams and Basey 1986; US Fish and Wildlife Service 2020). Orr (1935, 1940), Williams and Basey (1986), US Fish and Wildlife Service (2020), and others suggest, prior to historic development, the subspecies historically inhabited densely vegetated riparian corridors and floodplains just south of Sacramento and north of Fresno, along the Merced, Stanislaus, Tuolumne, and San Joaquin Rivers. Due to the threat of extinction, *S. b. riparius* is listed as an endangered species by the state of California (1994) and federal government (2000). The modern remnant population's distribution is fragmented and limited to protected refuges and is the result of Endangered Species Recovery Program species reintroduction established by the US Fish and Wildlife Service conservation and restoration managers (Williams and Basey 1986, US Wildlife Service 2020). The historic connectivity of *S. b. riparius* range has yet to be resolved; genetic studies indicate both moderate historic gene flow and recent divergence within this taxon (Matocq et al. 2017).

Active throughout the year, the *S. bachmani* is found within the Upper Sonoran Life Zone, typically represented by chaparral covered cismontane valleys and low mountain slopes. It prefers uniformity in vegetation, typically living within the dense brush habitat of chaparral, bramble, willow, or other woody brush for protection from predators, and rarely ventures more than a few feet out in areas of open vegetation (Hall 1951; Ingles

1947). *S. bachmani* travels along trails or runways between their brushy habitat and seasonal tall herbaceous cover adjacent to dense shrub or woody foliage (Smith et al. 2018). The species home range is typically under 2,000 m<sup>2</sup> and dependent upon the brushy homogeneity of their habitat. Their diet consists predominantly of grasses, thistle, clover, berries, and other seasonally available vegetation. *S. bachmani* physically differs from *S. audubonii* by exhibiting a smaller body size, a more rounded head and shorter rostrum, and shorter ears and legs (Hall 1951). The average measurement of *S. bachmani* includes a total length of approximately 300-375 mm. These characteristics distinguish live individuals of *S. bachmani*; skeletal differences will be discussed in Chapter 3.

#### *Desert Cottontail* (*Sylvilagus audubonii*)

*Sylvilagus audubonii* has a modern geographic range that extends from the Pacific Coast in the west to almost the Great Plains to the east. The farthest extent north is from Montana to Canada and southward to Mexico (Baja California, most of the Sonora and Chihuahua deserts south, to Mexico City). Along the western states, it extends from California, Nevada, Utah, and south to the Baja Peninsula, and along the Sonoran Coast of Mexico. *S. audubonii* specimens are documented in Pleistocene deposits from Rancho La Brea, California (Chapman and Willner 1978, Fox et al., 2019; Ramos 1998, Smith et al. 2018). The species ranges from low to moderate elevations, from below sea level (in Death Valley) up to 1829 m asl in the Great Central Valley, southern California coastal, and desert regions (Chapman and Willner 1978). *S. audubonii* is typically not documented as inhabiting areas along the north coast from San Francisco north to the California-Oregon

border, northeastern California, and the Cascades and Sierra Nevada east of Sacramento, Chico, and Redding (Hall 1951; Ingles 1947).

In California, the species mostly inhabits the Lower Sonoran Life Zone, characterized by steppe or prairie grasslands in low elevation valley areas (Chapman and Ceballos 1990), as well as areas with heavy brush and willows along rivers and areas of tall grass (Chapman and Willner 1978). In Butte County, desert cottontail is primarily associated with willow (*Salix* sp.), buttonwillow (*Cephalanthus occidentalis*), and wild grape (*Vitis californica*) (Chapman and Willner 1978).

Individual home range encompass approximately 2.83 to 6 hectares. Home range size of males and females differ by several acres; males range is on average approximately 6.4 hectare acres, and females range encompasses about 0.5 hectare acres. Unlike *S. bachmani*, *S. audubonii* will venture out over 30 meters or more from vegetative cover to forage.

Their diet is dependent upon habitat; the rabbits feed almost exclusively on various species of grasses but can eat a diverse range of available vegetation (e.g., forbs, tree and shrub leaves, tender bark), including acorns (Ingles 1947). The species is sensitive to habitat conditions and alterations. *S. audubonii* diet includes a selection of grasses (e.g., *Bromus rubens*), forbs, and shrub species. Foraging occurs in open areas and under shrubs. Chapman and Ceballos (1990) suggest land clearing may affect some populations due to decrease in natural habitat (e.g., available food and shelter).

*S. audubonii* is described physically as large for the genus and exhibits long hind legs, long ears, sparseness of hair on the ears, and shortness of hair on the feet (Chapman

and Willner 1978; Hall 1951:162-163; Ingles 1945,). Average external measurements include a total length of 350-420 mm and a weight up to 1,250 g (Chapman and Willner 1978). Skeletal characteristics will be discussed in Chapter 3.

In sum, the spatial distribution of *S. bachmani* and *S. audubonii* on the landscape is dependent upon altitudinal, food, and vegetation structure preferences such as *S. bachmani* requires the dense cover of chaparral compared to semi-open habitat of *S. audubonii*. Considering the habitat preferences and the distinct size differences between the two taxa, the prehistoric relative abundance of *S. audubonii* to *S. bachmani* from dated contexts may be reflective of local environmental trends associated with climate change or other causes.

### **Cultural Context**

The archaeological sequence and chronology for northern California foothills, specifically, the Oroville regional sequences, was developed by Olsen and Riddell (1963) with revisions by Ritter (1968) and later Kowta (1988). The local sequence generally consists of the early and middle Holocene, Mesilla Complex, Bidwell Complex, Sweetwater Complex, and the Oroville Complex. Although a general background summary is provided for each complex, the focus of this study is on Sweetwater and Oroville complexes, as these periods correspond with cultural shifts (e.g., increase in human population and subsistence intensification) and environmental changes that occurred during the late Holocene.

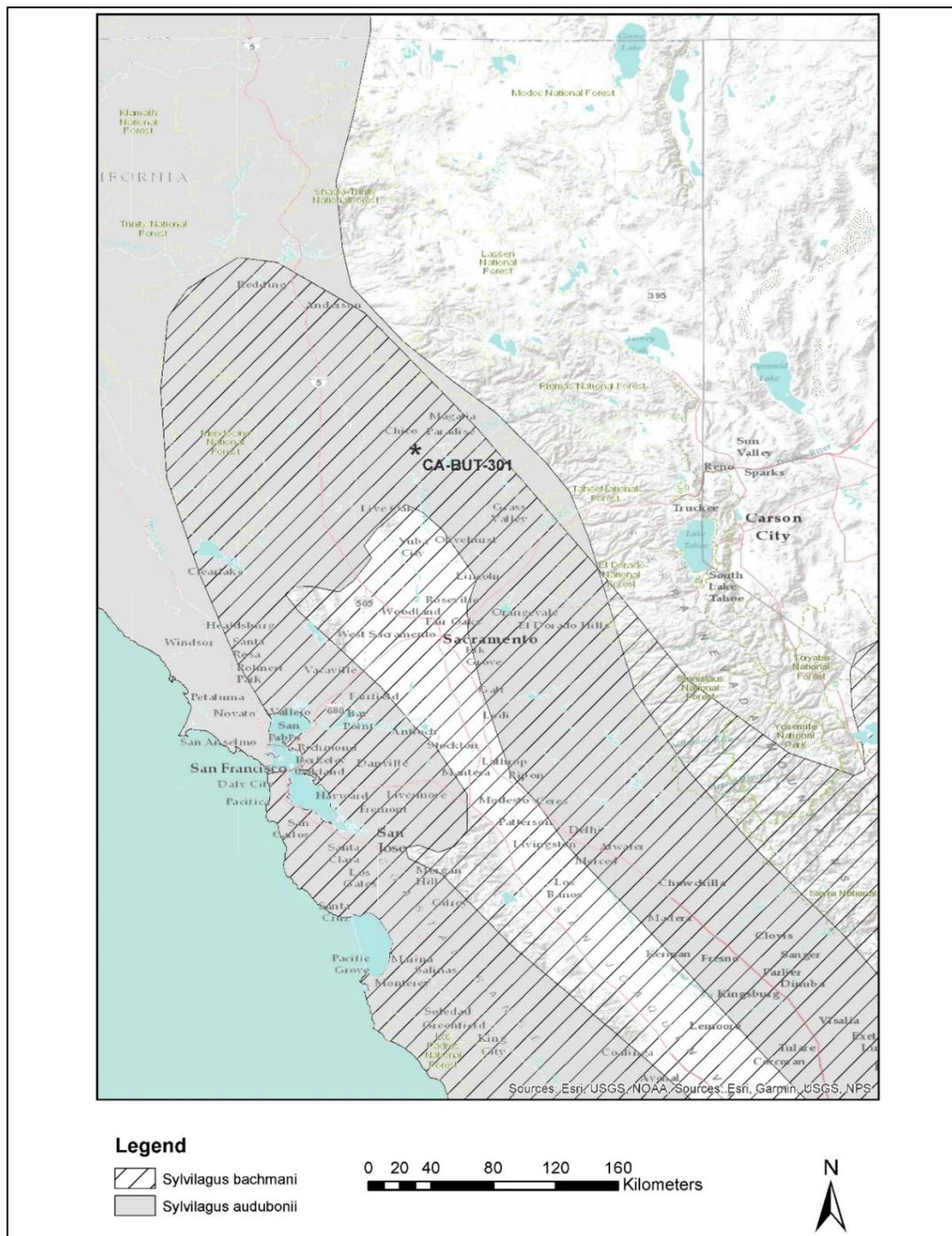


Figure 1. Modern Geographic distribution of *Sylvilagus audubonii* and *S. bachmani* in northern California, and approximate location of CA-BUT-301. Distribution GIS shapefile downloaded from International Union for Conservation of Nature (IUCN 2018). Map created in ArcMap version 10.

*Mesilla Complex (4500 to 2500 cal BP)*

The artifact assemblage for this complex is characterized by large dart sized projectile points (i.e., contracting stemmed and corner-notched), and millingslabs and handstones with some evidence of mortars and pestle use. The use of mortars and pestles suggest the introduction of acorn processing as a food resource during this time. Marine shell beads and ornaments are also represented, albeit in small numbers. Other artifacts include bone pins and spatulae, and small steatite bowls. The assemblage suggests that during the Mesilla Complex foothill groups practiced a mobile-forager adaption and subsistence was focused on large game, hard seeds, and vegetal resources.

*Bidwell Complex (2500 to 1100 cal BP)*

The Bidwell complex exhibits the continued use of large projectile points (large corner and side-notched, and wide stemmed dart points) and millingstone equipment (i.e., handstones and millingslabs, and mortars and pestles). Evidence of chisel-pointed stone pestles suggest the use of wooden mortars during this complex (Ritter 1968:95). While some artifacts assigned to the Bidwell complex illustrate a continuity with the previous sequence, the emergence of formalized cemetery areas, higher frequency of steatite vessels, and a diversified artifact assemblage suggest a more stationary settlement system (Delacorte and Basgall 2006; Ritter 1968). The increased presence of grooved and notched sinkers, freshwater mussel shell, and fish remains represents an elevated importance on riparian resources (Ritter 1968). Other artifacts include large basalt drills and various *Olivella* and *Haliotis* shell bead types.

*Sweetwater Complex (1100 to 500 cal BP)*

The Sweetwater complex is characterized by the introduction of the bow and arrow and the associated small contracting stem and corner-notched projectile points, as well as a higher frequency of mortar and pestle groundstone implements (hopper mortar and flat-ended pestle types) and bedrock mortars within the oak woodland areas (Ritter 1968). Slab metates and handstones appear less frequently than in the preceding periods. Other artifacts include schist tools (possibly functioning as sickles); steatite vessels, cups, and smoking pipes; bone tools (e.g., gorge hooks, awls, hair pins), and various shell beads and ornaments. Subsistence practices includes the hunting of large mammals (e.g., deer) and exploitation of riverine resources (e.g., shellfish, fish). The increase in frequency of mortar and pestles and bedrock mortars suggest a well-established acorn economy and subsistence intensification (Basgall 1987). Settlement patterns include large village sites along the Feather River with smaller groups dispersed on the adjacent upland foothill area (Ritter 1968).

*Oroville Complex (post -500 cal BP))*

The Oroville Complex assemblage represents the material cultural of the ethnohistoric Konkow-Maidu based on archaeological evidence and information provided by informants and documented by early ethnographers (e.g., Delacorte and Basgall 2006; Dixon 1905; Ritter 1968). The complex is characterized by small side-notched and triangular type projectile points, hopper and bowl mortars and pestles, bedrock mortars, bone tools (e.g., gorge hooks, narrow short gaming tubes, bone awls), stone beads, steatite

pipes, clam shell disc beads, *Olivella* beads and *Haliotis* shell ornaments, and various flaked tools. Steatite vessels are absent during this time and may have been replaced by basketry (Ritter 1968). Subsistence focused on an acorn economy supplemented by various vegetal, faunal, and riparian resources. Settlement shifted from dispersed groups to centralized villages with cemetery areas located away from living areas (Delacorte and Basgall 2006; Ritter 1968). Other artifacts attributed to this complex include perishable items such as basketry, feather implements, fish nets and cordage, and goods made of leather, shell, and wood.

In the Sacramento Valley, and northern California, resource intensification models suggest a decrease in foraging efficacy during the late Holocene that is marked by an increase in labor-intensive, subsistence intensification over time (Basgall 1987; Broughton 1994; Delacorte and Basgall 2006; Fisher 2018b). As the abundance of higher ranked large bodied faunal resources decreased, the diet breadth expanded to include lower ranked labor-intensive resources such as gathering and processing acorns and hunting small game, including rabbits. During the Sweetwater and Oroville complexes, the intensification of such resources may have encouraged Native American practices such as frequent low intensity burning of land to reduce underbrush and facilitate growth of edible plants and access to acorn collection areas (Anderson 2005; Crawford 2015).

### *Post-Contact Ethnographic History*

The northwestern Sierra Nevada Mountain foothills and the lower Feather River Canyon watershed to the upper reaches of the Sacramento River and adjacent valley area

are within the ethnographic region of the Maidu-speaking Konkow (or northwestern Maidu) (Dixon 1905; Kroeber 1925; Riddell 1978). The name Konkow is derived from the Maidu term for meadowland, *kóyo-mk'áwi*. Their territory ranged from a savanna grassland-oak environment along the valley floor to the foothill oak woodlands and coniferous forest of the western Sierra. The location of residential areas were typically dependent upon the natural topography and features of the landscape, such as tributaries of the Sacramento River, along the edges of the valley, and atop ridges, crest, knolls, or terraces of the Feather River canyon and tributaries within the Sierra foothills (Dixon 1905; Kroeber 1925). The political organization of the Konkow consisted of a sovereign village community that included distinct adjacent villages with a central village (Riddell 1978). A village was made up of several homes of nuclear families, and approximately three to five villages formed a village community. The central village had a large semi-subterranean, earth-covered lodge that served as a ceremonial gathering area and potentially the home of the head community advisor. The head advisor did not exert any strict political control over the autonomous villages within the community.

The Konkow practiced a year-round hunting and gathering subsistence pattern utilizing a variety of resources within the diverse ecological zones of their territory (Riddell 1978). Acorns (i.e., black oak: *Q. kelloggii*; canyon or golden oak: *Q. chrysolepis*; and interior live oak: *Q. wislizenii*) were a valuable resource collected in the fall, and a wide variety of plant resources were also utilized for subsistence and other practices, such as other nut crops (e.g., pine nuts: *Pinus sabiniana*), berries, and various roots, bulbs, leaves, seeds, and grass (Dixon 1905). The Konkow used digging sticks to extract roots, bulbs,

and other geophytes. Acorns and many other plant resources were stored for the winter. The Konkow hunted a variety of faunal resources for subsistence and utilitarian purposes, such as black tailed deer (*Odocoileus hemionus*), elk (*Cervus elaphus*), bighorn sheep, pronghorn (*Antilocapra americana*), squirrel (Scuridae), rabbit (*Sylvilagus* spp.), and an abundance of other terrestrial and riverine resources (e.g., waterfowl, fish, freshwater shellfish, insects, etc.) (Dixon 1905; Riddell 1978). The northern Maidu collected flora resources such as willow (*Salix* spp.), pine (*Pinus* spp.), cedar (*Cedrus* spp.), redbud (*Cercis occidentalis*), hazelnut shoots (*Corylus cornuta*), bear grass (*Xerophyllum tenax*), and other grasses and ferns for basketry (Potts 1977). Basketry material was collected from both valley and foothill habitats and brush was often burned to encourage new growth of green and pliable shoots (Potts 1977:35).

Although often documented in ethnographic sources, discussions regarding resource and land management activities conducted by precontract populations is often lacking in past archaeological studies. The Konkow were dependent upon the seasonal availability of resources within their ecological zones, and they developed management practices and technology to enhance the exploitation of such resources (Anderson 2005). The Konkow annually burned areas within their territory to clear brush in grassland areas and understory shrubs within forested areas to manage and promote plant growth (e.g., seed grasses and geophytes), open grazing areas, and clear areas used for travel along trails (Blackburn and Anderson 1993; Dixon 1905; Kroeber 1925). However, the antiquity of such practices, and how they fluctuated in use through time, is currently unknown.

## Summary

The regional proxy data suggest that environmental conditions during the MCA resulted in a more open, shade intolerant/fire adapted, vegetation structure, compared to a more closed, shade tolerant vegetation structure during the cooler period of the LIA. Considering the paleoclimatic record, the relative abundance of *S. audubonii* to *S. bachmani* is expected to increase and its geographical range widen during the MCA due to the expansion of its preferred semi-open habitat. Correspondingly, the shift in conditions and downslope advancement of forest cover during the LIA should decrease the abundance of *S. audubonii* and its geographic distribution will contract.

By utilizing a methodology for identification of leporids to a species level for analysis of archaeofaunal assemblage(s), archaeologists would be able to identify changes in the taxonomic abundance that may reflect changes in local environments influenced by climatic conditions and cultural practices. The distinction of *Sylvilagus* species and their temporal relative abundance is expected to reflect environmental conditions and variation in conditions. If there is a significant occurrence of *S. audubonii* in the archaeological assemblage during the LIA, the presence of the species may be indicative of anthropogenic burning that shaped vegetation conditions similar to the MCA. Maximizing subsistence resources by utilizing practices such as fire would be expected during times of resource intensification and high human population density.

## Chapter 3

### DISTINGUISHING *SYLVILAGUS* IN NORTHERN CALIFORNIA

Leporids represent an important resource for pre-contact people in Northern California, reflected by both ethnographic data and the frequent recovery of leporids from archaeological deposits. Identification of leporids to species from archaeological faunal remains can be a difficult and challenging component of faunal analysis. For example, considerable size differences between mature black-tailed jackrabbit hares (*Lepus californicus*) and rabbit (*Sylvilagus* spp.) skeletal material is conducive to taxonomic identification. However, identification between two species of rabbit (*S. audubonii* and *S. bachmani*) can be more challenging due to similarities between the species. A methodology for identification of leporids to the species level could benefit archaeological interpretation of human foraging practices and provide important data regarding the paleoenvironment in which people lived (e.g., Fisher 2012). This chapter begins by discussing existing leporid identification methods, including morphometric and morphological characteristic landmarks. This is followed by a review of the present study's methods and results.

#### **Existing Leporid Metric Identification Methods**

Several existing craniometric studies establish methodologies for leporid identification to species (Dalquest et al., 1989; Findley et al., 1975; Neusius and Flint 1985; Ramos 1999). These studies focused on cranial morphological indicators including measurements of mandibular and maxillary fragments, size, and enamel patterns from

teeth. Regarding the lattermost, enamel folds patterns in the posterior buccal re-entrant on the occlusal surface of the lower third premolar (P<sub>3</sub>) differ in the degree of crenulation among leporid species (Figure 2). The enamel fold pattern studies conducted by Dalquest et al. (1989) and Findley et al. (1975) found differences between *S. audubonii*, *S. floridanus* (eastern cottontail), and *S. nuttallii* (mountain cottontail) but did not include *S. bachmani* in their study.

Ramos's (1999) craniometric study examined interspecific morphological variability of 12 leporid species from different regions of northern and western North America, including *S. audubonii* and *S. bachmani*. Eighteen measurements of the maxilla and dentary tooth dimensions for each specimen were recorded and statistically analyzed. Based on the discriminant analysis, Ramos (1999) established a set of maxillary and mandibular traits and dimensions for species identification. Species that are closely related tend to share similar morphologies; *S. bachmani* is thought to be more closely related to the ancestral cottontail form than *S. audubonii* and therefore exhibit distinct characteristics that separate it from other species (Ramos 1999). For example, *S. audubonii* is significantly larger than *S. bachmani*, and this is reflected by larger alveolar lengths in the mandible and maxilla (Ramos 1999). Discriminate analysis of measurable characteristics of leporids maxillae and mandibles successfully distinguished *S. bachmani* from other *Sylvilagus* species with 90% confidence (Ramos 1999). Metric differences in the alveolar lengths for *S. audubonii* and *S. bachmani* examined by Ramos (1999) are presented in Table 1.

**Table 1. Differences in the alveolar lengths for *S. audubonii* and *S. bachmani* from Ramos (1999): Means  $\pm$  standard deviations. All values are in mm.**

Species	Zygomatic arch	Tooth row length	P2 width	P3 width	P4 width	M1 width	M2 width	M3 width
<i>S. audubonii</i>	4.62 $\pm 0.41$	12.72 $\pm 0.76$	3.01 $\pm 0.25$	4.43 $\pm 0.33$	4.27 $\pm 0.31$	4.06 $\pm 0.31$	3.67 $\pm 0.29$	1.65 $\pm 0.17$
<i>S. bachmani</i>	3.76 $\pm 0.32$	11.39 $\pm 0.68$	2.40 $\pm 0.20$	3.69 $\pm 0.26$	3.51 $\pm 0.25$	3.29 $\pm 0.26$	3.02 $\pm 0.23$	1.35 $\pm 0.17$

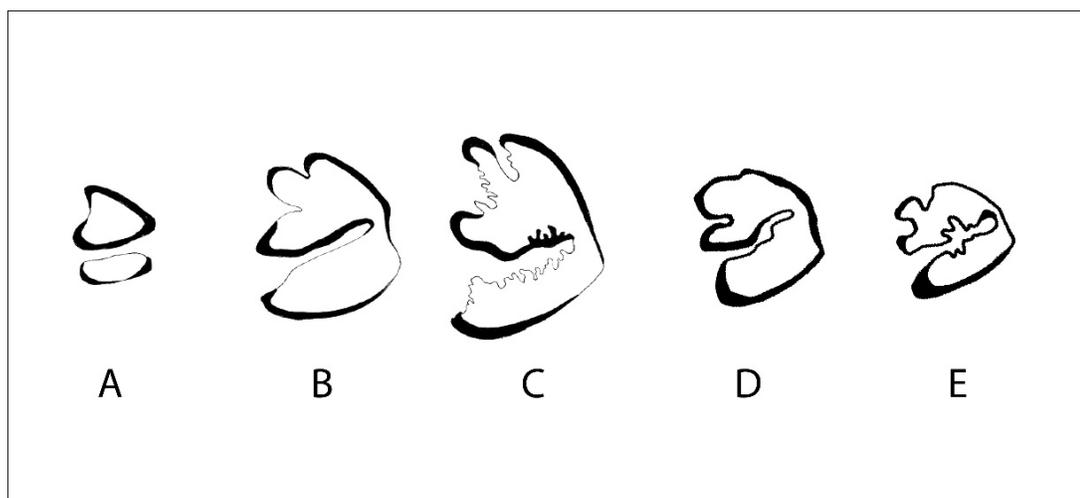
A recent craniometric study conducted by Fox et al. (2019), examined variability between P<sub>3</sub> crenulation patterns and linear measurements, diastema length, and toothrow length measurements of six extant leporid species. The study focused on regional differentiation among species and the sample collection examined 30 adult specimens of both *S. audubonii* and *S. bachmani* from low elevation areas in southern California. Fox et al. (2019) established a set of dentary region-specific identification criteria to discriminate between species. A combination of sized based measurements and crenulation patterns successfully distinguished adult *S. bachmani* and *S. audubonii* from other leporids with a low range of taxon-specific error, at 10% or under (Fox et al., 2019). Differences in dentary measurements for *S. audubonii* and *S. bachmani* examined by Fox et al., (2019) are presented in Table 2.

**Table 2. Differences in dentary measurements for *S. audubonii* and *S. bachmani*: Means  $\pm$  standard deviations. All values are in mm. (Fox et al., 2019).**

Species	Diastema length	Toothrow length	P3 length	P3 width	P3 width/length
<i>S. audubonii</i>	14.15 $\pm$ 1.07	12.71 $\pm$ 0.63	2.82 $\pm$ 0.21	2.35 $\pm$ 0.18	1.20 $\pm$ 0.10
<i>S. bachmani</i>	12.17 $\pm$ 0.92	11.58 $\pm$ 0.71	2.44 $\pm$ 0.19	1.93 $\pm$ 0.15	1.27 $\pm$ 0.08

Alveolar length and enamel patterns have been used successfully for distinguishing leporid taxa to some species, this require recovery of preserved complete or fragments of

mandibles with the alveolar row and teeth (specifically P<sub>3</sub>) (Findley et al., 1975; Fox et al., 2019; Hibbard 1963; Ramos 1999; White 1987). While these elements are frequently preserved and included in paleontological and archaeological assemblages, it potentially restricts analysis to relatively complete specimens (Ramos 1999). Presumably, size and potentially morphometric differences exist for the postcranial skeleton as well. The challenge is identifying differences that may be applied to paleontological and archaeofaunal remains that are affected by a variety taphonomic processes, such as culinary processing and post-depositional processes that result in fragmentation and destruction of lower density skeletal parts (Fisher 2018a; Lyman 1994; Pavao and Stahl 1999).



**Figure 2. Examples of PM3 enamel pattern differences for leporids. Illustrated classifications include: (A) *Brachylagus idahonensis*, (B) *Lepus americanus*, *L. arcticus*, *L. othus*, *L. timidus*, *T. townsendii*; (C) *L. alleni* and *L. californicus*; (D) *Sylvilagus nuttallii*; (E) *S. audubonii*. Figure adapted from Findley et al. (1975) and Ramos (1999).**

## Methods

Ramos (1999) and Fox et al., (2019) previously established cranial differences in leporid taxa and discriminate measurements for *S. audubonii* and *S. bachmani* were found

to be significantly different. By identifying similar differences in the postcranial skeleton, larger samples of fragmentary skeletal remains may be utilized to evaluate changes in the taxonomic representation, and thus environments, over time.

### *Postcranial Metrics*

To establish a set of criteria to accurately identify *Sylvilagus* to species, the present research focuses on examining postcranial morphological and morphometric characteristics of modern *S. bachmani* and *S. audubonii* specimens. The reference sample included museum and university lab specimens of known *S. bachmani* and *S. audubonii* individuals. Measured specimens were limited to adult individuals with completely fused proximal humeri. Specimens with an unfused epiphysis or indicators of an epiphyseal fusion line of the proximal humerus were considered skeletally immature and not included in the sample. Specimens of known sex were examined, and attempts were made to ensure both sexes were represented equally. Neither *S. audubonii* nor *S. bachmani* display any significant sexual dimorphic characteristics except that females are noted as slightly larger (longer and heavier) than males (Chapman 1971; Chapman and Ceballos 1990). Only three *S. audubonii* specimens are of unknown sex. To avoid geographic variation among populations within the species, specimen selection was limited to individuals collected from northern California west of the Sierra Nevada crest. Due to small sample size, an exception was made for two specimens from central California.

Anatomical structures of skeletal elements were measured and statistically analyzed. Standard postcranial measurements as defined and illustrated by von den Driesch

(1976) were utilized (Table 3). A total of thirty-two measurements were recorded for each comparative specimen.

**Table 3. Anatomical Measurements used in the present study. Measurements derive from von den Driesch (1976)**

<b>Skeletal Part</b>	<b>Measurement</b>	<b>Description</b>
Scapula	GLP	greatest length of the processus articularis
	LG	length of the glenoid cavity
	BG	breadth of the glenoid cavity
Radius & Ulna	GL	greatest length
	GL	greatest length
	GLI	greatest length of lateral part
	LI	length of later part
	PL	physiological length
Ulna	GL	greatest length
	SDO	smallest depth of olecranon
	DPA	depth across the processus anconaeus
	BPC	greatest breadth across the coronoid process=greatest breadth of the proximal articular surface
Radius	Bp	depth of proximal end
	BFp	greatest breadth of the Facies articularis proximalis
	Bd	breadth of distal end
	BFd	greatest breadth of the Facies articularis distalis
Humerus	GL	greatest length
	Bd	greatest breadth of the proximal end
	BT	greatest breadth of the trochlea
Innominate	SB	smallest breadth of the shaft of ilium
	SH	smallest height of the shaft of ilium
Femur	GL	greatest length
	GCL	greatest length from caput femoris – head
	Bp	greatest breadth of the proximal end
	BTr	greatest breadth of the region of the Trochanter tertius
	Bd	greatest breadth of the distal end
Tibiofibula	GL	greatest length
	Bp	greatest breadth of proximal end
	Bd	greatest breadth of distal end
	Dd	greatest depth of distal end
Calcaneus	GL	greatest length
	GB	greatest breadth

Dimensions of postcranial skeletal elements of the reference collection, such as the proximal or distal breadth of long bones, were measured with digital calipers with a cable input at 0.01 precision. Measurements were limited to those skeletal elements commonly

recovered from archaeological contexts utilizing  $\frac{1}{8}$  inch and  $\frac{1}{4}$  inch mesh sieves (Shaffer and Sanchez 1994) and bone elements that exhibit high bone structure density (Pavao and Stahl 1999). Anatomical measurements are represented from the left side of the animal body for paired skeletal parts.

Collected measurement data were subjected to statistical analysis utilizing International Business Machines (IBM) SPSS Statistics software. An independent two-sample t-test was conducted to test the hypothesis that *S. audubonii* and *S. bachmani* reference sample have significant different mean measurements for postcranial elements. Significant differences were identified by a significant probability ( $p$ ) alpha value of  $< 0.05$ .

### *Sample Selection*

A total of nine *S. audubonii* and 30 *S. bachmani* comparative specimens were available for measurement (Table 4 and 5; Appendix A). The skeletal specimens used for this study came from various zoological museums and laboratories in California. Of the total 39 specimens examined, 33 are housed at the Museum of Vertebrate Zoology at Berkeley (MVZ), University of California, Berkeley; two are housed at the Museum of Endothermic Vertebrates, Department of Biological Sciences, California State University, Sacramento (Sacramento State); and four are housed at the Sacramento State Zooarchaeology Laboratory, Sacramento State. The California Academy of Sciences in San Francisco, the Chico State Archaeology Laboratory, and Fresno State Natural History Museum was visited but the facilities did not have any complete skeletal specimens suitable

for the present study available. All the specimens for this study are from the northern California region, except for the two *S. audubonii* specimens from Kern County.

**Table 4. *Sylvilagus audubonii* Reference Sample Specimens.**

<b>Facility and Specimen No.</b>	<b>Collection Site</b>	<b>California County</b>	<b>Year Collected</b>	<b>Sex</b>	<b>Age</b>
ACF-1-156	No data	Yolo	2001	Unk.	adult
ACF-1-178	No data	Yolo	2008	M	adult
ACF-1-185	No data	Yolo	2008	Unk.	adult
ACF- 385	Yuba City	Sutter	1991	Unk.	adult
MVZ-29175	Soledad	Monterey	1918	M	adult
MVZ-43914	Red Bluff	Tehama	1928	M	adult
MVZ-57119	Buttonwillow	Kern	1933	F	adult
MVZ-28723	SW of Bakersfield	Kern	1918	M	adult
MVZ-228980	Dublin	Alameda	2006	F	adult

**Acronyms: ACF = Archaeological Curation Facility at Sacramento State, MNH = Museum of Natural History (also Museum of Endothermic Vertebrates) at Sacramento State; MVC = Museum of Vertebrate Zoology at University California Berkeley, Unk = unknown, M = male, F = female.**

### *Reference Sample Issues*

Intraspecific variability in size, corresponding with population, geography, and chronology, contribute to the need for an adequate reference specimen sample size (Lyman 2019). The strength of statistical data derived from the use of metric traits for species identification for closely related populations requires a considerable sized reference collection (Cardini and Elton 2007, Lyman 2019). Access to an adequate size comparative collection or reference sample is often problematic for zooarchaeological research and variables such as a lack of available reference specimens in museum or university collections, funding, locality, and time are contributing factors to obtaining a suitable sample size. The author contacted and visited several different California museums and

**Table 5. *Sylvilagus bachmani* Reference Sample Specimens.**

<b>Facility and Specimen No.</b>	<b>Collection Site</b>	<b>California County</b>	<b>Year Collected</b>	<b>Sex</b>	<b>Age</b>
MNH 1615	East Bay Utility Reservoir	Contra Costa	1952	F	adult
MNH-1617	East Bay Utility Reservoir	Contra Costa	1951	F	adult
MVZ- 63387	Alpine Creek Ranch	San Mateo	1932	F	adult
MVZ- 51682	Alpine Creek Ranch	San Mateo	1932	M	adult
MVZ-51687	Alpine Creek Ranch	San Mateo	1932	F	adult
MVZ-51686	Alpine Creek Ranch	San Mateo	1932	F	adult
MVZ-51685	Alpine Creek Ranch	San Mateo	1932	M	adult
MVZ-51684	Alpine Creek Ranch	San Mateo	1932	F	adult
MVZ-51681	Alpine Creek Ranch	San Mateo	1932	M	adult
MVZ-51683	Alpine Creek Ranch	San Mateo	1932	F	adult
MVZ-51680	Alpine Creek Ranch	San Mateo	1932	F	adult
MVZ-18545	Mt. Diablo	San Mateo	1912	F	adult
MVZ-47796	Moraga Fostire Ranch	Contra Costa	1927	M	adult
MVZ-29404	Seaside	Monterey	1919	M	adult
MVZ-63410	Alpine Creek Ranch	San Mateo	1933	F	adult
MVZ-63409	Alpine Creek Ranch	San Mateo	1933	F	adult
MVZ-63408	Alpine Creek Ranch	San Mateo	1933	F	adult
MVZ-63412	Alpine Creek Ranch	San Mateo	1933	M	adult
MVZ-63414	Alpine Creek Ranch	San Mateo	1933	M	adult
MVZ-63415	Alpine Creek Ranch	San Mateo	1933	M	adult
MVZ-63416	Alpine Creek Ranch	San Mateo	1933	F	adult
MVZ-63417	Alpine Creek Ranch	San Mateo	1933	F	adult
MVZ-63390	Alpine Creek Ranch	San Mateo	1933	F	adult
MVZ-63395	Alpine Creek Ranch	San Mateo	1933	M	adult
MVZ-63396	Alpine Creek Ranch	San Mateo	1933	F	adult
MVZ-63397	Alpine Creek Ranch	San Mateo	1933	F	adult
MVZ-63399	Alpine Creek Ranch	San Mateo	1933	M	adult
MVZ-63400	Alpine Creek Ranch	San Mateo	1933	F	adult
MVZ-63401	Alpine Creek Ranch	San Mateo	1933	F	adult
MVZ-63404	Alpine Creek Ranch	San Mateo	1933	F	adult

**Acronyms: ACF = Archaeological Curation Facility at Sacramento State, MNH = Museum of Natural History (also Museum of Endothermic Vertebrates) at Sacramento State; MVC = Museum of Vertebrate Zoology at University California Berkeley, Unk = unknown, M = male, F = female.**

university zoology/zooarchaeological labs for access to their vertebrate collections of *S. audubonii* and *S. bachmani* reference sample. A common problem encountered at each institution is most vertebrate collections of *S. audubonii* and *S. bachmani* consist primarily of skulls and skins; complete skeletons are comparatively rare. Additionally, the spread of the novel coronavirus disease 2019 (COVID-19) pandemic in the United States and resulting mandated stay-at-home orders and closure of museums and University labs beginning March of 2020 hindered access to reference samples and data collection. Specifically, the Natural History Museum of Los Angeles, California, holds a large collection of *S. bachmani* and *S. audubonii* but I was unable to access the collection due to COVID-19 museum closures.

For this thesis, the availability of complete skeletal comparatives of both taxa is limited (*S. bachmanii*  $n = 30$ ; *S. audubonii*  $n = 9$ ), and my sample size of *S. audubonii* may not capture variation within and between populations. Comparisons across the two populations were not made based on sex because of the small sample size. Most of the *S. bachmani* reference sample were collected from the same geographic location, Alpine Creek Ranch, San Mateo, California. These specimens were wild caught and originally harvested over a two-year period in the 1930s.

For independent sample t-test conducted for this study, it is assumed both samples come from normally distributed populations with equal standard of deviation. For applicability in the archaeological record, an assumption of interspecific and intraspecific genetic stasis is assumed (Lyman 2019). The sample dataset for this study is comprised of 39 specimens and is less than optimal for a morphometric study but still holds value as a

basis to the metric method and as a dataset that can be built upon. It is prudent to state that the following results from this study should be considered preliminary until a larger sample size is acquired for future analysis.

## Results

Means and standard deviations of the 32 postcranial elements of *S. bachmanii* and *S. audubonii* metrics demonstrate a difference between the two species. The t-test Levene's F statistic for equal variances assumed indicated that variance among the two species was statistically equal for the majority of measurements, with the exception of only five measurements: Scapula-GLP, Humerus-Bt, Innominate-SB, Innominate-SH, and Tibulafibula-Dd (Appendix B).

Two-tailed t-tests for *S. audubonii* and *S. bachmani* demonstrated that the means for all measurements are significantly different among the two species for all measurements with the exception of the Radius BFp ( $t = .379$ , d.f. = 30,  $p = .7$ ). This measurement is the breadth of the facies articularis proximalis located at the proximal end of the radius (von den Dresch 1976). The lack of significant difference for this measurement is possibly attributed to analyst error of inconsistent measurement technique for this portion of the bone, or alternatively, the limited sample size of *S. audubonii*. The means and 1-sigma and 2-sigma standard deviation ranges for postcranial fore limb elements and hind limb elements are provided in Table 6 and 7, respectively.

**Table 6. Summary of Statistics for Species Postcranial Fore Limb Elements Examined: Means  $\pm$  Standard Deviation, 1-sigma and 2-sigma ranges. All values in mm.**

Element	<i>S. bachmani</i>			<i>S. audubonii</i>		
	$\bar{x} \pm \sigma$	1 $\sigma$ range	2 $\sigma$ range	$\bar{x} \pm \sigma$	1 $\sigma$ range	2 $\sigma$ range
Scapula GLP	7.64 $\pm$ 0.29	7.35-7.93	7.06-8.22	8.99 $\pm$ 0.64	8.35-9.63	7.71-10.27
Scapula LG	7.29 $\pm$ 0.29	7.00-7.58	6.71-7.87	8.17 $\pm$ 0.30	7.87-8.47	7.57-8.77
Scapula BG	5.32 $\pm$ 0.25	5.07-5.57	4.82-5.82	6.45 $\pm$ 0.24	6.21-6.69	5.97-6.93
Radius/Ulna Ulna GL	53.45 $\pm$ 1.99	51.46-55.44	49.47-57.43	65.81 $\pm$ 1.92	63.89-67.73	61.49-69.65
Radius/Ulna Radius GL	44.58 $\pm$ 1.94	42.64- 46.52-	40.70-48.46	55.99 $\pm$ 1.53	54.46-57.52	52.93-59.05
Radius/Ulna GLI	51.46 $\pm$ 3.67	47.79-55.13	44.12-58.8	64.95 $\pm$ 2.00	62.95-66.95	60.95-68.95
Radius/Ulna LI	43.88 $\pm$ 1.75	42.13-45.63	40.38-47.38	54.13 $\pm$ 1.48	52.65-55.61	51.17-57.09
Radius/Ulna PL	43.65 $\pm$ 1.65	42-45.3	40.35-46.95	54.82 $\pm$ 1.27	53.55-56.09	52.28-57.36
Ulna GL	52.97 $\pm$ 2.56	50.41-55.53	47.85-58.09	65.28 $\pm$ 2.01	63.27-67.29	61.26-69.3
Ulna SDO	4.90 $\pm$ 0.32	4.58-5.22	4.26-5.54	5.5 $\pm$ 0.15	5.35-5.65	5.20-5.80
Ulna DPA	5.60 $\pm$ 0.28	5.32-5.88	5.04-6.16	6.1 $\pm$ 0.15	5.92-6.28	5.74-6.46
Ulna BPC	4.40 $\pm$ 0.38	4.02-4.78	3.64-5.16	4.84 $\pm$ 0.11	4.73-4.95	4.62-5.06
Radius Bp	4.63 $\pm$ 0.18	4.45-4.81	4.27-4.99	5.17 $\pm$ 0.16	5.01-5.33	4.85-5.49
Radius BFp	3.26 $\pm$ 0.52	2.74-3.87	2.22-4.3	3.17 $\pm$ 0.51	2.66-3.68	2.17-4.19
Radius Bd	4.32 $\pm$ 0.58	3.74-4.9	3.16-5.48	4.84 $\pm$ 0.44	4.4-5.28	3.96-5.72
Radius BFd	3.58 $\pm$ 0.39	3.19-3.97	2.8-4.36	4.14 $\pm$ 0.30	3.84-4.44	3.54-4.74

## Discussion

Demonstrated observable differences exist between taxon measurements suggesting the potential to use simple metrics provided by von den Driesch (1976) to identify specimens to *S. bachmani* and *S. audubonii* using fragmented archaeofaunal and paleontological remains. The statistical results were significant in all cases except one (Radius BFp), and the means and standard deviations proved capable of separating the

species. An increase in reference sample size would conceivably increase the representativeness of inter- and intra-species variation and thus increase the adequacy of the statistical results for the population, providing a more solid data set.

**Table 7. Summary Statistics Summary Statistics for Postcranial Hind Limb Elements examined: Means  $\pm$  Standard Deviations, 1-sigma and 2-sigma ranges. All values are in mm.**

Hind limb Element	<i>S. bachmani</i>			<i>S. audubonii</i>		
	$\bar{x} \pm \sigma$	1 $\sigma$ range	2 $\sigma$ range	$\bar{x} \pm \sigma$	1 $\sigma$ range	2 $\sigma$ range
Humerus GL	48.01 $\pm$ 1.42	46.59-49.43	45.17-50.85	57.54 $\pm$ 1.53	56.01-59.07	54.48-60.6
Humerus Bd	6.40 $\pm$ 0.18	6.22-6.58	6.04-6.76	7.3 $\pm$ 0.13	7.17-7.43	7.04-7.56
Humerus BT	4.70 $\pm$ 0.27	4.43-4.97	4.16-5.24	5.6 $\pm$ 0.42	5.18-6.02	4.76-6.44
Innominate SB	3.41 $\pm$ 0.19	3.22-3.6	3.03-3.79	4.05 $\pm$ 0.44	3.61-4.49	3.17-4.93
Innominate SH	4.70 $\pm$ 0.23	4.47-4.93	4.24-5.16	6.4 $\pm$ 0.83	5.57-7.23	4.74-8.06
Femur GL	63.74 $\pm$ 1.44	62.3-65.18	60.86-66.62	74.09 $\pm$ 0.2.49	71.6-76.58	69.11-79.07
Femur GCL	61.78 $\pm$ 1.40	60.38-64.58	58.98-64.58	70.95 $\pm$ 2.39	68.56-73.34	66.17-75.73
Femur Bp	11.68 $\pm$ 0.51	11.17-12.19	10.66-12.7	13.58 $\pm$ 0.61	12.97-14.19	12.36-14.80
Femur BTr	11.77 $\pm$ 0.46	11.31-12.23	10.85-12.69	13.47 $\pm$ 0.47	13-13.94	12.53-14.14
Femur Bd	10.29 $\pm$ 0.39	9.9-10.68	9.51-11.07	12.08 $\pm$ 0.38	11.7-12.49	11.32-12.84
Tibiofibula GL	72.72 $\pm$ 2.39	70.33-75.11	67.94-77.5	86.57 $\pm$ 1.44	85.13-88.01	83.69-89.45
Tibiofibula Bp	10.79 $\pm$ 0.56	10.23-11.35	9.67-11.91	12.36 $\pm$ 0.58	11.78-12.94	11.2-13.52
Tibiofibula Bd	8.88 $\pm$ 0.47	8.41-9.35	7.94-9.82	10.24 $\pm$ 0.93	9.31-11.17	8.38-12.1
Tibiofibula Dd	4.69 $\pm$ 0.22	4.47-4.91	4.25-5.13	5.23 $\pm$ 0.09	5.14-5.23	5.05-5.41
Calcaneus GL	16.45 $\pm$ 0.92	15.53-17.37	14.61-18.29	19.14 $\pm$ 0.53	18.61-19.67	18.08-20.2
Calcaneus GB	5.51 $\pm$ 0.48	5.03-5.99	4.55-6.47	7.15 $\pm$ 0.58	6.57-7.73	5.99-8.31

Despite the limitations regarding small sample size for *S. audubonii*, the efficacy of the data analysis is supported by the statistical results that illustrate differences exist between the two taxa. The provided metrics should be used in conjunction with other

established approaches to gain greater reliability in species identification, including Ramos's (1999) and Fox and colleagues' (2019) previously established metrics for the cranium along with the enamel folds patterns on the occlusal surface of the lower third premolar (P<sub>3</sub>).

The method presented here can be applied to archaeological and paleontological faunal assemblages for taxonomic identification of fragmentary faunal material to the species level, increasing the relevant sample beyond cranial specimens. Archaeological site faunal assemblages can be utilized to evaluate changes in the taxonomic representation, and thus provide information on changing environmental conditions and resource exploitation over time. The relative abundance of species of an archaeological assemblage informs researchers of ecological resource areas and prehistoric fauna types that were either hunted locally or from distant niches. Observed changes in the relative abundance of a taxa of an assemblage can be applied to interpret a suite of research issues that address faunal exploitation on the landscape and the relationship between the target environment and human induced broad spatial and temporal trends such as resource depression, resource intensification, population demographics (Fisher 2018b), prey selection, transport, and hunting decisions (Broughton and Bayham 2003; Byers and Ugan 2005; Fisher 2015), species biogeography (Bovy 2012; Fisher 2012; Grayson and Delpech 2005), and paleoenvironment (Lyman 1991).

Wildlife restoration managers are often faced with determining the appropriate restoration efforts for an endangered species and whether funding should support relocation or reintroduction of a species that might not have historically be located in a specific

geographic area. For instance, the historic distribution of *S. b. riparius* in the southern San Joaquin Valley is currently unknown. This method could be applied to a sample of archaeological sites with dated deposits within the lower San Joaquin River region and foothill areas to identify the temporal and spatial distribution of the species. Conservation efforts would benefit from a multidisciplinary understanding of *S. b. riparius* biogeographic range, and thus data from an archaeological context can inform wildlife managers of the species prehistoric distribution to help focus species recovery efforts.

## Chapter 4

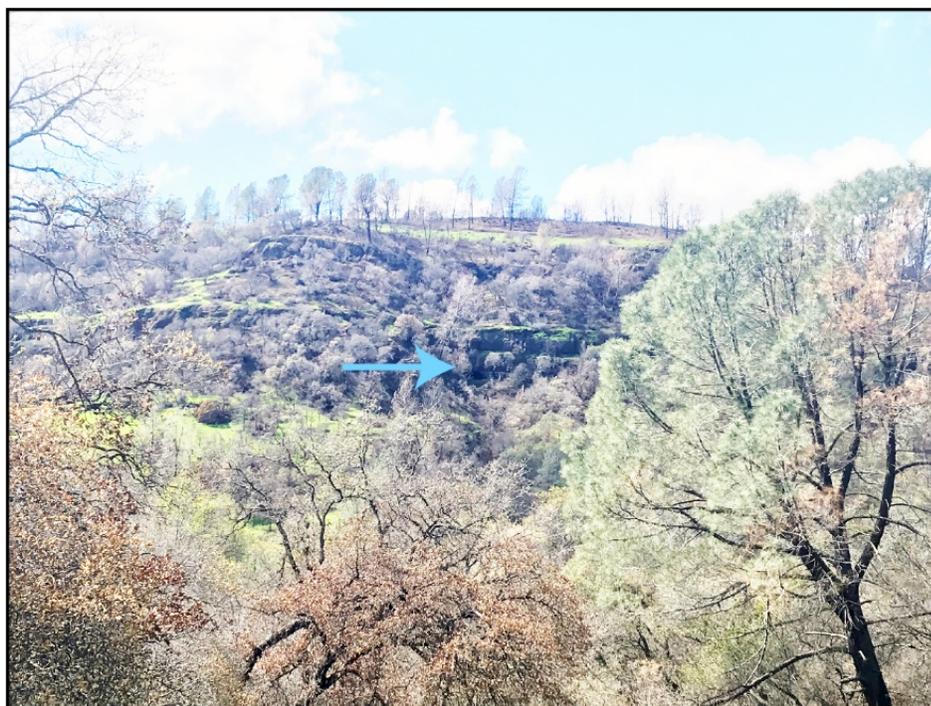
*SYLVILAGUS* SPECIES OF KATHY'S ROCKSHELTER (CA-BUT-301)

Zooarchaeological analysis can provide prehistoric biogeographic data to further examine changes in a species relative abundance and shifts in local environmental conditions (Fisher 2012, 2018b; Grayson and Delpech 2005; Lyman 2004, 2006). This study will evaluate relative the frequency of *S. bachmani* and *S. audubonii*, two species of rabbit that have different habitat preferences and contrasting geographic range. *S. bachmani* typically favors the closed bushy habitat of chaparral of the upland and foothill areas. In contrast, *S. audubonii* is found in a more semi-open grassland areas of the valley. In order to investigate the distribution of the taxa and any shifts in frequency, it is necessary to identify an archaeological faunal assemblage from a location where the two species geographic ranges overlap, and within a dated context of sufficient time depth represented in order to distinguish changes in species representations.

CA-BUT-301 (Kathy's Rockshelter), a pre- and post-contact site located in Butte County, California, meets the requirements for this study. Kathy's Rockshelter is within the overlapping geographic distribution of both *S. audubonii* and *S. bachmani* and has a large faunal assemblage. Based on artifacts and chronometric data, the site appears to have been inhabited seasonally for approximately 2000 years (Fisher 2018b). Kathy's Rockshelter assemblage provides an excellent test case for evaluating temporal shifts in the relative abundance of both species.

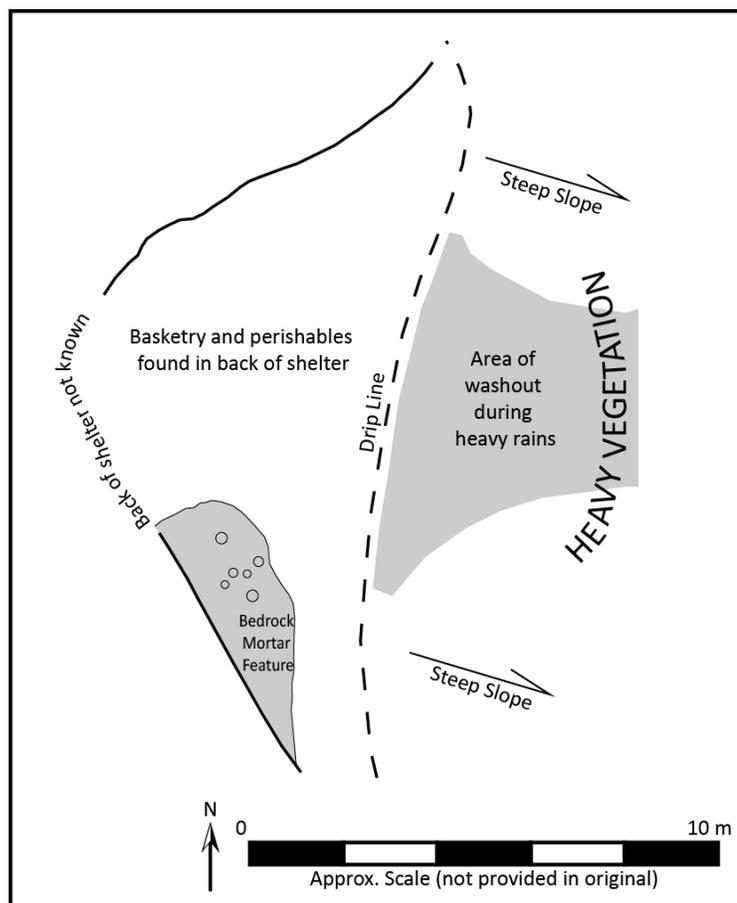
### Site Background

Kathy's Rockshelter is located in the northwestern Sierra Nevada foothills along the eastern facing slope of a northwest to south trending ridge (Morgan Ridge) at an elevation of 350 meters (1150 feet), and approximately 250 meters (820 feet) upslope from Dry Creek. The rockshelter is situated on a steep front slope (over 50%) of an ephemeral drainage along the lower shelf of a lava flow formation that consist of two layers of exposed rock outcroppings, shelters, and overhangs that form the western edge of a canyon (Figure 3). The front of the shelter lacks accumulated sedimentation due to the drainage that flows over the rock outcroppings. The site exhibits a shallow interior with a low hanging roof and measures 50 feet by 30 feet from the dripline to the backwall of the cave (Figure 4).



**Figure 3. View of Kathy's Rockshelter from the east across Dry Creek.**

The natural environment is within an Upper Sonoran biotic zone characterized by a mix of blue oak woodland, gray pine, and chaparral foothill vegetation zone. Flora such as blue (*Quercus douglasii*) and interior live (*Q. wislizenii*) oak, gray pine (*Pinus sabiana*), and an understory of chaparral shrubs such as wedgeleaf ceanothus (*Ceanothus cuneatus*), whiteleaf manzanita (*Arctostaphylos viscida*), and poison oak (*Toxicodendron diversilobum*). A variety of native perennial bunch grass and annual forbs, as well as introduced invasive species, are typical of the region (Davis et al., 2016).



**Figure 4. Sketch Map of CA-BUT-301 from Fisher (2020), adapted from original hand sketched map**

Common mammalian species of the area include mule deer (*Odocoileus hemionus*), black bear (*Ursus americanus*), coyote (*Canis latrans*), California ground squirrel (*Citellus beecheyi*), pocket gopher (*Thomomys* sp.), jackrabbit (*Lepus californicus*), and the two species of concern, *S. audubonii* and *S. bachmani*, along with other small terrestrial mammals. Fish, such as native minnows and possibly anadromous salmonids, and freshwater mussels (*Margaritifera* sp.) may have been available in Dry Creek and Butte Creek, but more likely from the Feather River. Various birds and reptiles of lesser economic importance would have been available in Dry Creek canyon and adjacent Morgan Ridge as well.

The site area is within the Butte Creek watershed and several freshwater sources (i.e., springs, seeps, Dry Creek) are near the rock shelter (California State University, Chico, 1998). The watershed supports a diverse mosaic of floral and faunal resources exploitable for subsistence, utilitarian tools, or religious practices by aboriginal people that occupied the area. The site area and surrounding region is within the ancestral home of the northeastern Maidu (or Konkow) (see Chapter 2).

The site was originally excavated from 1969 to 1971 by archaeological staff and students from California State University, Sacramento (Sacramento State) led by graduate student Stephen Humphries. The assemblage is curated at the Archaeological Curation Facility at Sacramento State (Accession 81-13). Except for a thesis on projectile point typology (Bethard 1988), most of the cultural material was not systematically analyzed until 2013 (Fisher 2018b, 2020). At that time, undergraduate and graduate students began piecing together the archival records and analyzing the cultural material. The relatively dry

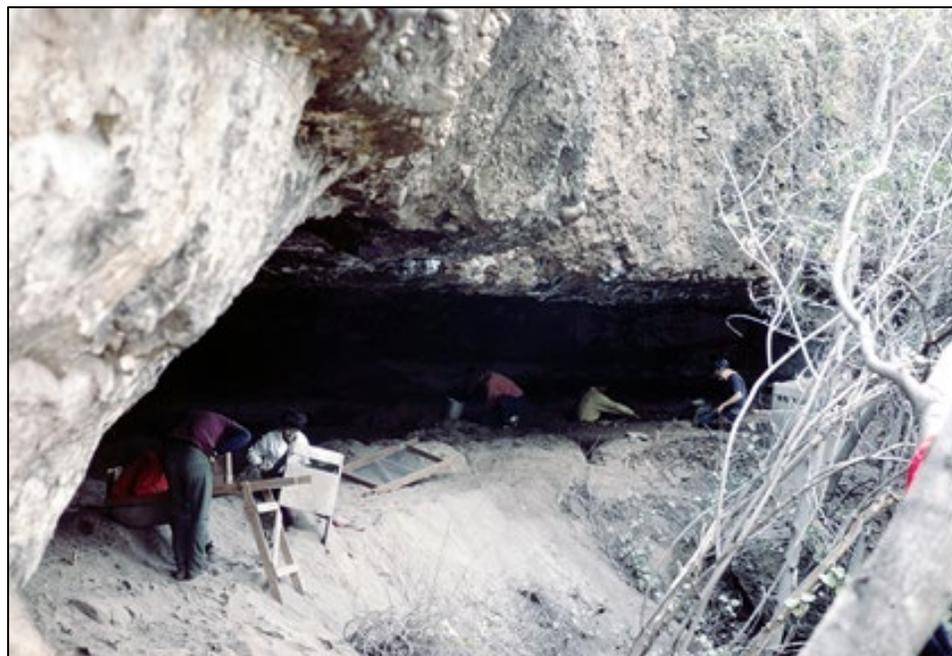
conditions of the rockshelter provided a favorable environment for preservation of the archaeological deposit. The assemblage is diverse, consisting of milling equipment; flaked stone tools; faunal and floral remains; preserved modified wood, basketry, cordage; and coprolites, among other artifact and ecofact classes (Fisher 2018b, 2020). Radiocarbon dates, obsidian hydration readings, and diagnostic tools indicate the site was occupied seasonally during the Mesilla, Bidwell, Sweetwater, and Oroville Complexes, and into the Historic era (Bethard 1988; Fisher 2018b, 2020).

### *Excavation History*

Humphreys surveyed the Messilla Valley, recording several sites and excavating a sample in the area to better understand the chronology and prehistoric lifeways of the region. Recognizing that CA-BUT-301 appeared relatively undisturbed upon initial discovery, Humphreys began excavations in April 1969 (Fisher 2020). Sacramento State excavations continued periodically until ending in December 1971 when the majority of the deposit had been uncovered (Figure 5) (Jerald J. Johnson, personal communication to J. Fisher 2014). Today, little sediment remains inside the shelter and the remaining bedrock has been heavily damaged, likely by recreational activities (Fisher 2020).

Data gaps in the archival field excavation records include missing profile drawings, incomplete excavation records, field notes, and a detailed site excavation map (Fisher 2018b, 2020). Review of available unit photographs, profile drawings, and excavation records were used together to establish a baseline understanding of the excavation methods and resulting data from the site (Fisher 2020). As a result of the 1969 – 1971 site

investigation, a total of 19 units (1.5 meters by 1.5 meters) were excavated at 10 centimeter arbitrary levels measured below surface (cmbs). The units were laid out in a north to south orientated grid, but the province of each unit is not well documented. Units were numbered Test Pit (TP) 1 through 19. Recovered material was dry sieved through quarter-inch and eighth-inch mesh screens.



**Figure 5. Overview of CA-BUT-301 excavation (c. 1969-1971), view approximately east to northeast, photograph courtesy of Sacramento State Archaeological Curation Facility.**

Profile drawings suggest some intact stratigraphic deposits, although bioturbation by rodents is occasionally noted in unit records. Units TP 1 and 2 were disturbed by avocational archaeologists (Fisher 2020), likely teenagers living in the region (Ron Cooke, personal communication to J. Fisher). Some features were recorded with little detail and include ash lenses, rock features, portable mortars, and a bedrock mortar feature (Fisher 2020). The depth of the units ranged from 10 cmbs to 130 cmbs, typically terminated when

excavations encountered bedrock. Column samples were extracted from TP 14 and 19. Overall, a total of 23 cubic meters of soil was excavated from the site (Fisher 2020).

### *Chronology*

Radiocarbon and obsidian hydration readings and temporal diagnostic artifacts inform the stratigraphic chronology of CA-BUT-301, providing an understanding of cultural deposit's vertical integrity and a baseline for temporal continuity comparisons (Fisher 2018b). The site chronology is based on twenty-two AMS radiocarbon dates obtained from large mammal bone collagen and paleobotanical remains from TP 13, 14, and 15, supplemented by obsidian hydration of 103 obsidian flakes and 23 tools from TP 13, 14, and 15 (Fisher 2018b). All of the obsidian hydration readings are from samples sourced using pXRF to the North Coast Ranges and Medicine Lake Highland regions. The radiocarbon dates indicate some isolated stratigraphic mixture; TP 13 produced younger dates at 40 to 50 cmbs and three dates produced from TP 14 yielded no variation in dates across depth (Fisher 2020). Samples from between 100 to 130 cmbs in depth did not yield conclusive radiometric assays. The distribution of temporal artifacts (e.g., *Olivella* beads), including Bethard's (1988) projectile point typology analysis, suggests the chronological sequence for CA-BUT-301 generally aligns with the chronology established by radiocarbon and obsidian hydration rates. Although the deepest stratigraphic context of the site was successfully dated using radiocarbon and obsidian hydration, Bethard (1988) tentatively argued large stemmed dart points recovered from the deepest levels date to the Mesilla complex.

The top two subsurface levels of the site, surface to 10, and 10 to 20 cmbs, yielded indigenously modified European manufactured goods indicative of a post-European contact occupation, representing historic use of the site around AD 1860 to 1870 (Fisher 2018b, 2020). A majority (70%) of the historic artifacts were recovered from surface to 10 cmbs (Fisher 2018b). The radiocarbon sampling at depths between 10 and 30 cmbs yielded an age between AD 1485 to 1834, a time interval that corresponds roughly with the Little Ice Age (LIA; ca. AD 1400 to 1700). Over eighty percent of recovered small side notched (c.f. desert side notched) and triangular (c.f. cottonwood triangular) projectile points dating to this time interval were recovered from these depths (Fisher 2018b). Vertical stratigraphic mixing is evident between 30 and 50 cmbs, represented by overlapping radiocarbon ages and obsidian hydration readings above and below these levels (Fisher 2018b). Acknowledging the blending of deposits between levels, Fisher (2018b) suggests the dominance of diagnostic small corner- and contracting-stemmed projectile points between these levels is indicative of habitation at CA-BUT-301 between 1150 to 450 BP, although a paucity of radiocarbon readings dating to the MCA (AD 800-1350) suggests limited use of the site during much of this time (Fisher 2018b). A date range from 1590 to 1190 BP for 50 to 100 cmbs in depth is based on the dominance of dart sized projectile points, *Olivella* bead forms, and median radiocarbon readings. Depths below 100 cmbs are suspected to date to the Mesilla Complex based on projectile point forms (Bethard 1988). In sum, dated archaeological material from CA-BUT-301 suggests the site was occupied during the Bidwell, Sweetwater, Oroville, and possibly Mesilla Complex.

*Resource Intensification and Environmental Change at Kathy's Rockshelter*

Human behavior ecology (HBE) in archaeological research is utilized as the theoretical framework under which models are constructed and employed to examine and link cultural material to human behavioral concepts within the ecological and social settings (Coddling and Bird 2015). Models developed from the HBE framework provide archaeological research with theoretical predictions about human behavior in relation to technological, social, and environmental concepts. Optimal foraging models derived from HBE are used to predict optimal human subsistence behavior within various environmental context including decisions regarding prey (Prey Choice Model) or resource patch-strategy (Patch Choice Model) (Broughton 1994, 2002). Foraging models are commonly used in zooarchaeology to formulate subsistence predictions and interpretation of archaeofaunal assemblages at several different analytical scales based on long-term consequences of hunter-gatherer decisions (Lupo 2007).

Specifically, the Prey Choice Model is based on classic economic principals and provides a framework for assessing the relative cost and benefits of different subsistence resources. The model predicts a forager will target high ranking prey (e.g., large body size species, high net return) in a patch whenever these animals are encountered, and the acquisition of lower ranked prey is dependent upon encounter rates of high-ranking resources (Broughton 1994; Lupo 2007). If local populations of high ranked prey become depressed, a decrease in their relative abundance should be reflected in an archaeofaunal assemblage and should be a measure of the reduction in encounter rates of the high-ranked prey on the surrounding landscape over time (Broughton 2010). Abundance indices are

used by zooarchaeologists to evaluate temporal shifts in high ranked prey as a measure of foraging efficiency. A decrease in foraging efficiency is marked by the increased acquisition of high-cost, lower ranked resources, a hallmark of economic intensification (Broughton 1994, Fisher 2018b).

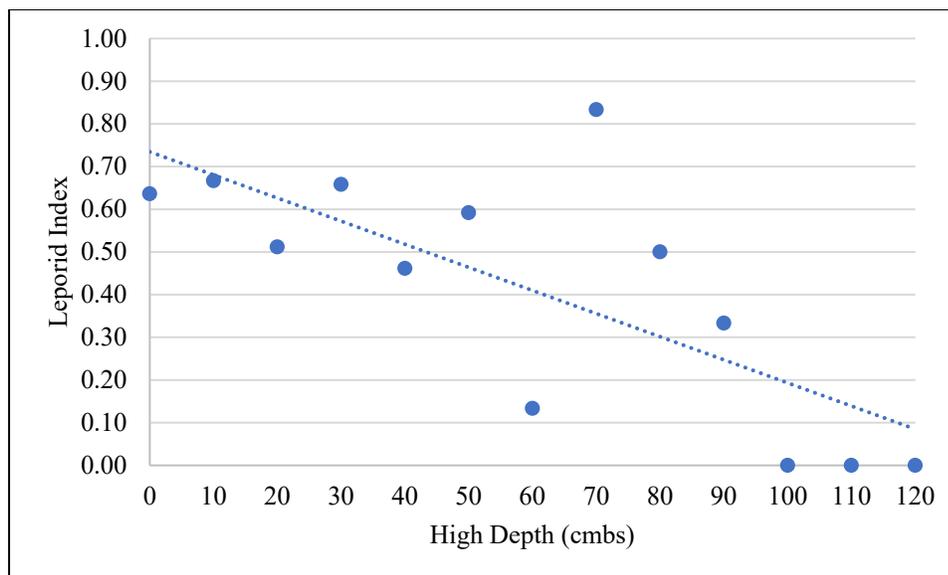
Previously conducted zooarchaeological, botanical, and tool type analysis of the assemblage from Kathy's Rockshelter suggests the habitation pattern of the site follows a subsistence procurement strategy of decreased high-ranking terrestrial resources (i.e., artiodactyls, principally *O. hemionus*) and an intensification of lower ranked resources including smaller terrestrial fauna, freshwater shellfish (*Margaritifera* sp.), and a variety of plants. A shift in the subsistence pattern occurs during the Historic period as the faunal remains from the uppermost deposits of the site indicate an increase in large bodied artiodactyls (i.e., *Cervus canadensis* and *O. hemionus*) corresponding with a deintensification of high cost resources (Fisher 2018b). This subsistence transition and rebound in abundance of large terrestrial vertebrates is possibly the result of demographic collapse of local indigenous population resulting from the direct and peripheral effects of early European contact and the spread of infectious diseases (Fisher 2018b).

Resource intensification studies that explore temporal reductions in foraging efficacy requires a control for environmental change at a site, and the leporid index is often used as a proxy measure of changes in the local environment. An abundance index was used to assess the relative frequency of leporids throughout the dated deposits of the site (Fisher 2020). The leporid index is a standardized ratio that measures the proportion of a taxa by dividing the sum of *Sylvilagus* by the sum of all leporids (*Lepus* plus *Sylvilagus*):

$$AI = \frac{\sum Sylvilagus}{\sum Sylvilagus + \sum Lepus}$$

The leporid index is commonly used to examine temporal changes in the environment (Fisher 2012; Grayson and Delpech 2005; Lyman 1991; Szuter and Bayham 1989). Jackrabbits and cottontails are tied to specific habitat and ecological requirements for their survival. Jackrabbits have the ability to quickly run from the predators and as such prefer a more open habitat. Conversely, cottontails hide from their predators and prefer more vegetative cover. Thus, the proportion of *Lepus* to *Sylvilagus* recovered from a dated archaeological context could reflect the surrounding habitat structure and changes in the environment. To statistically test whether there is a significant change in relative abundance, the index is used in conjunction with chi-square tests.

The leporid index for CA-BUT-301 illustrates a significant linear trend of decreasing abundance of black-tailed jackrabbit (*Lepus californicus*) to cottontails (*Sylvilagus* spp.) at the site ( $\chi^2 = 37.3$ ,  $p < .001$ ; Figure 6) (Fisher 2020). The index values indicate a greater occurrence of *Sylvilagus* in the uppermost deposits of the site (0 to 40 cmbs), and an abundance of *L. californicus* in the lower deposits (40 to 90 cmbs). There is no significant departure from the trend. The decreasing abundance of *L. californicus* in the upper deposits suggests the vegetation structure of the local environment became increasingly more closed over time since jackrabbits prefer open habitats to evade predators. Similarly, *S. audubonii* typically occupies moderately open habitat that lacks a dense understory of vegetation compared to *S. bachmani* (Flux and Aneermann 1990).



**Figure 6. Relative abundance of *Lepus californicus* to *Sylvilagus* (Leporid Index) by depth (Fisher 2020).**

It is expected that as climatic conditions changed from warmer and drier to cooler and wetter, the paleoenvironmental habitat and vegetation structure evolved in ways that was unfavorable for both *Lepus* and *S. audubonii*, potentially affecting their local distribution on the landscape. Considering this shift towards increased representation of *Sylvilagus* in general, it is hypothesized that the local environment changed in ways favorable to *S. bachmani* over *S. audubonii*.

### **Sample Size and Methods**

The preservation and recovery of the CA-BUT-301 faunal assemblage is ideal due to the dry conditions and depositional context of the site. The entire assemblage includes a total of 38,375 faunal remains, of which, 14,602 faunal specimens have been examined and 3,382 specimens identified to the taxonomic level of order or below (Jacob Fisher, personal communication). The remaining faunal assemblage was not analyzed due to observed

disturbances, previous non-systematic excavation by avocational archaeologists, or lack of deposit depth. At the time of analysis, *Sylvilagus* remains were not identified to species due to lack of modern comparative data, but it was suspected that both species were present based on the size differences of specimens and variation in the morphology of the lower third premolar occlusal surface (Jacob Fisher personal communication).

The specimens of *Sylvilagus* spp. recovered from the site and examined for this study included 183 specimens. The fragmentary remains include several skeletal elements of femur, mandible, scapula, innominate, ulna, calcaneus, tibia, and radius. The number of identified specimens (NISP) for *Sylvilagus* spp. among each temporal period is modest but substantial enough to identify shifts in the environment over the past 1590 years (Table 8). Archaeofaunal remains recovered from levels dating to periods of potential climatic variation are of particular interest to examine any shifts of species relative abundance during the occupation of the site.

**Table 8. Number of Identified specimens (NISP) of *Sylvilagus* spp. by excavated unit level (Fisher 2018b).**

<b>Depth (cmbs)</b>	<b><i>Sylvilagus</i> NISP</b>
0-10	26
10-20	27
20-30	19
30-40	63
40-50	19
50-60	16
60-70	4
70-80	3
80-90	5
90-100	1
100-110	-
110-120	-
120-130	-

For the present study, specimens previously identified as *Sylvilagus* were analyzed using the distinguishing metrics established in Chapter 3 with the goal of identifying which species are represented at Kathy's Rockshelter and whether their relative abundances change over time. Standard methods in zooarchaeological analysis were implemented (Driver 2011; Lyman 2008, 2019). Only adult *Sylvilagus* specimens were reviewed.

Measured skeletal elements include the mandible depth and length of the alveolar and diastema (using values provided by Fox et al., [2019] and Ramos [1999]), femur, scapula, innominate, ulna, calcaneus, tibia, and radius. All archaeological specimens previously identified as *Sylvilagus* were measured, recorded, and tabulated (Appendix B). To identify the archaeofaunal fragments to species, all measured specimens were compared to the 1- and 2- sigma standard deviation range established using modern reference samples (Chapter 3, Table 6 and 7). If a metric is within 2-sigma range, there is a 95.5% probability that the specimen belongs to the species. If a skeletal element falls within 1-sigma range, then there is a 68.3% probability that the species identification is correct. In the case of overlap between taxonomic ranges, a positive species identification was made if two additional measurements from a single specimen were within that species range. If all measurements were within the limits of both species, the specimen was categorized as *Sylvilagus* spp.

It is highlighted that this study does not include the full set of recovered *Sylvilagus* from the site. Skeletal elements excluded from the statistical analysis of modern comparatives, such as such metatarsals and the astragalus, were omitted from archaeological sample. Such elements include those not typically recovered from

archaeological contexts utilizing 1/8 inch and 1/4 inch mesh sieves (Shaffer and Sanchez 1994) and bone elements that exhibit low bone structure density (Pavao and Stahl 1999). Only measurable *Sylvilagus* specimens exhibiting epiphyseal fusion were analyzed from the archaeological assemblage. Fragmented skeletal elements no longer exhibiting the required bone morphology were also not included in this study.

## Results

### *Species Identification at CA-BUT-301*

Of the 183 identified *Sylvilagus* specimens available from Kathy's Rockshelter assemblage, 116 specimens did not meet the requirements to be included in the study. Of the remaining 65 specimens that metrics could be applied, 34 specimens were identified as *S. bachmani*, two specimens were identified as *S. audubonii*, and 32 specimens were unassigned (Table 9; Appendix B).

**Table 9. Occurrence (NISP) of *Sylvilagus* Species across Depth at CA-BUT-301, Specimens below the 95% Confidence Range for *S. bachmani* included.**

Depth (cmbs)	<i>S. bachmani</i>	<i>S. audubonii</i>	<i>Sylvilagus</i> spp.	Total
0-10	11	-	5	16
10-20	7	-	3	10
20-30	5	-	2	7
30-40	6	2	11	19
40-50	2	-	3	5
50-60	2	-	2	4
60-70	-	-	-	-
70-80	-	-	1	1
80-90	1	-	2	3
Total	34	2	29	65

Two problems were encountered when making taxonomic identifications based on metrics. First, 12 fragments were identified below the lower limit of the 95% confidence level. This may reflect regional variation in species size compared to the reference sample, or the measurements may have been conducted on fused skeletal elements, but given the fragmentary nature of the archaeological assemblage, it is difficult to know for certain whether the individuals were skeletally mature. Considering the size difference between the two species, those specimens that measured below the confidence interval for *S. bachmani* most likely belong to that species. When specimens that were not in the 95% confidence interval are removed, the total of identified *S. bachmani* is reduced to 22 (Table 10).

Second, the measurement for the depth of the mandible was excluded from this study due to potential analyst error considering that the measurements were significantly outside the range of the established reference measurements developed by Ramos (1999) for the two species. The two specimens confidently assigned to *S. audubonii* are tibia fragments (a proximal left and a distal left) from the same excavation level (Cat. No. 81-13-1321; Test Pit 13, 30-40 cmbs) that may have come from the same individual. Theoretically, the fact that specimens may have derived from the same individual could be resolved by calculating the minimum number of individuals (MNI). In this case, the calculation of MNI would potentially reduce the small sample size even further, making statistical analysis more challenging due to the decrease in sample size. Since MNI is dependent on NISP (e.g., Lyman 2008), NISP is retained in further analyses.

**Table 10. Occurrence (NISP) of *Sylvilagus* Species across Depth at CA-BUT-301, Specimens below the 95% Confidence Range for *S. bachmani* excluded.**

Depth (cmbs)	<i>S. bachmani</i>	<i>S. audubonii</i>	<i>Sylvilagus</i> spp.	Total
0-10	7	-	9	16
10-20	5	-	5	10
20-30	4	-	3	7
30-40	4	2	13	19
40-50	1	-	4	5
50-60	-	-	4	5
60-70	-	-	-	-
70-80	-	-	1	1
80-90	1	-	2	2
Total	22	2	41	65

#### *Temporal Variation in Sylvilagus species at CA-BUT-301*

Considering the Kathy's Rockshelter leporid index results, it is expected that the environment became increasingly closed and thus the frequency of *S. bachmani* should increase overtime. Despite this expectation, the results presented here indicate there is not much temporal variation in *Sylvilagus* species at Kathy's Rockshelter, as the only two *S. audubonii* specimens appear in the 30 to 40 cmbs level. These specimens are from Test Pit 13 where five obsidian hydration readings from obsidian debitage derived from Medicine Lake Highlands and two radiocarbon dates are available. The two radiocarbon dates are inconsistent of one another. A large mammal long bone shaft fragment produced a median age of 1369 rcybp, whereas a manzanita (*Arctostaphylos* spp.) seed produced a median age of 788 rcybp (Fisher 2018b).

The obsidian hydration rim readings from this excavation level range from 1.4 to 2.7 microns with a mean of 2.2 microns. The conversion rate used by Fisher (2020) produces estimated age range of 370 to 1058 BP, with a mean age of 763 BP. When the

youngest reading (1.4 microns) is treated as an outlier, the mean age is 848 BP, consistent of the OH readings from 30-40 cmbs depth elsewhere at the site that produced a mean ages of 854 BP and 875 BP (North Coast Range and Medicine Lake Highlands, respectively).

Collectively, the estimated ages place the TP 13 30-40 cmbs level at approximately 800 years old. Fisher (2020) suggests these estimated ages and the dominance of small contracting stemmed points in combination with dated *Olivella* bead types provides an estimated date of 800 BP for the 30 to 40 cmbs level. This date corresponds with the warmer and drier environmental conditions associated with the terminal MCA.

Due to the small sample size of identified specimens to species level, a Fisher's Exact Test was performed to examine temporal trends between species and dated deposits associated with the LIA (0 to 30 cmbs) and MCA (30 to 40 cmbs) (Table 11).

**Table 11. NISP of *S. bachmani* and *S. audubonii* among Dated Deposits Correlating with the Medieval Climatic Anomaly (MCA) and the Little Ice Age (LIA)**

Depth (cmbs)	Climatic Period	<i>S. bachmani</i>	<i>S. audubonii</i>	Total
0-30	LIA	23	-	23
30-40	MCA	6	2	8
Total		29	2	31

The test showed no statistically significant difference in the distribution of species among the 0-30 cmbs level and 30-40 cmbs levels ( $p = .06$ ). However, considering the nearly significant  $p$ -value, a larger sample size could produce significant results.

A second Fisher's Exact Test was performed with only specimens confidently identified to *S. bachmani* and *S. audubonii* (excluding specimens not within 95% confidence level) to examine whether results would differ (Table 12). Although this decreases the sample size, it excludes specimens that may be erroneously identified as

brushrabbit when they are potentially juvenile desert cottontails. The test results are the same as the previous analysis, and there is no statistically significant difference in the distribution of species among the 0-30 cmbs level and 30-40 cmbs levels ( $p = .06$ ). Again, a larger sample size could produce significant results.

**Table 12 NISP of *S. bachmani* and *S. audubonii* confidently identified for CA-BUT-301 from Dated Deposits Correlating with the Medieval Climatic Anomaly (MCA) and the Little Ice Age (LIA):excludes specimens not within the 95% confidence level**

Depth (cmbs)	Climatic Period	<i>S. bachmani</i>	<i>S. audubonii</i>	Total
0-30	LIA	16	-	16
30-40	MCA	4	2	6
Total		20	2	22

## Discussion

The postcranial species identification method developed from the reference sample was applied to the archaeological test case to address the following thesis goals: to distinguish the *Sylvilagus* specimens to the species level from fragmented archaeological remains, and examine if the presence or absence of the species from CA-BUT-301 can provide data on the temporal distribution of leporids, and correspondingly changes in the local environment.

Analysis of Kathy's Rockshelter leporid assemblage reflects a temporal linear trend of decreasing abundance of *L. californicus* to *Sylvilagus* spp. The results of this analysis reveals *S. bachmani* dominates the assemblage throughout the deposit, suggesting a closed local environment throughout the occupation of the site. The possible exception is the two identified specimens of *S. audubonii* that appear in the assemblage at the 30 to 40 cmbs

level. While this occurrence is not statistically significant, it illustrates the possible presence of *S. audubonii* during drier and warmer paleoenvironmental conditions (AD 1050-1150) associated with the MCA. The presence, albeit small, of *S. audubonii* during this time period is consistent with the hypothesis as expected: *S. audubonii* would expand its distribution when MCA conditions resulted in a more open vegetation structure. Although the data is statistically inconclusive, increasing the sample size using well dated sites in the area may prove successful in examining temporal shifts in resource abundance in relation to environmental conditions and human behavior.

If the local environmental conditions were conducive to *Lepus* during the earlier occupation of the site, why the lack of *S. audubonii* in older deposits? The linear trend of *L. californicus* and low frequency of *S. audubonii* in the lower deposits of the site suggest climate change may not be the primary mechanism influencing the data. Instead, I suggest that the leporid index in this case is capturing foraging efficiency rather than environmental change in the region. The ranking of a resource is determined by body size (mass) in correlation with the energetic return rate (kcal/hr) (Bayham 1979; Broughton 1994; Simms 1985). The shift from the higher ranked *Lepus* (13,475-15,400 kcal/hr; Simms 1985) to lower ranked *Sylvilagus* spp. (8,983-9,800 kcal/h; Simms 1985) at Kathy's Rockshelter could be driven by intensification processes rather than environmental conditions.

The reference sample for *S. audubonii* is small and likely not large enough to capture metric anatomical variability in size (i.e., males, females, juveniles) within the species as well as geographic variation. Several specimens from CA-BUT-301 could not be confidently identified to species due to the overlap in metrics within both species. This

is possibly the result of (1) the small sample size of the reference collection; (2) size overlap between *S. bachmani* males and *S. audubonii* females; (3) the presence of skeletally immature specimens in the archaeological assemblage; (4) taphonomic processes, such as post-depositional processes that result in fragmentation and destruction of bone; or a combination of the above. This highlights the need for a larger *S. audubonii* comparative reference sample to capture variation between the species and increase the efficiency of the method.

The general lack of postcranial skeletal elements attributed to *S. audubonii* as a result of this analysis suggest some uncertainty may remain in using the criteria developed here. As discussed above, several factors may have influenced this outcome. These results are preliminary, and a larger sample size will assist in capturing variation between species and increase the statistical power. In addition, the postcranial statistics presented here should be used in conjunction with other reliable taxa identification methods to differentiate between two closely related leporid species from archaeological and paleontological fragmented remains. Ramos (1999) suggests that the mandible is the most successful element to differentiate between leporid species, and Fox et al., (2019) recommend using a combination of sized based measurements and crenulation patterns to differentiate between species.

## Chapter 5

## DISCUSSION &amp; CONCLUSION

The first goal of this thesis research was to expand existing methods for discriminating between two closely related leporid species, *S. audubonii* and *S. bachmani*, by developing diagnostic postcranial skeletal metrics from museum reference samples of both species. The second goal was to apply the resulting metric data to fragmentary archaeofaunal remains from Kathy's Rockshelter (CA-BUT-301) in an effort to evaluate temporal shifts in the relative abundance of the two taxa as a proxy measure for the paleoenvironment over time. Kathy's Rockshelter was selected for this study because the site was occupied throughout periods of environmental climate change and is within the geographic range and boundary of both species.

Several craniometric studies exist for distinguishing leporid species from different regions of northern and western North America, including *S. audubonii* and *S. bachmani* (Dalquest et al., 1989; Findley et al., 1975; Fox et al., 2019; Neusius and Flint 1985; Ramos 1999). Prior to this study, data for postcranial morphometrics for *S. audubonii* and *S. bachmani* was non-existent in the literature. This study strived to add postcranial metrics that can be used to discriminate *Sylvilagus* species to expand existing identification measures for both zooarchaeological and paleontological purposes.

My research and analysis of *S. audubonii* and *S. bachmani* began by reviewing existing biogeography literature for both species, identify available reference samples, and conducting a total of 32 measurements of anatomical structures of skeletal elements for

adult specimens of both species. The measurements were recorded and statistically analyzed. The means and standard deviations of the 32 postcranial measurements of *S. bachmani* and *S. audubonii* proved capable of differentiating between the two California species. The proposed method and data developed here, although preliminary, can be used to discriminate between two closely related *Sylvilagus* to the species level from fragmentary archaeological remains.

Due to the lack of availability of modern post-cranial specimens combined with museum closures associated with COVID-19, the reference sample size examined for this thesis was smaller than expected and may be considered low to adequately capture variation between the species. Therefore, the results are considered preliminary and the reliability of the method would benefit from expanding the reference sample with additional specimens and examining any variation between adult males and females. Given the sample size, the method should be used in combination with other existing identification measures to identify two closely related, often difficult to distinguish, *Sylvilagus* to the species level.

The second phase of this thesis research was the application of the metrics to the Kathy's Rockshelter *Sylvilagus* assemblage. The results successfully assigned 34 specimens to *S. bachmani*, two specimens were attributed to *S. audubonii*, and 31 specimens could not be confidently assigned due to overlap between the two taxa. In general, *S. bachmani* is present throughout the lower and upper levels of the deposit (0 to 60 cmbs), and the two specimens assigned to *S. audubonii* are limited to the 30 to 40 cmbs level. Although not statistically significant, the small presence of *S. audubonii* occurs

during a warmer period (900 – 800 BP) when a more semi-open environment and preferable habitat to the species is expected. Unfortunately, the resulting sample size for this thesis was too low to confidently infer changes in local environment influenced by climatic conditions or human behavior and cultural practices.

Unfortunately, the data presented here for Kathy's Rockshelter comes short of compelling evidence to elucidate temporal climate variation and changing habitat structure in relation to the relative abundance of *Sylvilagus* spp. The lack of change in the relative frequencies of *S. audubonii* to *S. bachmani* despite temporal shifts in the leporid index suggest the index may be measuring foraging efficiency rather than local environmental trends associated with climate change, where foragers may have been increasingly exploiting smaller bodied *Sylvilagus* as part of an economic intensification process. Future work distinguishing habitat preferences of *Lepus* and *Sylvilagus* spp. in the region is necessary to fully rule out environmental factors.

#### *Future Directions*

This study provides a foundation from which future research could expand by increasing the total number of *S. bachmani* and *S. audubonii* reference samples to the existing data to ensure better accuracy for discriminating between both species. Adding metrics from more specimens would improve the reliability of the statistics and strengthen the applicability of the method.

The archaeological test case, Kathy's Rockshelter, albeit a small sample, illustrates the first application of the postcranial species identification metrics to fragmentary

archaeological remains. Future research would apply the distinguishing criteria to a larger zooarchaeological leporid sample from local northern California archaeological site assemblages that exhibit well dated chronological controls and are within the geographic distribution of both species (or in boundary areas). Application of this method to a larger archaeological dataset could potentially illustrate statistically significant results on leporid responses to climate change.

This method could likewise be used to examine the population history of *Sylvilagus bachmani riparius* in the southern San Joaquin Valley to assist wildlife managers or conservation biologist with data regarding the historic distribution of the species. The correct identification and representation of *S. bachmani* within local pre-contact zooarchaeological assemblage(s) from well dated contexts can broadly inform restoration ecologists about the biogeography of a species by providing temporal and species distribution data. The data analysis would be used as proxy to help fill in the gaps regarding the species distribution prior to European settlement in the valley, aid in habitat reconstruction, and assist wildlife managers with the implementation of species reintroduction and conservation policies.

Zooarchaeological studies are an important aspect of archaeological research and contribute to the interpretation of past human-prey acquisition relationship. Leporids are one of the most represented mammals recovered from pre-contact archaeological deposits and the identification of remains to genus or the species level can inform about human behavior and past environmental conditions. My thesis research demonstrates the potential for postcranial *Sylvilagus* archaeological fragmentary remains to be identified to the

species level and contributes to improving and expanding existing methods of zooarchaeological analysis and species identification. The application of this method (in conjunction with other existing identification methods) to other dated archaeological sites in the region could increase our understanding and interpretation of the species changing abundances in respect to forager-prey relationship as a link between human behavior and the environment in which they lived.

## APPENDIX A

*S. BACHMANI* AND *S. AUDUBONII* REFERENCE SAMPLE METRICS

**Measurements of the Scapula.**

<b>Specimen #</b>	<b>Scapula GLP</b>	<b>Scapula LG</b>	<b>Scapula BG</b>
SUS MNH 1615	7.9	7.38	5.08
CSUS-MNH-1617	7.69	7.42	5.35
UCB-MVZ-63387	8.25	7.01	5.01
UCB-MVZ-51682	8.08	7.56	5.32
UCB-MVZ-51687	7.67	6.92	5.16
UCB-MVZ-51686	7.82	7.27	5.35
UCB-MVZ-51685	8.19	7.5	5.59
UCB-MVZ-51684	7.65	7.47	5.11
UCB-MVZ-51681	7.75	7.46	5.62
UCB-MVZ-51683	7.62	7.41	5.45
UCB-MVZ-51680	7.37	7.27	5.22
UCB-MVZ-18545	7.89	7.37	5.6
UCB-MVZ-47796	7.31	7.08	5.4
UCB-MVZ-29404	7.17	6.94	5.01
UCB-MVZ-63410	7.43	7.33	5.57
UCB-MVZ-63409	7.33	6.89	5.1
UCB-MVZ-63408	7.61	7.44	5.17
UCB-MVZ-63412	7.51	7.28	5.01
UCB-MVZ-63414	7.99	7.95	5.87
UCB-MVZ-63415	7.2	6.64	4.96
UCB-MVZ-63416	7.68	7.47	5.52
UCB-MVZ-63417	7.4	6.97	4.96
UCB-MVZ-63390	7.18	7.21	5.5
UCB-MVZ-63395	7.43	7.18	5.39
UCB-MVZ-63396	7.91	7.81	5.47
UCB-MVZ-63397	7.63	6.9	5.9
UCB-MVZ-63399	7.55	7.09	5.36
UCB-MVZ-63400	8.13	7.75	5.07
UCV-MVZ-63401	7.46	7.34	5.26
UCV-MVZ-63404	7.51	7.41	5.28
CSUS ACF 1-156	9.1	8.35	6.44
CSUS-ACF-1-178	10.15	7.87	6.31
CSUS-ACF-1-185	9.74	8.37	6.76
CSUC-ZAL-385	9.13	7.82	6.36
UCB-MVZ-29175	8.26	7.9	6.64
UCB-MVZ-43914	8.31	8.03	6.33
UCB-MVZ-57119	9.04	8.75	6.86
UCB-MVZ-28723	8.41	8.32	6.13
UCB-MVZ-228980	8.81	8.17	6.3

**Measurements of the Radius/Ulna. Values of 999 indicate the measurement was unavailable.**

<b>Specimen #</b>	<b>Radius/Ul na GL</b>	<b>Radius/Ul na GL</b>	<b>Radius/Ulna GLI</b>	<b>Radius/Ul na LI</b>	<b>Radius/Ul na PL</b>
CSUS MNH 1615	53.38	44.86	52.93	43.62	43.56
CSUS-MNH-1617	52.92	45.31	52.73	43.43	43.85
UCB-MVZ-63387	54.81	41.23	54.03	45.56	45.27
UCB-MVZ-51682	55.53	46.45	54.53	45.86	44.74
UCB-MVZ-51687	50.19	40.87	49.36	41.46	41.44
UCB-MVZ-51686	53.77	44.77	50.7	44.34	43.88
UCB-MVZ-51685	56.74	48.08	55.9	47.18	46.73
UCB-MVZ-51684	54.17	45.51	44.3	44.28	44.92
UCB-MVZ-51681	55.65	46.28	53.8	44.97	44.66
UCB-MVZ-51683	51.73	43.34	42.66	42.37	42.03
UCB-MVZ-51680	53.37	45.22	51.91	43.93	43.54
UCB-MVZ-18545	47.88	39.44	38.92	38.81	38.7
UCB-MVZ-47796	52.22	43.57	50.43	42.29	42.53
UCB-MVZ-29404	48.98	41.03	48.44	40.34	40.43
UCB-MVZ-63410	54.12	45.36	52.05	43.58	44.54
UCB-MVZ-63409	52.1	43.31	51.25	42.71	42.54
UCB-MVZ-63408	51.37	43.21	49.67	42.04	41.8
UCB-MVZ-63412	52.63	44.66	51.48	43.5	42.81
UCB-MVZ-63414	56.08	46.54	54.25	46.03	45.1
UCB-MVZ-63415	53.54	45.14	52.87	44.26	43.62
UCB-MVZ-63416	54.1	45.66	53.33	44.49	43.8
UCB-MVZ-63417	53.23	44.13	52.34	43.22	43.06
UCB-MVZ-63390	54.39	45.34	53.7	45.1	44.7
UCB-MVZ-63395	54.13	45.53	53.27	44.8	44.23
UCB-MVZ-63396	54.78	46.46	53.32	45.43	44.97
UCB-MVZ-63397	53.94	45.43	53.38	44.99	44.17
UCB-MVZ-63399	55.09	46.25	53.99	45.6	45.43
UCB-MVZ-63400	54.38	45.48	52.81	44.29	44.64
UCV-MVZ-63401	55.57	45.97	53.31	45.02	45.23
UCV-MVZ-63404	52.99	43.21	52.32	43.18	42.87
CSUS ACF 1-156	999	999	999	999	999
CSUS-ACF-1-178	63.54	54.67	62.13	52.77	54.03
CSUS-ACF-1-185	999	999	999	999	999
CSUC-ZAL-385	65.25	55.12	64.43	54.02	54.8
UCB-MVZ-29175	67.59	57.56	66.6	56.32	55.49
UCB-MVZ-43914	63.73	54.2	63.2	52.65	52.71
UCB-MVZ-57119	67.87	57.77	66.86	55.62	56.1
UCB-MVZ-28723	66.93	56.62	66.52	54.51	55.8
UCB-MVZ-228980	999	999	999	999	999

**Measurements of the Ulna. Values of 999 indicate the measurement was unavailable.**

<b>Specimen #</b>	<b>Ulna GL</b>	<b>Ulna SDO</b>	<b>Ulna DPA</b>	<b>Ulna BPC</b>
CSUS MNH 1615	53.05	5.28	5.38	4.42
CSUS-MNH-1617	53.57	5.68	6.18	4.67
UCB-MVZ-63387	55.57	5.58	6.36	4.68
UCB-MVZ-51682	46.37	5.68	5.84	4.87
UCB-MVZ-51687	50.38	4.69	5.59	4.64
UCB-MVZ-51686	52.75	5.16	5.86	4.52
UCB-MVZ-51685	56.46	4.92	6.02	4.69
UCB-MVZ-51684	53.31	4.84	6.02	4.42
UCB-MVZ-51681	55.41	4.86	5.82	4.77
UCB-MVZ-51683	51.27	4.85	5.81	4.6
UCB-MVZ-51680	53.37	4.77	5.62	4.66
UCB-MVZ-18545	44.94	4.29	5.11	4.12
UCB-MVZ-47796	52.3	4.73	5.32	4.43
UCB-MVZ-29404	49.25	4.45	5.33	4.19
UCB-MVZ-63410	54.11	4.79	5.57	4.47
UCB-MVZ-63409	52.23	4.91	5.62	4.76
UCB-MVZ-63408	51.28	4.86	5.71	4.53
UCB-MVZ-63412	52.61	4.69	5.63	4.59
UCB-MVZ-63414	56.15	4.52	5.96	4.61
UCB-MVZ-63415	53.44	4.86	5.64	4.18
UCB-MVZ-63416	54.12	5.13	5.55	4.63
UCB-MVZ-63417	53.17	4.88	5.76	4.19
UCB-MVZ-63390	54.36	4.79	5.47	4.35
UCB-MVZ-63395	54.18	5.2	5.59	4.44
UCB-MVZ-63396	54.5	5.09	5.61	3.19
UCB-MVZ-63397	54.26	4.9	5.53	4.75
UCB-MVZ-63399	55.66	4.74	5.23	3.86
UCB-MVZ-63400	53.67	4.74	5.25	3.38
UCV-MVZ-63401	54.43	4.73	5.41	4.47
UCV-MVZ-63404	52.94	4.56	5.39	4.34
CSUS ACF 1-156	62.46	5.52	5.8	5.05
CSUS-ACF-1-178	63.54	5.79	6.01	4.83
CSUS-ACF-1-185	65.34	5.3	6.12	4.91
CSUC-ZAL-385	64.95	5.4	6.08	4.84
UCB-MVZ-29175	67.35	5.52	6.24	4.74
UCB-MVZ-43914	63.61	5.5	6.2	4.67
UCB-MVZ-57119	67.84	5.65	6.38	4.9
UCB-MVZ-28723	67.19	5.41	6.28	4.84
UCB-MVZ-228980	999	999	999	999

**Measurements of the Radius. Values of 999 indicate the measurement was unavailable.**

<b>Specimen #</b>	<b>Radius Bp</b>	<b>Radius Bfp</b>	<b>Radius Bd</b>	<b>Radius BFd</b>
CSUS MNH 1615	4.42	999	6.58	999
CSUS-MNH-1617	4.71	999	3.28	999
UCB-MVZ-63387	4.38	999	5.28	999
UCB-MVZ-51682	4.41	999	3.81	999
UCB-MVZ-51687	4.39	3.46	3.75	999
UCB-MVZ-51686	5.13	2.57	4.97	999
UCB-MVZ-51685	4.7	2.6	4.19	999
UCB-MVZ-51684	4.49	3.38	3.77	2.89
UCB-MVZ-51681	5.02	3.25	3.65	2.41
UCB-MVZ-51683	4.67	3.58	3.81	2.87
UCB-MVZ-51680	4.62	3.18	4.69	3.86
UCB-MVZ-18545	4.58	2.82	3.94	3.87
UCB-MVZ-47796	4.69	3.92	4.33	3.92
UCB-MVZ-29404	4.4	3.36	4.28	3.81
UCB-MVZ-63410	4.63	3.39	4.18	3.95
UCB-MVZ-63409	4.87	2.25	4.63	3.81
UCB-MVZ-63408	4.52	3.12	4.26	3.6
UCB-MVZ-63412	4.69	3.15	4.28	3.78
UCB-MVZ-63414	4.72	2.99	4.25	3.34
UCB-MVZ-63415	4.6	2.22	4.25	3.59
UCB-MVZ-63416	4.76	3.18	4.54	3.74
UCB-MVZ-63417	4.72	2.56	4.3	3.76
UCB-MVZ-63390	4.55	3.39	4.34	3.49
UCB-MVZ-63395	4.88	3.63	4.21	3.48
UCB-MVZ-63396	4.74	3.53	4.38	3.61
UCB-MVZ-63397	4.67	4	4.87	3.99
UCB-MVZ-63399	4.61	3.67	4.25	3.93
UCB-MVZ-63400	4.48	3.94	4.1	3.4
UCV-MVZ-63401	4.76	3.68	4.17	3.61
UCV-MVZ-63404	4.49	4.14	4.46	3.67
CSUS ACF 1-156	5.28	2.79	4.49	4.05
CSUS-ACF-1-178	5.06	999	4.22	4.19
CSUS-ACF-1-185	5.29	999	4.86	4.15
CSUC-ZAL-385	5.07	2.51	4.91	4.18
UCB-MVZ-29175	5.21	3.19	5.63	4.6
UCB-MVZ-43914	5.14	3.87	4.49	3.5
UCB-MVZ-57119	5.45	3.67	5.12	4.21
UCB-MVZ-28723	4.92	3.04	5.03	4.3
UCB-MVZ-228980	999	999	999	999

**Measurements of the Humerus.**

<b>Specimen #</b>	<b>Humerus GL</b>	<b>Humerus Bd</b>	<b>Humerus BT</b>
CSUS MNH 1615	49.52	6.38	4.8
CSUS-MNH-1617	49.76	6.54	4.57
UCB-MVZ-63387	49.34	6.43	4.76
UCB-MVZ-51682	49.46	6.38	4.73
UCB-MVZ-51687	46.8	6.34	4.5
UCB-MVZ-51686	47.51	6.2	4.23
UCB-MVZ-51685	50.45	6.3	4.83
UCB-MVZ-51684	47	6.39	4.79
UCB-MVZ-51681	49.01	6.54	4.93
UCB-MVZ-51683	45.31	6.5	4.8
UCB-MVZ-51680	46.71	6.57	4.89
UCB-MVZ-18545	45.6	6.13	4.32
UCB-MVZ-47796	48.13	6.25	4.81
UCB-MVZ-29404	45.55	5.95	4.89
UCB-MVZ-63410	47.95	6.32	4.92
UCB-MVZ-63409	46.28	6.69	4.96
UCB-MVZ-63408	47.42	6.27	4.84
UCB-MVZ-63412	47.06	6.16	4.11
UCB-MVZ-63414	48.97	6.51	4.55
UCB-MVZ-63415	47.53	6.55	4.98
UCB-MVZ-63416	48.86	6.35	4.54
UCB-MVZ-63417	47.33	6.64	4.82
UCB-MVZ-63390	49.36	6.15	4.88
UCB-MVZ-63395	48.04	6.64	4.7
UCB-MVZ-63396	48.86	6.46	4.92
UCB-MVZ-63397	47.7	6.74	5.01
UCB-MVZ-63399	48.97	6.53	5.26
UCB-MVZ-63400	50.72	6.58	5.19
UCV-MVZ-63401	48.32	6.58	5.13
UCV-MVZ-63404	46.79	6.4	5.19
CSUS ACF 1-156	56.52	7.25	5.47
CSUS-ACF-1-178	56.21	7.24	5.9
CSUS-ACF-1-185	58.24	7.34	5.21
CSUC-ZAL-385	58.57	7.45	5.25
UCB-MVZ-29175	60.04	7.3	6.18
UCB-MVZ-43914	55.71	7.65	6.04
UCB-MVZ-57119	59.13	7.4	5.62
UCB-MVZ-28723	57.43	7.43	5.24
UCB-MVZ-228980	56.01	7.2	6.26

**Measurements of the Innominate.**

<b>Specimen #</b>	<b>Innominate</b>	<b>Innominate</b>
	<b>SB</b>	<b>SH</b>
CSUS MNH 1615	2.8	5.13
CSUS-MNH-1617	3.51	4.78
UCB-MVZ-63387	3.36	4.68
UCB-MVZ-51682	3.49	4.42
UCB-MVZ-51687	3.52	4.54
UCB-MVZ-51686	3.51	4.26
UCB-MVZ-51685	3.53	4.88
UCB-MVZ-51684	3.16	4.79
UCB-MVZ-51681	3.57	4.82
UCB-MVZ-51683	3.55	4.66
UCB-MVZ-51680	3.52	4.3
UCB-MVZ-18545	3.37	4.37
UCB-MVZ-47796	3.61	4.99
UCB-MVZ-29404	3.7	5.06
UCB-MVZ-63410	3.36	5.03
UCB-MVZ-63409	3.56	4.91
UCB-MVZ-63408	3.65	4.74
UCB-MVZ-63412	3.7	4.89
UCB-MVZ-63414	3.12	4.9
UCB-MVZ-63415	3.18	4.96
UCB-MVZ-63416	3.35	4.75
UCB-MVZ-63417	3.59	5.04
UCB-MVZ-63390	3.36	4.94
UCB-MVZ-63395	3.3	4.77
UCB-MVZ-63396	3.36	4.95
UCB-MVZ-63397	3.51	4.9
UCB-MVZ-63399	3.31	4.94
UCB-MVZ-63400	3.36	4.78
UCV-MVZ-63401	3.19	4.43
UCV-MVZ-63404	3.33	4.68
CSUS ACF 1-156	4.11	6.57
CSUS-ACF-1-178	3.68	5.84
CSUS-ACF-1-185	4.26	7.12
CSUC-ZAL-385	4.36	8.15
UCB-MVZ-29175	4.75	6.8
UCB-MVZ-43914	3.46	5.8
UCB-MVZ-57119	3.42	5.53
UCB-MVZ-28723	4.24	6.15
UCB-MVZ-228980	4.25	5.87

**Measurements of the Femur.**

<b>Specimen #</b>	<b>Femur GL</b>	<b>Femur GCL</b>	<b>Femur Bp</b>	<b>Femur BTr</b>	<b>Femur Bd</b>
CSUS MNH 1615	64.46	63.23	12.32	12.22	11.35
CSUS-MNH-1617	64.85	62.61	12.3	12.07	10.31
UCB-MVZ-63387	66.45	64.1	12.34	12.41	10.45
UCB-MVZ-51682	64.06	62.36	12.58	11.28	10.16
UCB-MVZ-51687	62.27	60.33	12.54	11.48	11.09
UCB-MVZ-51686	63.38	61.48	11.19	11.76	10.11
UCB-MVZ-51685	64.99	63.23	11.82	12.2	10.38
UCB-MVZ-51684	63.21	60.78	11.91	12.12	10.28
UCB-MVZ-51681	64.81	62.77	11.62	12.21	10.63
UCB-MVZ-51683	62.09	59.92	11.74	11.21	10.19
UCB-MVZ-51680	62.97	60.89	11.54	11.72	10.72
UCB-MVZ-18545	62.57	999	10.32	10.78	9.62
UCB-MVZ-47796	63.34	61.17	11.76	11.9	10.32
UCB-MVZ-29404	61.54	59.58	11.02	10.94	9.54
UCB-MVZ-63410	63.94	62.07	11.91	11.8	10.41
UCB-MVZ-63409	60.2	59.08	11.16	12.03	10.6
UCB-MVZ-63408	61.86	60.08	11.12	11.67	9.92
UCB-MVZ-63412	63.2	60.33	11.62	11.65	9.89
UCB-MVZ-63414	65.41	63.27	11.93	11.87	10.48
UCB-MVZ-63415	63.28	61.06	11.62	11.27	10.51
UCB-MVZ-63416	63.56	61.58	11.81	11.92	10.31
UCB-MVZ-63417	64.62	62.45	11.5	11.39	9.7
UCB-MVZ-63390	64.73	62.49	11.42	11.88	10.1
UCB-MVZ-63395	64.77	62.66	12.39	12.09	10.31
UCB-MVZ-63396	65.81	63.86	11.99	12.74	10.02
UCB-MVZ-63397	64.29	62.2	11.06	11.84	10.83
UCB-MVZ-63399	63.04	61.19	11.32	11.21	10.25
UCB-MVZ-63400	66.43	64.23	11.79	12.28	10.29
UCV-MVZ-63401	63.72	62.59	11.8	12.22	10.18
UCV-MVZ-63404	62.35	60.22	11.18	11.07	10.04
CSUS ACF 1-156	72.04	68.97	12.83	13.07	11.51
CSUS-ACF-1-178	74.01	70.47	13.07	12.73	11.75
CSUS-ACF-1-185	72.44	69.88	13.87	13.92	11.86
CSUC-ZAL-385	73.48	70.12	13.47	13.55	12.05
UCB-MVZ-29175	79.81	76.45	14.85	14.13	12.72
UCB-MVZ-43914	72.5	70.02	13.51	13.73	12.26
UCB-MVZ-57119	76.39	73.25	14.13	13.88	12.42
UCB-MVZ-28723	73.25	70.26	13.38	13.16	11.84
UCB-MVZ-228980	72.89	69.18	13.19	13.12	12.35

**Measurements of the Tibiofibula. Values of 999 indicate the measurement was unavailable.**

<b>Specimen #</b>	<b>Tibiofibula GL</b>	<b>Tibiofibula Bp</b>	<b>Tibiofibula Bd</b>	<b>Tibiofibula Dd</b>
CSUS MNH 1615	73.4	11.46	9.11	4.62
CSUS-MNH-1617	72.15	10.94	9.84	4.65
UCB-MVZ-63387	75.44	10.85	9.49	4.44
UCB-MVZ-51682	75.08	10.76	9.01	4.53
UCB-MVZ-51687	70.3	10.11	8.56	4.42
UCB-MVZ-51686	72.55	10.88	8.49	4.39
UCB-MVZ-51685	76.74	11.01	9.04	4.61
UCB-MVZ-51684	71.55	10.71	8.87	4.42
UCB-MVZ-51681	73.43	11.05	8.66	4.83
UCB-MVZ-51683	71.81	10.71	8.09	4.56
UCB-MVZ-51680	70.91	11.13	8.89	4.76
UCB-MVZ-18545	66.02	8.5	7.15	4.97
UCB-MVZ-47796	71.41	11.21	8.92	4.87
UCB-MVZ-29404	67.89	10.06	8.4	4.78
UCB-MVZ-63410	72.16	11.26	8.9	4.96
UCB-MVZ-63409	70.19	11.28	9.3	5.02
UCB-MVZ-63408	71.56	10.45	8.76	5.04
UCB-MVZ-63412	72.12	10.66	8.67	4.24
UCB-MVZ-63414	76.15	11.18	9.31	4.74
UCB-MVZ-63415	72.79	10.47	9.05	4.77
UCB-MVZ-63416	72.5	11.02	9.13	4.67
UCB-MVZ-63417	73.81	10.58	8.64	4.25
UCB-MVZ-63390	74.54	11.06	8.69	4.69
UCB-MVZ-63395	74.64	11.02	9.2	4.95
UCB-MVZ-63396	75.16	10.1	9.23	4.71
UCB-MVZ-63397	74.37	11.21	9.27	5.02
UCB-MVZ-63399	73.86	10.94	9.03	4.72
UCB-MVZ-63400	75.22	11.15	9.02	4.86
UCV-MVZ-63401	74.16	11.11	9.12	4.69
UCV-MVZ-63404	69.79	11.09	8.82	4.73
CSUS ACF 1-156	84.88	11.33	9.67	5.07
CSUS-ACF-1-178	87.35	13.05	10.28	5.22
CSUS-ACF-1-185	85.29	12.51	12.3	5.3
CSUC-ZAL-385	87.04	12.31	9.86	5.21
UCB-MVZ-29175	999	999	999	999
UCB-MVZ-43914	85.15	12.07	9.66	5.23
UCB-MVZ-57119	88.52	12.98	10.2	5.38
UCB-MVZ-28723	87.76	12.32	9.76	5.22
UCB-MVZ-228980	999	999	999	999

**Measurements of the Calcaneus. Values of 999 indicate the measurement was unavailable.**

<b>Specimen #</b>	<b>Calcaneus GL</b>	<b>Calcaneus GB</b>
CSUS MNH 1615	999	999
CSUS-MNH-1617	999	999
UCB-MVZ-63387	15.01	6.01
UCB-MVZ-51682	17.27	5.25
UCB-MVZ-51687	16.56	5.31
UCB-MVZ-51686	16.17	4.96
UCB-MVZ-51685	17.11	4.82
UCB-MVZ-51684	16.77	5.76
UCB-MVZ-51681	17.03	5.75
UCB-MVZ-51683	15.45	5.5
UCB-MVZ-51680	16.34	5.89
UCB-MVZ-18545	15.9	5.01
UCB-MVZ-47796	16.64	5.45
UCB-MVZ-29404	12.83	4.01
UCB-MVZ-63410	16.48	5.23
UCB-MVZ-63409	16.43	5.59
UCB-MVZ-63408	16.57	5.84
UCB-MVZ-63412	16.14	6.28
UCB-MVZ-63414	17.9	5.28
UCB-MVZ-63415	16.85	5.99
UCB-MVZ-63416	16.52	5.67
UCB-MVZ-63417	16.48	5.88
UCB-MVZ-63390	999	999
UCB-MVZ-63395	16.77	5.3
UCB-MVZ-63396	16.83	6.07
UCB-MVZ-63397	17.01	5.27
UCB-MVZ-63399	17.39	5.67
UCB-MVZ-63400	16.88	6.02
UCV-MVZ-63401	16.77	5.91
UCV-MVZ-63404	16.26	5.22
CSUS ACF 1-156	19.26	6.81
CSUS-ACF-1-178	19.45	7.19
CSUS-ACF-1-185	19.78	7.94
CSUC-ZAL-385	18.82	7.76
UCB-MVZ-29175	999	999
UCB-MVZ-43914	19.29	6.58
UCB-MVZ-57119	999	999
UCB-MVZ-28723	18.25	6.64
UCB-MVZ-228980	999	999

APPENDIX B

CA-BUT-301 ARCHAEOLOGICAL SAMPLE METRICS

**Measurements of the Scapula.**

<b>Cat #</b>	<b>Lab#</b>	<b>Unit</b>	<b>High Depth</b>	<b>Low Depth</b>	<b>Identified Taxon</b>	<b>Scapula GLP</b>	<b>Scapula LG</b>	<b>Scapula BG</b>
1314	0002	13	000	010	<i>S.bachmani</i>	7.54	7.1	4.27
1300	0040	12	000	010	<i>S.bachmani</i>		6.41	4.65
1293	0058	08	000	010	<i>S.bachmani</i>	7.21	7.19	4.75
1316	0006	13	010	020	<i>S.bachmani</i>		5.91	5.27
1296	0005	10	020	030	<i>S.bachmani</i>	7.42	5.28	4.82
1353	0052	15	020	030	<i>S.bachmani</i>	6.23	4.66	
1369	0069	16	030	040	<i>S.bachmani</i>	7.07	6.84	4.78
1369	0122	16	030	040	<i>S.bachmani</i>		5.24	4.63
1324	0002	13	040	050	<i>S.bachmani</i>	6.96	5.14	5.46
1372	0019	16	050	060	<i>S.bachmani</i>		6.39	4.7
1358	0003	15	050	060	<i>S.bachmani</i>		5.22	4.28

**Measurements of the Ulna.**

<b>Cat #</b>	<b>Lab#</b>	<b>Unit</b>	<b>High Depth</b>	<b>Low Depth</b>	<b>Identified Taxon</b>	<b>Ulna SDO</b>	<b>Ulna DPA</b>
1301	0058	12	010	020	<i>S.bachmani</i>	4.35	4.7

**Measurements of the Radius.**

<b>Cat #</b>	<b>Lab#</b>	<b>Unit</b>	<b>High Depth</b>	<b>Low Depth</b>	<b>Identified Taxon</b>	<b>Radius Bp</b>	<b>Radius BFp</b>	<b>Radius Bd</b>
1351	0022	15	010	020	<i>S.bachmani</i>	4.36	3.72	
1368	0009	16	020	030	<i>S.bachmani</i>	4.32	4.23	
1307	0002	12	080	090	<i>Sylvilagus spp.</i>			4.17

**Measurements of the Humerus.**

<b>Cat #</b>	<b>Lab#</b>	<b>Unit</b>	<b>High Depth</b>	<b>Low Depth</b>	<b>Identified Taxon</b>	<b>Humerus Bd</b>	<b>Humerus BT</b>
1959	015	12	020	030	<i>Sylvilagus spp.</i>	5.66	5.15
1369	0070	16	030	040	<i>Sylvilagus spp.</i>	6.14	5.14
1369	0082	16	030	040	<i>S.bachmani</i>	5.44	4.62
1967	0023	16	030	040	<i>S.bachmani</i>	5.13	4.32
1303	0018	12	040	050	<i>S.bachmani</i>	5.94	4.66
1307	0001	12	080	090	<i>Sylvilagus spp.</i>	6.08	4.98

**Measurements of the Innominate.**

<b>Cat #</b>	<b>Lab#</b>	<b>Unit</b>	<b>High Depth</b>	<b>Low Depth</b>	<b>Identified Taxon</b>	<b>Innominate SB</b>	<b>Innominate SH</b>
1314	0001	13	000	010	<i>S.bachmani</i>	3.16	4.22
1300	0041	12	000	010	<i>Sylvilagus</i> spp.	4.1	4.48
1300	0042	12	000	010	<i>S. bachmani</i>	2.67	4.45
1300	0043	12	000	010	<i>S.bachmani</i>	3.07	4.55
1301	0029	12	010	020	<i>S.bachmani</i>	2.77	3.35
1350	0023	15	010	020	<i>Sylvilagus</i> spp.	3.19	4.56
1356	0043	15	030	040	<i>Sylvilagus</i> spp.	3.01	4.81

**Measurements of the Femur.**

<b>Cat #</b>	<b>Lab#</b>	<b>Unit</b>	<b>High Depth</b>	<b>Low Depth</b>	<b>Identified Taxon</b>	<b>Femur Bp</b>	<b>Femur BTr</b>	<b>Femur Bd</b>
1300	39	12	000	010	<i>S.bachmani</i>	10.43	10.55	
1293	61	08	000	010	<i>S.bachmani</i>	10.23	10.6	
1301	28	12	010	020	<i>S.bachmani</i>			9.48
1959	62	12	020	030	<i>S.bachmani</i>			8.58
1967	20	16	030	040	<i>S.bachmani</i>	10.85	9.41	

**Measurements of the Tibiofibula.**

<b>Cat #</b>	<b>Lab#</b>	<b>Unit</b>	<b>High Depth</b>	<b>Low Depth</b>	<b>Identified Taxon</b>	<b>Tibiofibula GL</b>	<b>Tibiofibula Bp</b>
1369	0071	16	030	040	<i>S.bachmani</i>	69.35	8.56
1321	0002	13	030	040	<i>S.audubonii</i>		12.29

**Measurements of the Tibiofibula (distal end)**

<b>Cat #</b>	<b>Lab#</b>	<b>Unit</b>	<b>High Depth</b>	<b>Low Depth</b>	<b>Identified Taxon</b>	<b>Tibiofibula Bd</b>	<b>Tibiofibula Dd</b>
1336	0028	14	000	010	<i>S.bachmani</i>	7.93	4.4
1369	0071	16	030	040	<i>S.bachmani</i>	8.08	4.36
1321	0004	13	030	040	<i>S.audubonii</i>	9.36	5.47
1307	0004	12	080	090	<i>S.bachmani</i>	7.72	7.97

**Measurements of the Calcaneus.**

<b>Cat #</b>	<b>Lab#</b>	<b>Unit</b>	<b>High Depth</b>	<b>Low Depth</b>	<b>Identified Taxon</b>	<b>Calcaneus GL</b>	<b>Calcaneus GB</b>
1386	0039	18	000	010	<i>S.bachmani</i>	12.6	5.34
1316	0007	13	010	020	<i>S.bachmani</i>	15.1	5.75
1351	0016	15	010	020	<i>S.bachmani</i>	14.86	5.81
1959	014	12	020	030	<i>Sylvilagus</i> spp.	15.35	6.12
1339	0003	14	020	030	<i>S.bachmani</i>	15.96	5.77
1370	0018	16	040	050	<i>Sylvilagus</i> spp.	18.14	6.06
1303	0017	12	040	050	<i>Sylvilagus</i> spp.	15.39	6.12

**Measurements of the Mandible.**

<b>Cat #</b>	<b>Lab #</b>	<b>Unit</b>	<b>High Depth</b>	<b>Low Depth</b>	<b>Identified Taxon</b>	<b>Depth of Mandible</b>	<b>Diastema Length</b>	<b>Alveolar Length</b>
1365	0003	16	000	010	<i>Sylvilagus</i> spp.	10.47	12.56	11.26
1300	0044	12	000	010	<i>S.bachmani</i>	8.78	10.35	11.54
1300	0045	12	000	010	<i>Sylvilagus</i> spp.	9.97		12.57
1293	0056	08	000	010	<i>Sylvilagus</i> spp.	9.67	12.18	9.76
1293	0057	08	000	010	<i>Sylvilagus</i> spp.	10.13	12.92	12.44
1316	0001	13	010	020	<i>Sylvilagus</i> spp.	10.86	13.69	12.19
1350	0026	15	010	020	<i>Sylvilagus</i> spp.	10.33		12.55
1369	0063	16	030	040	<i>Sylvilagus</i> spp.	10.1	12.35	12.2
1369	0065	16	030	040	<i>Sylvilagus</i> spp.	10.11	12.88	
1369	0066	16	030	040	<i>Sylvilagus</i> spp.	10.47		12.82
1369	0096	16	030	040	<i>Sylvilagus</i> spp.	10.34	12.23	12.73
1321	0003	13	030	040	<i>Sylvilagus</i> spp.	10.72	13.43	12.35
1302	0021	12	030	040	<i>Sylvilagus</i> spp.	8.79		
1302	0022	12	030	040	<i>Sylvilagus</i> spp.	9.25	13.44 (tip broken)	10.12
1967	0018	16	030	040	<i>Sylvilagus</i> spp.	10.52	12.08	12.84
1967	0019	16	030	040	<i>Sylvilagus</i> spp.	9.63	11.89	12.2
1323	0001	13	040	050	<i>Sylvilagus</i> spp.	10.38	12.73	11.69
1324	0002	13	040	050	<i>S.bachmani</i>			
1372	0020	16	050	060	<i>Sylvilagus</i> spp.	10.27	12.88	12.94
1372	0021	16	050	060	<i>Sylvilagus</i> spp.	10.33	13.18	
1278	018	05	070	080	<i>Sylvilagus</i> spp.	9.83		12.62

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