



Pellet and scat analysis as indicators of past and present habitats
by April Charmaine H Craighead

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in
Biological Sciences

Montana State University

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Abstract:

An analysis of 738 raptor and Raven (*Corvus corax*) pellets, and 51 coyote (*Canis latrans*) scats from four different habitats within Yellowstone National Park, Wyoming was conducted to determine if pellets and scats from different habitats could be discriminated from one another based on prey species numbers and composition found within the pellets and scats. These data were then compared to paleontological data from Lamar Cave to determine whether the modern levels of Lamar Cave (<300 years) represented the local sagebrush grassland near the cave or one of the other habitats sampled.

Lamar Cave is a unique paleontological site in that it is well-dated, contains still extant species, is part of a relatively intact ecosystem and shows high affinity with the local area. These factors made comparisons between paleontological data the modern pellet and scat data relevant.

Two different methods were used to determine which habitat the modern level of Lamar Cave most closely resembled 1) the pseudo-pellet method based on reconstructing "pellets" from the disaggregated Lamar Cave data, using the known distributions of modern pellets and scats and, 2) the stratigraphic subunit method based on disaggregating the modern data to make it similar to the Lamar Cave data. These data were then used in a classification and regression tree (CART) program to determine which habitat the Lamar Cave most closely resembled using six and five of the most common small mammal taxa.

Results from the analysis indicated that the Lamar Cave data more closely resembled a habitat different from the area currently near Lamar Cave with six taxa using both methods. Results using only five taxa, indicated that the Lamar Cave data most closely resembled the local sagebrush grassland currently found near Lamar Cave.

The methodology and results from this study are relevant to the study of both modern and paleontological ecosystems; different modern habitats can be discriminated from one another based on generalist raptor, Raven and carnivore scats, and paleontological sites that are similar to Lamar Cave can be analyzed to reflect the habitats from which cave data were sampled.

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MONTANA STATE UNIVERSITY
Bozeman, Montana

December 2000

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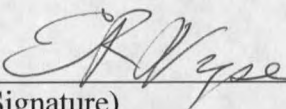
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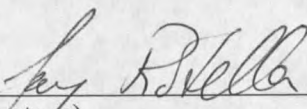
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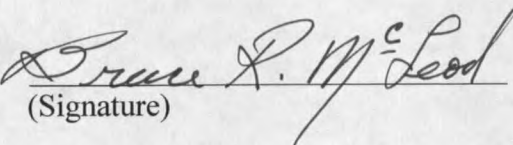
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ACKNOWLEDGEMENTS

I would like to thank Dr. Elizabeth Hadly for introducing me to the world of paleoecology, taphonomy and Lamar Cave. I would also like to thank her for seeing me through this master's degree. I would like to thank my committee for their insight, expertise, and patience in helping me finish. I especially would like to thank Dr. John Borkowski for his part in this master's thesis. Without his input, support and guidance I'm sure this project would not have been a success.

There have been many people who have influenced my life and have guided me to the end of this master's thesis. First, I would like to thank my parents for their moral support and understanding of a project that seemed very foreign to them. I would like to thank Drs. Lisa Graumlich and Emily Cobabe for their time, encouragement, and thoughtful guidance when times were difficult. Much of the insight and knowledge that I gained in this project was from the previous work of Drs. Frank and John Craighead. They were some of the pioneers in raptor research and they set a very high standard for the rest of us to follow.

I would like to thank the various individuals and institutions who provided assistance to this project; Fred Hudoff, Montana State University, Cinnabar Foundation, Scott Opler Fund, Inc. and the Mountain Research Center, Montana State University. I am grateful for the use of facilities at the Smithsonian Museum of Natural History in Washington D.C. and the Museum of Natural History in Denver.

Finally I wish to thank my husband Lance for all he's done for me.

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ABSTRACT

An analysis of 738 raptor and Raven (*Corvus corax*) pellets, and 51 coyote (*Canis latrans*) scats from four different habitats within Yellowstone National Park, Wyoming was conducted to determine if pellets and scats from different habitats could be discriminated from one another based on prey species numbers and composition found within the pellets and scats. These data were then compared to paleontological data from Lamar Cave to determine whether the modern levels of Lamar Cave (<300 years) represented the local sagebrush grassland near the cave or one of the other habitats sampled.

Lamar Cave is a unique paleontological site in that it is well-dated, contains still extant species, is part of a relatively intact ecosystem and shows high affinity with the local area. These factors made comparisons between paleontological data the modern pellet and scat data relevant.

Two different methods were used to determine which habitat the modern level of Lamar Cave most closely resembled 1) the pseudo-pellet method based on reconstructing "pellets" from the disaggregated Lamar Cave data, using the known distributions of modern pellets and scats and, 2) the stratigraphic subunit method based on disaggregating the modern data to make it similar to the Lamar Cave data. These data were then used in a classification and regression tree (CART) program to determine which habitat the Lamar Cave most closely resembled using six and five of the most common small mammal taxa.

Results from the analysis indicated that the Lamar Cave data more closely resembled a habitat different from the area currently near Lamar Cave with six taxa using both methods. Results using only five taxa, indicated that the Lamar Cave data most closely resembled the local sagebrush grassland currently found near Lamar Cave.

The methodology and results from this study are relevant to the study of both modern and paleontological ecosystems; different modern habitats can be discriminated from one another based on generalist raptor, Raven and carnivore scats, and paleontological sites that are similar to Lamar Cave can be analyzed to reflect the habitats from which cave data were sampled.

CHAPTER 1

INTRODUCTION

The foundations of paleoecology are based on the disciplines of paleontology and ecology. Paleoecology is the study of past communities (paleosynecology) or the habits and habitats of past individual species (paleoautecology) (Ager 1963, Wing *et al.* 1992). The evidence that paleoecologists use to reconstruct past communities and individual species consists primarily of the plant and animal species present in the fossil record, and their relative abundances. The fossil record is unique in that it permits observations of communities over a wide range of time intervals (10^2 to 10^7 years). Recorded within paleontological sites are clues that paleoecologists use to interpret changes in climate and ecosystems through time (Andrews 1990, Graham 1993, Guilday and Parmalee 1965, Hadly 1996, Hockett 2000, Mead and Phillips 1981).

The foundations of ecology are based on the disciplines of biology, demography and biometry (Krebs 1972). Ecology is the study of relationships between organisms and their environment. Ecologists study species and communities that are dynamic in space but static in time; paleoecologists study species and communities that are static in space but dynamic in time (Ager 1963). Ecological processes and species composition of the present are studied to predict future changes in plant and animal species and to infer past changes in similar plant and animal species. Although, modern ecological and paleontological viewpoints may differ, questions arise that can be addressed by comparing species and habitats from the past found within paleontological sites, with similar species and habitats of the present.

To make comparisons of past conditions with present conditions requires the assumption that species found in paleontological sites are representative of the habitat from which they were sampled. The purpose of this paper is to address the question of whether or not paleontological sites accurately represent the habitats from which they were sampled. Thus, processes and biases that contribute to a paleontological site must be clearly understood. Biases such as temporal gaps or an interruption in deposition, "time-averaging", and taphonomy may skew the interpretation of a paleontological site (Andrews 1990, Behrensmeyer 1984, Graham 1993).

A degree of time-averaging occurs as a feature in many fossil sites since many fossils of different ages may be found in the same stratigraphic unit. Time-averaging can occur within a fossil site as a result of various biological and physical mechanisms that mix older and younger materials together. Mechanisms that can contribute to time-averaging are: 1) mixing before burial, 2) bioturbation, 3) mixing of older fossils into younger sediments, 4) mixing of younger remains into older sediments, and 5) mixing by subsurface sediment flow (Andrews 1990, Graham 1993). Any one of these factors may time-average a paleontological site by a decade, century, millennium or more (Behrensmeyer 1972).

Taphonomy is the process by which organisms are culled from the environment and accumulate within a paleontological site. Taphonomy is the sum of all of the processes influencing fossil remains beginning with death to lithification to collection (Andrews 1990, Behrensmeyer 1972, Bonnicksen 1986, Brain 1981). Some of the main factors contributing to taphonomy are: 1) type of death: predation or attrition, 2) the

transport of bones after death through scavenging, wind or water, 3) the weathering of bones, and 4) the loss of the organic component of bone and its replacement by minerals (Andrews 1990 Behrensmeyer 1972). With these taphonomic factors considered, the spatial scale of taphonomy within a fossil site may be very small or large depending on the type of death, whether remains were transported or not, or whether weathering has occurred. Fortunately many taphonomic processes leave distinctive traces on the fossils. If the specific traces or agents can be identified, then there is an indication of what biases may have occurred in the fossil assemblage (Behrensmeyer 1972).

Research conducted in Yellowstone National Park, Wyoming, began to answer the question of whether a paleontological site represented the habitat it was sampled from with the excavation of Lamar Cave (Hadly 1996). This cave has been extensively studied. Lamar Cave is a well-dated site near the confluence of the Lamar River and Slough Creek in the northern range of Yellowstone National Park, Wyoming, USA. Analysis of Lamar Cave revealed thousands of mammalian, avian, amphibian, fish and reptilian fossils that span the last 3000 years. All species identified thus far are still present within this ecosystem. Study of the small mammal fauna represented in Lamar Cave revealed biotic responses to climatic changes at the 10^2 - to the 10^3 -year time scale during periods of both more mesic and more xeric conditions than at present (Hadly 1996). Time-averaging of samples was found to have occurred within the Lamar Cave fossil assemblage but the amount of time-averaging was found to be beneficial in interpreting the community composition. As much as 93% of the mammalian fauna

currently present in the local sagebrush grassland habitat occurs as fossils in Lamar Cave (Hadly 1999).

Over time there have been many agents that have added to Lamar Cave's fossil assemblage; these include raptors (hawk and owl), Ravens (*Corvus corax*), mammalian carnivores, and wood rats. The main collecting agent for the mammalian fossils in Lamar Cave is the bushy-tailed wood rat (*Neotoma cinerea*) which collects a variety of bones, pellets, scats, and vegetation for its midden. The Lamar Cave assemblage contains prey remains from several sources which have been aggregated primarily by wood rats over the history of the cave. Raptors and Ravens regurgitate pellets that contain the undigested remains of their latest meal. Carnivores such as wolves (*Canis lupus*) and coyotes (*Canis latrans*) produce scats containing prey remains and leave bones in the form of carcasses. Pellets, scats, and bones are collected by wood rats and cached in their middens. Thus fossil middens from Lamar Cave represent many raptor and raven pellets and carnivore scats amassed over time. Bones remaining from the pellets and scats in caves where they are well protected are then studied to reconstruct past species communities and to infer climate (Andrews 1990, Hadly 1996, Hockett 2000).

Hadly (1999) studied the relationship between modern pellets and scats and the fossil deposits in Lamar Cave by collecting raptor and raven pellets, carnivore scats, and by conducting small mammal trapping in order to sample the current small mammal community adjacent to Lamar Cave. Her results indicated that rank order abundance was similar between the raptor pellets, carnivore scats and Level 1 of Lamar Cave, which was radiocarbon dated as modern. The research described herein extends Hadly's study by

first assessing whether raptor and raven pellets and carnivore scats from four different habitats contained a "signature" that was unique to that habitat. Data from one of the other modern levels from Lamar Cave (Level 3) were then compared to the modern pellet and scat data collected from four different habitats to determine whether the Lamar Cave assemblage more closely resembled one of the four habitats. One habitat, Lamar Valley, was adjacent to Lamar Cave; the others were 30 km to 60 km distant from Lamar Cave.

The objectives of this project are two-fold: 1) to determine whether different habitats within the Yellowstone ecosystem can be discriminated from one another using generalist raptor (owl and hawk) and Raven pellets and coyote scats, and 2) to determine which of these habitats the most recent levels from Lamar Cave resemble. Potential biases affecting the distribution of the data from the modern pellets and scats include prey preference of predators and variation in the home range of predators. In addition to these factors, biases that may affect the Lamar Cave fossil assemblage data include bias by wood rats in their selection of items to cache for their middens, processes of taphonomy, and possible change in the predator community over time.

This thesis is organized to include a professional paper for submission. The first 5 chapters are presented in traditional thesis format. Chapter 2 includes a description and background of the study area. Chapter 3 will discuss methods of pellet analysis. Chapter 4 addresses the food habits of raptors, ravens and coyotes in Yellowstone National Park. Chapter 5 explains the methodology used and the results obtained. Chapter 6 is written as an independent paper which will include the possible biases affecting both the modern

and paleontological datasets. The discussion and conclusions for the thesis as a whole are presented at the end of Chapter 6.

CHAPTER 2

STUDY AREA

Yellowstone National Park encompasses 8,892 km² and includes portions of three different states: Montana, Wyoming and Idaho (Rodman *et al.* 1996). The Park is situated between the 44th and 45th north parallels of latitude and the 110th and 111th west meridians of longitude (Despain 1990, Dirks and Martner 1982). Due to its intercontinental placement and mountainous terrain, Yellowstone National Park contains a variety of habitat types that in turn support diverse biological communities. The Park is located near the center of a complex relatively pristine montane ecosystem of mostly national parks, wilderness and national forest lands-the Greater Yellowstone Ecosystem which encompasses about 44,000 km².

Physiography

Yellowstone National Park can be characterized as a high elevation, forested, volcanic plateau that has been eroded to various degrees by glaciation and stream flow (Dirks and Martner 1982, Rodman *et al.* 1996). The plateau is encircled by mountains to the north, south, and east while terrain to the west gradually decreases towards the Snake River Plain. Found within the Park boundaries are the headwaters of the Snake, Yellowstone, Madison, and Gallatin rivers. The Continental Divide traverses from the southeast corner to the western boundary of the Park. The average elevation in the Park is 2,479 m, the highest elevation in the Park is at Eagle Peak (3786 m) in the southeastern part of the Park and the lowest elevation is near Gardiner (1766 m) at the northwest entrance (Dirks and Martner 1982, Rodman *et al.* 1996).

Climate and Weather

As a result of its geographic placement, Yellowstone National Park experiences a variety of weather patterns. Climate can be categorized into two broad categories: one that is common to the large valleys and central plateaus, and another that typifies the mountains and crests of the southwestern plateaus. The montane climate of the crests and plateaus is similar to the Pacific Coastal climate in that it typically receives high winter precipitation in the form of snow. The interior valleys receive most of their precipitation as rain and the climate more closely resembles that of the Great Plains and intermountain regions (Despain 1987). Annual precipitation often depends on upon the relative strengths and positions of air masses from the Pacific, Gulf of Mexico and Arctic regions. Weather fronts moving in from the west via the Columbia River – Snake River plains are slightly dried by the Coastal and Cascade ranges. Air masses from the Gulf of Mexico are moist but must travel long circuitous routes to reach the Park. Cold continental air masses from the Arctic flow southward along the Great Plains and into the Yellowstone River valley into the northern portion of the Park (Despain 1987). Hence climate and precipitation in the northern part of the Park is drier and receives less precipitation than in the southern part of the Park. In general, climate within the Park can be regarded as having long cold winters and short cool summers (Despain, 1990, Dirks and Martner 1982, Rodman *et al.* 1996).

Geology

Throughout most of the Park's history (2.7 to 0.6 billion years before present) it has been under large-scale tectonic compression. Subsequently, the area was eroded then

flooded by large inland seas, which deposited calcium carbonate, sand and clay up to 3,050 m thick. Volcanic eruptions beginning from 70 to 80 million years before present (ybp) deposited andesitic volcanic rocks throughout most of the Park. In the central part of the Park, rhyolitic volcanic rocks were deposited 2 to .076 million ybp (Despain 1990, Rodman *et al.* 1996). The rhyolitic and andesitic rock types differ in mineral content and water-holding capacity. Both factors are important in soil and plant production.

Three separate glacial periods have covered 90% of the Park with ice during the Pleistocene (early, middle and late Pleistocene). These glacial periods have greatly affected the landscape within the Park. During these periods glaciers gouged mountains and valleys, and deposited glacial till and glaciofluvial sediments throughout various regions of the Park. Evidence of the recent glacial activity can be seen in the numerous glacial erratics found throughout the Park.

Magma underneath the surface provides a unique and active heat source in certain areas of the Park. Heat generated from the magma gives rise to geysers, fumaroles, hot springs and mudpots that exist throughout the Park. Soil parent material in the thermal areas varies from extremely acid to basic. The extremes in soil types are reflected in unique assemblages of algae, bacteria, and plants (Rodman *et al.* 1996).

Study Areas

Since its inception as a national park in 1872, the land inside the boundaries of Yellowstone National Park has been set aside for preservation. A series of preservation measures resulted in minimal human alteration of habitat. Thus the natural processes that effect wildlife habitat remain mostly intact throughout most of the Park.

Four primary study areas were selected within the Park to represent varied elevation and vegetation gradients for sampling a wide range of small mammal communities (Figure 1). The study sites were located near Gardiner, Montana (Figure 2), near the confluence of Slough creek and the Lamar River in the northern part of the Park, within the vicinity as Lamar Cave (Figure 3), near Old Faithful in the western part of the Park (Figure 4), and within Hayden Valley in the central region of the Park and near Yellowstone Lake (Figure 5). Elevations at the study areas are 1733 m near Gardiner, 2066 m near Slough Creek-Lamar River, 2400 m near Old Faithful, and 2566 m in Hayden Valley.

Figure 1. The Yellowstone Study Area

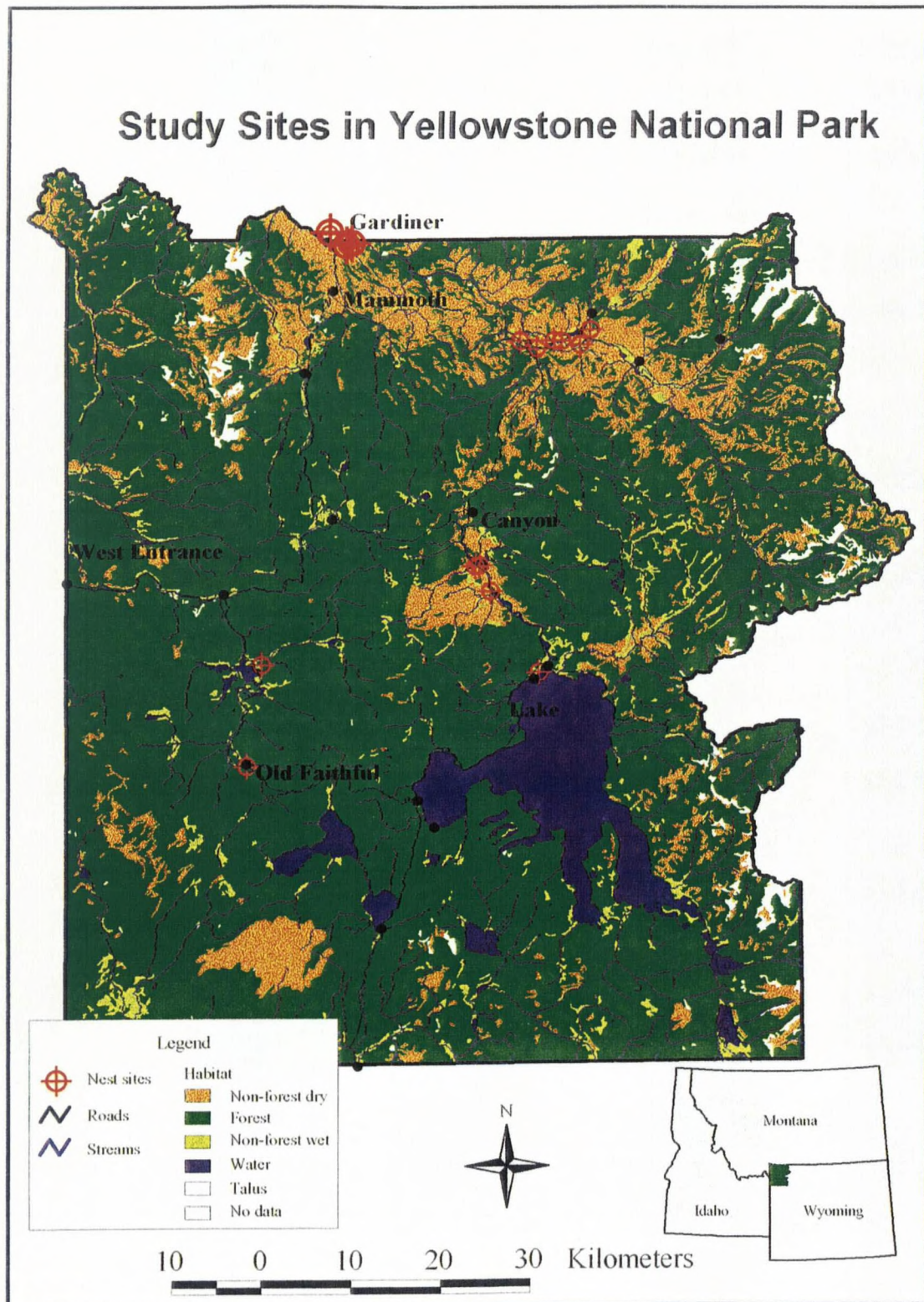


Figure 2. The Gardiner Study Area.

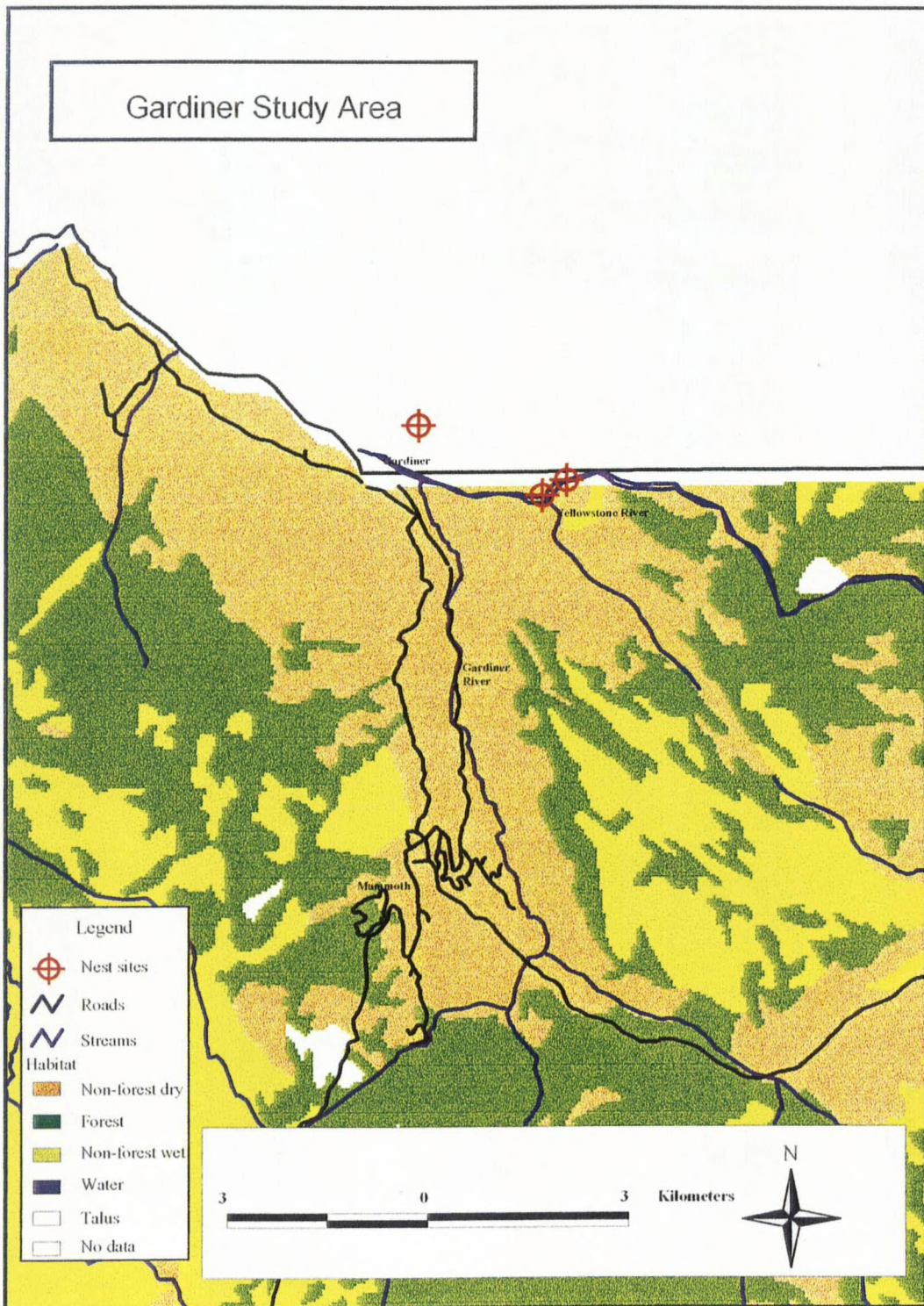


Figure 3. The Lamar Valley Study Area

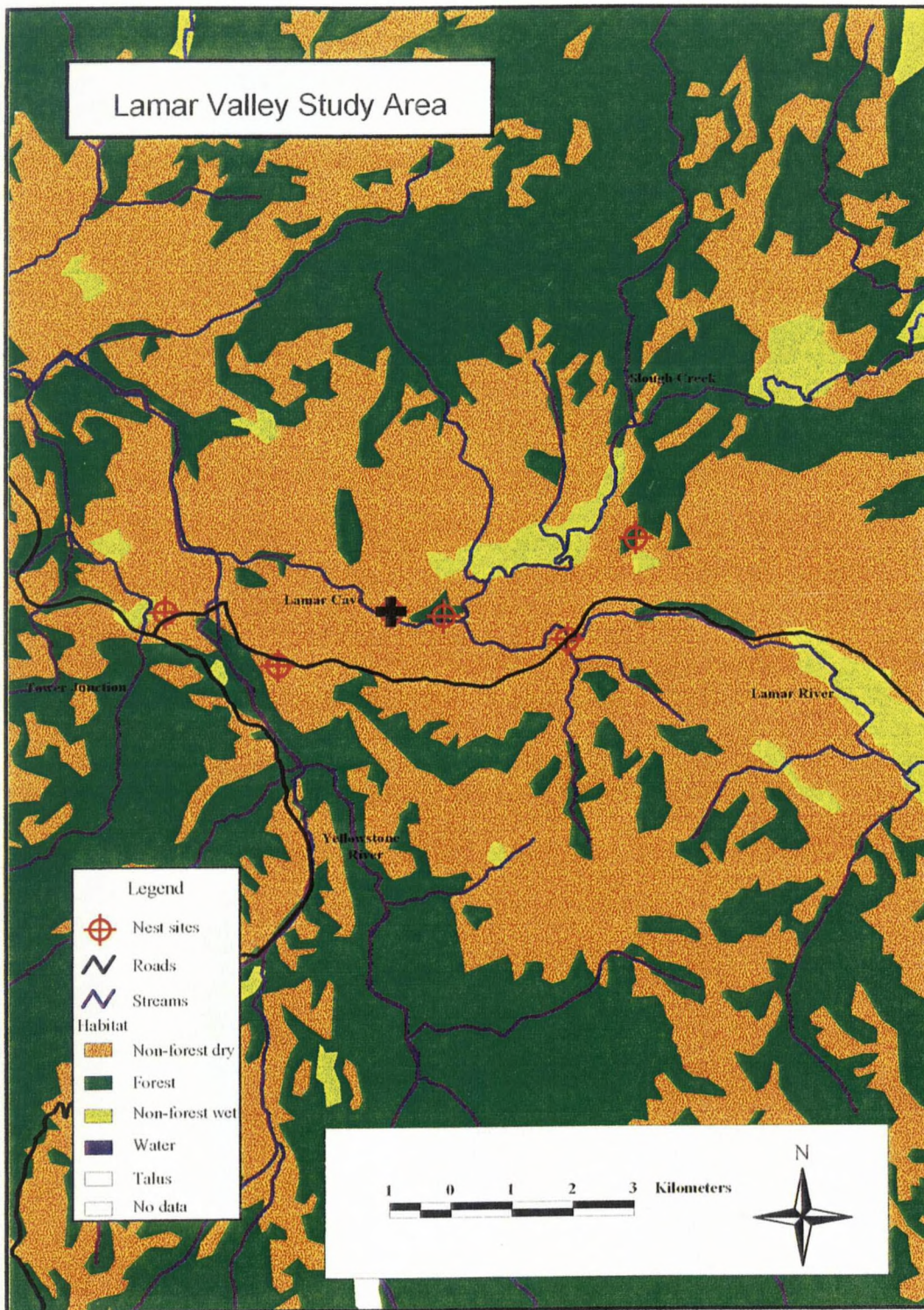


Figure 4. The Old Faithful Study Area.

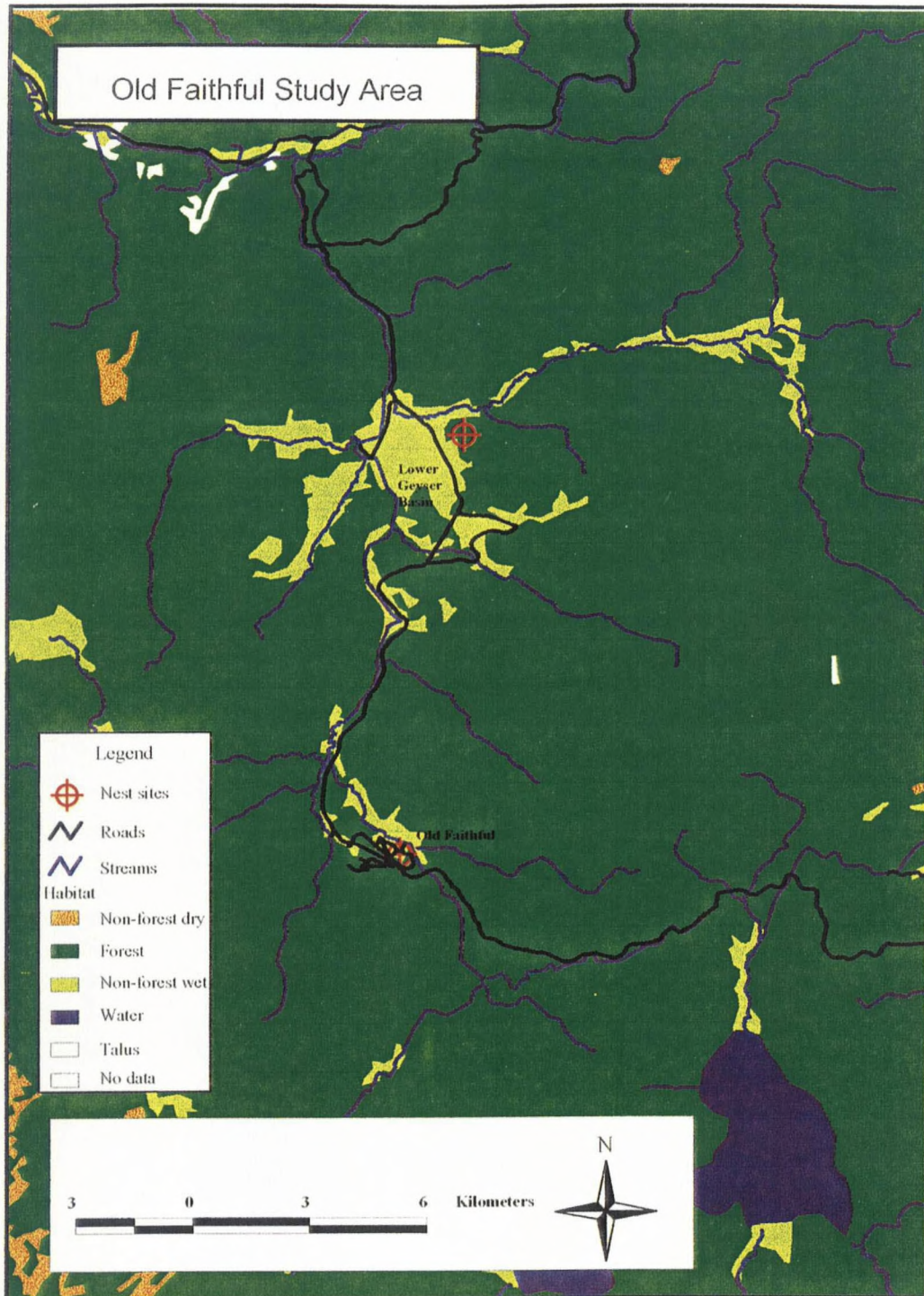


Figure 5. The Hayden Valley Study Area.

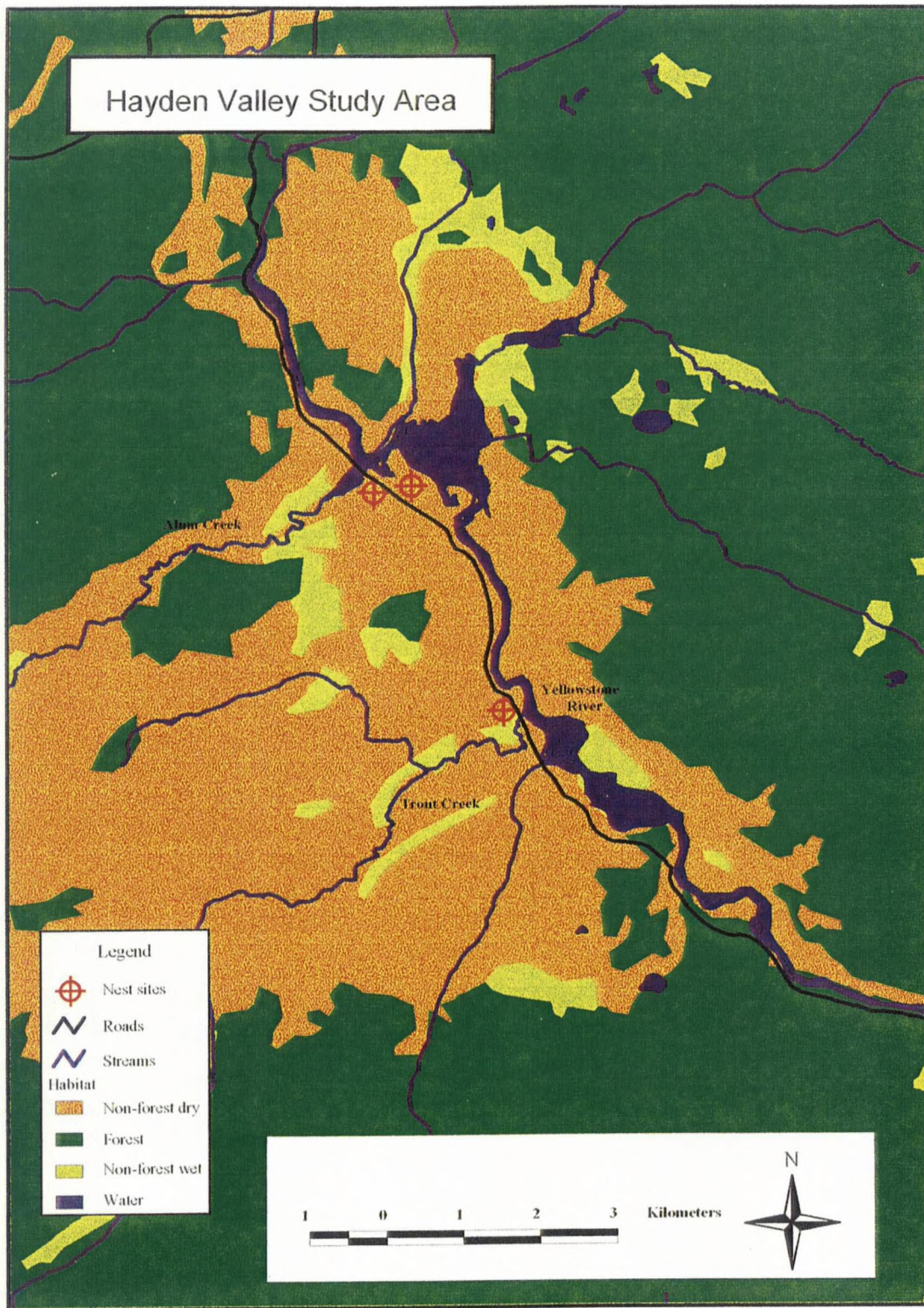
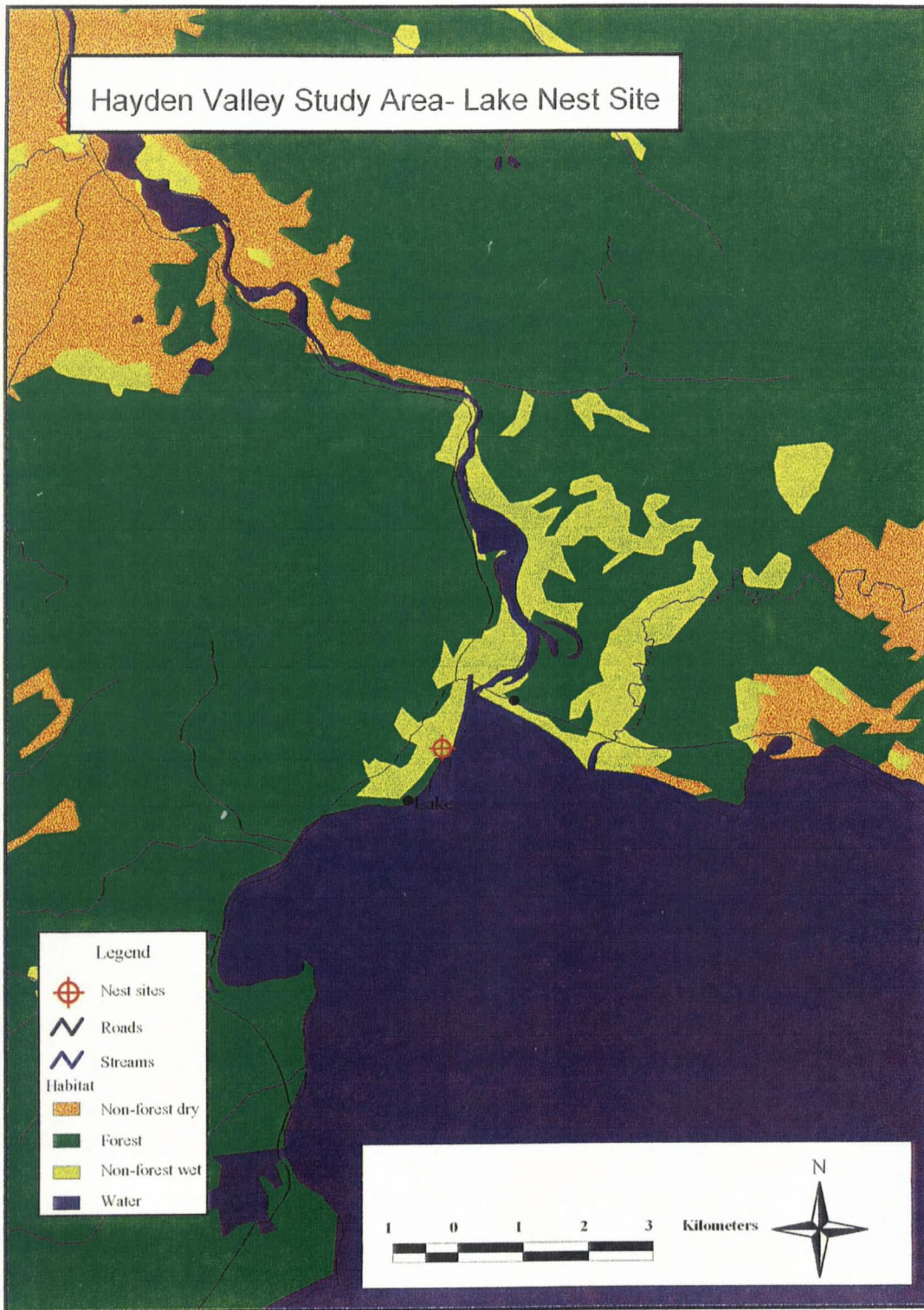


Figure 6. The Hayden Valley Study Area and the Lake nest site.



Gardiner area

The area near Gardiner is the only area in the Park that contains vegetation types similar to those found throughout the Great Basin region (Despain 1973). The Gardiner area experiences moderately arid environmental conditions and is considered primarily a dry shrubland composed of bluebunch wheatgrass (*Agropyron spicatum*) and Sandberg's bluegrass (*Poa sandbergii*). Steeper terrain supports big sagebrush (*Artemisia tridentata*). Forested areas are relatively open and are dominated by juniper (*Juniperus scopalorum*) and Douglas fir (*Pseudotsuga menziesii*). Riparian zones support narrowleaf cottonwood (*Populus angustifolia*), Douglas fir, Wood's rose (*Rosa woodii*) and sedges (*Carex* spp.) (Despain 1990, Mueggler and Stewart 1978). The area near Gardiner receives the least annual precipitation in the Park at 254 mm as recorded by the Gardiner climate station.

The low elevation arid habitat near Gardiner is habitat for a variety of ungulates, small mammals and reptiles. It is important winter range for elk (*Cervus elaphus*), pronghorn (*Antilocarpa americana*), and bison (*Bison bison*) (Singer and Mack 1999). The area supports a variety of lagomorphs including white-tailed jackrabbits (*Lepus townsendii*), desert cottontails (*Sylvilagus audubonii*), and mountain cottontails (*S. nuttali*) (Streubel 1989). The area near Gardiner is the only habitat in the Park that supports prairie rattlesnakes (*Crotalus viridis*) which are found in warm, lower elevation areas throughout its range (Koch and Peterson 1995).

Lamar area

In the Lamar Cave area, vegetation is dominated by big sagebrush and Idaho fescue (*Festuca idahoensis*). Associated species include needle-and-thread (*Stipa comata*) and bluebunch wheatgrass. North-facing aspects are dominated by Douglas fir and mallow ninebark (*Physocarpus malvaceus*) (Mueggler and Stewart 1978). The Douglas fir zone lies between 2000 m and 2333 m along the Lamar River valley. Moist swales are composed primarily of aspen (*Populus tremuloides*), shrubby cinquefoil (*Potentilla fruticosa*) and Idaho fescue. Annual precipitation in this portion in the northern range is 432 mm (Tower Falls Climate Station).

Lamar Cave is located near the confluence of the Lamar River and Slough Creek at 1860 m. Elevation within 1 km of the cave ranges from 1830 m to 1950 m. It is a shallow cave with dimensions of 6.2 m depth, 3.7 m width, and 2 m height. The cave is in a south-facing cliff trending SE, within a short canyon reach of the Lamar River (Hadly 1990). Lamar Cave is unique in its position within the Lamar area with respect to the variety of species that may be represented within the fossil assemblage. The fossils found within Lamar Cave include species associated with the Rocky Mountains and Great Plains (Hadly 1990). For a detailed description of Lamar Cave see Hadly (1990).

Vegetation within the Lamar Cave area is a sagebrush grassland comprised of microhabitats and ecotones (Hadly 1996). The Lamar area supports a large variety of ungulates, carnivores, small mammals and avian species (Johnson and Crabtree 1999). Small mammal species indicative of this sagebrush grassland are the Uinta ground squirrel (*Spermophilus armatus*), Northern pocket gopher (*Thomomys talpoides*) and the

montane vole (*Microtus montanus*). These three species occupy the different microhabitats found within the Lamar area. Voles occupy the mesic grassy microhabitats, pocket gophers utilize microhabitats rich in forbs, and Uinta ground squirrels live in the more xeric conditions of the sagebrush grassland (Hadly 1999). The Douglas fir forests within the Lamar area support shrews (*Sorex* spp.), red squirrels (*Tamiasciurus hudsonicus*), northern pocket gophers, red-backed voles (*Clethrionomys gapperi*), and deer mice (*Peromyscus maniculatus*). In more mesic areas, Western jumping mice (*Zapus princeps*) can be found (Streubel 1989).

Old Faithful area

The area surrounding Old Faithful is dominated by stands of lodgepole pine (*Pinus contorta*), and elk sedge (*Carex geyeri*). The lodgepole zone lies between 2533 to 2800 m in elevation. Soils derived from the underlying Quaternary rhyolite flows have been found to be positively associated with lodgepole pine (Despain 1973). More mesic forested areas support subalpine fir (*Abies lasiocarpus*), and bluejoint reedgrass (*Calamagrostis canadensis*) (Steele *et al.* 1983). Wet meadows support tufted hairgrass (*Deschampsia cespitosa*), redtop (*Agrostis stolonifera*), and alkali cordgrass (*Spartina gracilis*). Thermally influenced vegetation is dominated by Ross's bentgrass (*Agrostis rossiae*) and is widespread within the Old Faithful area and geyser basins. Similar to other interior regions of the Park, the Old Faithful area receives precipitation mainly in the form of snow with an average annual precipitation of 711 mm (Old Faithful climate station).

The coniferous forests around the Old Faithful area support a variety of forest dwelling species including red squirrels, yellow-pine chipmunks (*Tamias amoenus*), red-backed voles, water voles (*Microtus richardsoni*), deer mice and possibly snowshoe hares (*Lepus americanus*). Lodgepole pine forests are not considered a rich faunal area since the ground cover does not include an abundance of cover for small mammals. Small mammal trapping studies conducted in the thermal areas found only deer mice and those were found near downed trees that had fallen into the flats and near dense patches of grass (Streubel 1989).

Hayden Valley area

Hayden Valley is dominated by big sagebrush and Idaho fescue. Moist meadows contain silver sage (*Artemisia cana*) and tufted hairgrass. Riparian areas in the Valley are dominated by sedges. The soils underneath sagebrush grasslands in Hayden Valley are derived from thick layers of lake sediment laid down during the last ice age during the Pleistocene when this area was an ancient lake bed (Despain 1973). Forested areas within the Hayden Valley and Yellowstone Lake areas are composed of lodgepole pine and subalpine fir (Despain 1990). Annual precipitation for this area is 703 mm in the northern part of the Hayden valley near Canyon and 518 mm near Lake (Canyon snotel station and Lake climate station).

Like other lodgepole forests within the Park, Hayden Valley supports red squirrels, yellow-pine chipmunks, red-backed voles, deer mice, and the occasional snowshoe hare. The mesic meadows in Hayden Valley support shrews, voles, and water voles near streams and springs (Streubel 1989).

These four areas represent the majority of habitat types found within the Park. The major habitat types in each area were systematically searched by checking for active nests in trees and evidence of roosting sites beneath trees in the form of pellets. Search areas were chosen that appeared to offer typical habitat to support small mammal communities indicative of that particular habitat.

CHAPTER 3

PELLET AND SCAT ANALYSIS

Avian pellets

Since birds lack teeth, their digestive systems have evolved to specialize in processing unmasticated food. Most birds swallow their food whole, or in the case of some raptors, rip their food into smaller pieces. The major parts of a bird's digestive system: the oral cavity, esophagus, crop, two-chambered stomach (gizzard and proventriculus), liver, intestine, and cloaca, are further specialized to accommodate various diets. The digestive systems of birds extract nutrients with high efficiency from rapidly processed food. These are adaptations linked to flight and high metabolic rates (Gill 1995). Many avian species have a unique mechanism to rid themselves of the indigestible prey remains. These remains are consolidated in the gizzard in the form of a compacted pellet. Through muscle contraction the pellet is moved to the glandular stomach where the pellet, or casting, remains until it is regurgitated. Pellets are formed by a number of different birds including hawks, owls, corvids, gulls, herons and storks (Bang 1972).

Pellets have long been used to determine the diets of raptors. Many studies have investigated the validity of using pellets to analyze diet and have determined that pellets are reliable indicators of diet, and number of prey eaten, especially for owl species (Errington 1930, Craighead and Craighead 1956, Marti 1974, Salamolard 2000). Pellets are ideal for studying food habits because they tend to be localized at roosting or nesting sites and pellet collection can be accomplished without disturbing the study population

(Craighead and Craighead 1956, Duke *et al.* 1976, Engel and Young 1989). Paleontologists and archeologists have analyzed pellets that amassed over time in protected locations such as caves and rock shelters to determine small mammal communities from the past (Andrews 1990, Brain 1981, Guilday 1969, Guilday and Parmalee 1965, Hadly 1996, Hockett 2000). To understand the value of the contribution that pellets have made to various scientific disciplines, we must first examine the process of pellet formation.

The compacted pellet is formed by muscle action in the ventriculus or gizzard during digestion and passes to the proventriculus or glandular stomach where it remains until it is ejected (Kusmer 1990). A pellet consists of indigestible materials such as chitin, fur, bones, teeth, feathers, plant material and insect exoskeletons encased in fur or feathers (Hoffman 1988). Freshly cast pellets are covered by a shiny mucus which serves to ease its passage through the oesophagus and hold the contents of the pellet together (Bang 1972). Pellets from different species of birds vary in size depending on the size of the esophagus of the bird and the amount of food consumed. Larger birds have a larger esophageal diameter than a smaller bird, and therefore produce a larger pellet (Bang 1972, Hoffman 1988).

Hawks and owls differ in pellet production in several ways and these have been well studied. In contrast, little information on pellet production in corvids is available. Owls typically produce two pellets a day and egest (regurgitate) one pellet per meal usually egesting pellets during the day at roosting sites (Duke *et al.* 1976, Hoffman 1988, Kusmer 1990). Conversely, Duke *et al.* (1976) found that hawks typically egested only a

single pellet for 80% of their meals. Pellets typically are egested at dawn.

When an owl strikes its prey, damage is done to the skeleton by the talons and to the occipital region of the skull by the beak (Kusmer 1990, Mayhew 1977). Owls then swallow their prey whole or in a few large chunks. This style of eating results in skeletal elements within the pellet that remain relatively undamaged and intact. Hawks, on the other hand, use hooked beaks to divide and dismember prey. This method limits the quantity and quality of bones in the pellet and makes prey identification difficult (Mayhew 1977).

Duke *et al.* (1975) found that hawks and owls have different pH levels of gastric acid in the stomach. Hawks tended to have stronger acid levels ($\text{pH} = 1.6$) while owls tended to have weaker acid levels ($\text{pH} = 2.35$). These differences in acid levels result in profound differences in the amount of damage done to the bones and teeth within the pellet. Pellets from hawks have a substantial amount of pitting, etching, and erosion on the bones of prey species (Andrews 1990, Mayhew 1977). Several studies have tried to quantify these differences between different raptor (hawk and owl) species by looking at the breakage patterns, amount of digestive erosion, and skeletal elements represented in the pellets (Dodson and Wexlar 1979, Hoffman 1988, Korth 1979, Kusmer 1990, Mayhew 1977, photographs in Andrews 1990). These studies demonstrate significant differences between the quality of bone assemblages in the remains of different raptors and mammalian carnivores. Similar differences were apparent in the Yellowstone samples retrieved for this study as well as the Lamar Cave samples (Hadly 1999).

Coyote scats

Mammalian carnivores produce daily scats that contain prey remains. These scats then can be analyzed to determine prey species and numbers of individuals eaten. Many studies have conducted scat analysis on coyotes to determine diet composition as well as their contribution to fossil assemblages (Andrews and Evans 1983, Bekoff 1977, Crabtree and Sheldon 1999, Murie 1940). One important factor distinguishing raptor pellets from carnivore scats is that all digestion in avian predators is completed in the stomach. In mammalian carnivores digestion continues in the intestines as the food passes through the system. Digestion therefore is longer, more complex and thus more thorough in mammalian predators (Andrews 1990, Andrews and Evans 1983). Digestion in mammalian predators thus produces more fragmented bone remains and a lower percentage of identifiable ingested biomass than in raptors.

Andrews and Evans (1983) determined that canids such as coyotes do produce a species-unique signature in the remains of the bones in scats. Distinctive characteristics within coyote scats include postcranial remains that greatly outnumber cranial fragments. Skull fragments when present, are extensively broken, mandibles are fragmentary, and mandibular and maxillary processes are always broken. When present, teeth are heavily damaged, which is attributed to dental crushing by the predator.

Methods

Summer field seasons extended from May to August in 1998 and from June to August in 1999. I collected 1,236 pellets from the four different study areas (Gardiner, Lamar Cave vicinity, Old Faithful, and Hayden Valley) within Yellowstone National

Park. These study sites were selected to contrast different habitats within the Yellowstone ecosystem where raptors and Ravens are common. Pellets were collected from Red-tailed Hawks (*Buteo jamaicensis*), Swainson's Hawks (*Buteo swainsoni*), Short-eared Owls (*Asio flammeus*), Long-eared Owls (*Asio otus*), Great Horned Owls (*Bubo virginianus*), and Common Ravens (*Corvus corax*) (Table 1). I collected pellets from a total of 139 known roosting and nesting sites to ensure that the pellets collected would be from known raptors. I collected pellets from 19 different roosting sites and 3 nest sites in the Gardiner area. In the Lamar area, pellets were collected from 47 roosting sites and 8 nest sites. From the Old Faithful area, pellets were collected from 25 roosting sites and 2 nest sites. In the Hayden Valley, pellets were collected from 33 roosting sites and 2 nest sites. The total number of roosting sites utilized by the avian predators is unknown because roosting sites vary in location over time and pellets from winter roosting sites were not collected. Pellets from the different habitats were collected from nests and roosting sites approximately every two weeks to once a month depending on the nesting stage of the raptors and Ravens.

Pellets were numbered in chronological order according to year collected, labeled and placed in plastic sacks. A total of 738 pellets were processed from all four habitats (Table 1). The remaining 498 pellets were not processed and are housed with the rest of the collection in the Hadly lab at Stanford University. Pellets were soaked in soapy water and allowed to dry overnight. Of the 738 pellets processed, 63 pellets did not contain any identifiable teeth or cranial elements. Of the remaining 675 pellets, 30 unbroken pellets from each species were measured to the nearest centimeter. Unbroken pellets were

assumed to be deposited during the breeding season; winter pellets become fragmented to some degree by the time the snow melts. In the case of the Short-eared Owl only eight pellets were measured. Pellets were dissected and the bones, teeth, and cranial materials were separated and identified to species when possible.

A total of 51 coyote scats were collected from 35 different sites within the four different habitats. All scats were washed and allowed to dry overnight. Seven scats did not contain any identifiable teeth or cranial elements. Scats were dissected and bones and teeth were identified to species whenever possible. Scat measurements were not taken for this study. Animal remains larger than rabbits in raptor pellets and carnivore scats were excluded from this analysis.

MNI was calculated for each pellet and scat for each of the habitats. MNI and the corresponding NISP was also calculated for each pellet and scat for the different habitats.

Table 1. Number of pellets processed by habitat and bird species in four habitats in Yellowstone National Park, Wyoming during 1998 to 1999.

Species	Gardiner		Lamar area		Cave		Old Faithful		Hayden Valley		Total
	1998	1999	1998	1999	1998	1999	1998	1999	1998	1999	
RTHA	0	0	30	35	0	13	0	0	0	0	78
SWHA	0	0	0	0	0	0	0	0	0	41	41
SEOW	0	0	0	0	0	0	0	0	25	9	34
LEOW	0	0	0	0	0	0	0	0	0	49	49
GHOW	69	30	62	31	71	34	0	0	0	0	297
CORA	10	32	52	38	0	14	0	0	0	30	176
Total	141		248		132		154		675		

RTHA = Red-tailed Hawk
 SWHA = Swainson's Hawk
 SEOW = Short-eared Owl
 LEOW = Long-eared Owl
 GHOW = Great Horned Owl
 CORA = Common Raven

Results

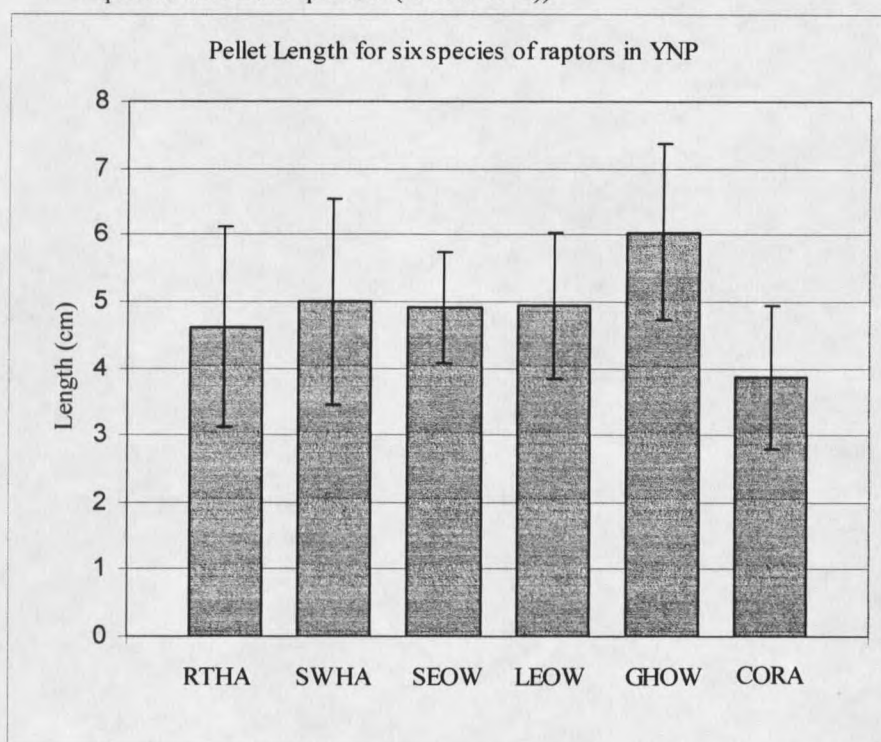
Minimum numbers of individuals (MNI) were determined and number of identified specimens (NISP) was calculated for each pellet and scat (Grayson 1978). MNI represents the absolute minimum number of individuals represented in a sample based on the maximum number of a single skeletal element in a collection. For this study, species identifications were from cranial elements, particularly teeth. NISP differs from MNI in that each element identified within the sample is included in the total; teeth and cranial elements are summed together. NISP thus approximates a maximum number of individuals.

Pellet analysis of 675 pellets identified 1,520 minimum number of individuals (MNI) that include small mammals, birds, amphibians, reptiles and fish. Number of identified specimens (NISP) for the 675 pellets was 12,440. Analysis of 44 coyote scats resulted in a MNI of 185. NISP for the carnivore scats was 1,369. Total MNI for pellets and scats was 1,705 and NISP was 13,809. Individual insects (N = 845) were identified from the pellet and scat sample representing seven different families of three different orders (See chapter 4). No further analysis was conducted on the insects identified.

Pellets from the different species of raptors in Yellowstone varied from one another in size (Figure 6), texture, and smell. Color of the pellet varied and typically reflected the fur color of the prey species most recently eaten. Great Horned Owls had the largest pellets and ravens had some of the smallest pellets in this study. Pellets from all of the owl species were sausage-shaped, compact, and with many of the skeletal elements present and intact. Within the Great Horned Owl pellets, mandibles were frequently

intact while the skull was usually fragmented in the occipital region. Short-eared and Long-eared Owls had similar pellets but they were smaller and narrower than the Great Horned Owl pellets. Skeletal elements from the pellets of Short-eared and Long-eared Owls also were generally intact, and had little erosion or pitting; mandibles and skulls were usually intact with very little breakage.

Figure 7. Pellet length and standard deviation of six species of raptors in Yellowstone National Park (N= 30 pellets from each species. (SEOW N=8)).



RTHA = Red-tailed Hawk
 SWHA = Swainson's Hawk
 *SEOW = Short-eared Owl
 LEOW = Long-eared Owl
 GHOW = Great Horned Owl
 CORA = Common Raven

The pellets from Red-tailed and Swainson's Hawks were similar to each other but were very different from the owl species. Pellets from both of these species were relatively large in size and the contents were loosely contained within the pellet. Over

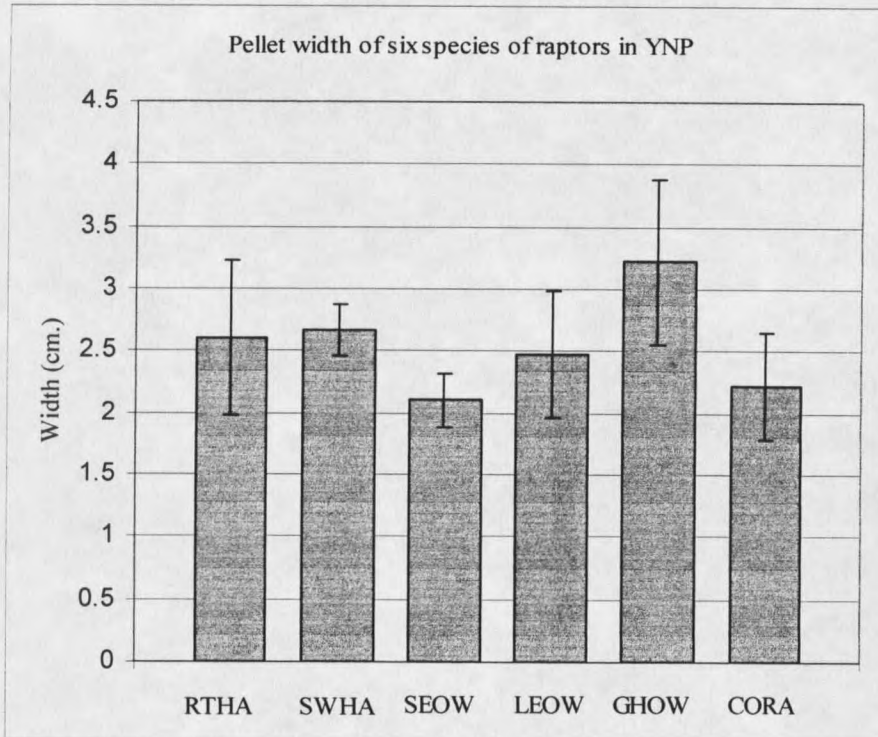
time, these pellets tended to become 'stringy' in shape as they degraded. In the pellets of both hawk species there were fewer identifiable skeletal elements than in owl pellets, and skulls and mandibles were highly fragmented and eroded. Teeth were very degraded, pitted and fragile. There tended to be a strong musk-like odor associated with the pellets collected from Red-tailed Hawks and Swainson's Hawks.

Ravens had the most diverse pellets in size and shape. Pellets were usually sausage-shaped but some were almost completely round. Raven pellets tended to be very compact and skeletal elements were present and intact. Skulls and mandibles of Raven prey species were either absent or highly fragmented but there was not the high degree of erosion and pitting that was observed in the hawk pellets. Teeth found in raven pellets were more easily identified than teeth found in hawk pellets. Raven pellets tended to have a high percentage of insect parts found within the pellets. Ravens are also known to scavenge prey from other animals or from roadkills, which could bias pellet analysis by including prey species that were scavenged on.

Pellet length and width were measured to the nearest centimeter for 30 pellets from each species of raptors and Ravens except for the Short-eared Owl in which only 8 pellets were measured. Mean pellet length and width and standard deviation were calculated for each species of raptors and Ravens (Figure 6). Mean pellet lengths were very similar between the five different raptors and Ravens within the four different study areas. The similarity in mean pellet length was especially close between Red-tailed Hawk, Swainson's Hawk, Short-eared and Long-eared Owls.

Mean pellet width from the five different raptors and Ravens were similar from the four different study areas (Figure 7). In general, pellets from Great Horned Owls had the widest pellets and Short-eared Owls and Ravens had the narrowest pellets.

Figure 8. Pellet width and standard deviation of six species of raptors in Yellowstone National Park (N=30 pellets from each species. SEOW N=8)).



RTHA = Red-tailed Hawk
 SWHA = Swainson's Hawk
 SEOW = Short-eared Owl
 LEOW = Long-eared Owl
 GHOW = Great Horned Owl
 CORA = Common Raven

Pellet analysis is a valuable tool in establishing diet estimates and number of prey eaten for a number of different raptor species (Errington 1930, Craighead and Craighead 1954, Marti 1976, Salamolard *et al.* 2000). In general, owl pellets contain the most accurate representation of species and number of prey consumed. Previous studies conducted on pellet analysis have concluded that bones and teeth from owls represented

approximately 80% to 90% of the total prey species eaten (Errington 1930, Duke 1976). The pellets from hawks are poor indicators of overall numbers of prey eaten due to eating style and pH levels in the stomach (Errington 1930, Hoffman 1987, Mayhew 1977). A complete record of pellet data is contained in Appendix A.

The distribution of MNI per pellet and scat was determined for each habitat (Figures 8-11). These different distributions of MNI from the four study areas were incorporated in data analysis in creating pseudo-pellets (See chapter 5). MNI and the corresponding NISP were determined for each of the different habitats (Figures 12-15).

Discussion

Results from other studies indicate that owl pellets reveal the most accurate picture of diet while the diurnal raptors contain many more unidentifiable elements and provide less information about the quantity and identification of prey eaten (Errington 1930, Craighead and Craighead 1956, Marti 1974). The results of this study indicate that owl pellets contained more identifiable elements than did the pellets of Red-tailed Hawks and Swainson's Hawks. Therefore the results from this study indicate that owls provide a more accurate picture of the diet than did the diurnal raptors. Raven pellets ranked somewhere in between, with skeletal elements common, but diagnostic mandibles and skulls missing. Pellets from this study revealed characteristic etching, pitting and erosion patterns from owls and hawks when viewed under a microscope.

The faunal remains within coyote scats were highly fragmented with bone and teeth mostly broken and corroded. Cranial elements were often missing or fragmented. Delicate bones from mammals, birds, amphibians and reptiles probably do not survive the

digestive process and are probably underrepresented in scats.

Pellet length and size were similar for all of the different raptors and Ravens. Due to the similarity in pellet size and shape it would be difficult to correctly identify an isolated pellet to a particular species of raptor or Raven.

The distribution of MNI per pellet and scat was quite different between the study areas. The majority of the MNI data for the Gardiner area tended to be distributed between pellets that contained a MNI of one to a MNI of five (84%). In the Lamar area, the majority of the MNI data was distributed between pellets that contained an MNI of one and an MNI of two (69.5%). In the Old Faithful area, MNI data was distributed between pellets that contained an MNI of one and an MNI of two (66%). MNI data in the Hayden Valley was distributed between pellets that contained an MNI of one to an MNI of three (87%).

Differences between the four study areas were also seen in the MNI and corresponding NISP of pellet data. The shape and patterns were different between the study areas with NISP being more evenly spread in the Gardiner area then in the other study areas. In the Old Faithful and Hayden Valley NISP data were more restricted to a MNI of one to a MNI of six. The different MNI and NISP per habitat and patterns in the MNI and NISP data indicate differences between the four study areas. Other differences that may exist between the four habitats will be explored in chapter 4.

Figure 9.

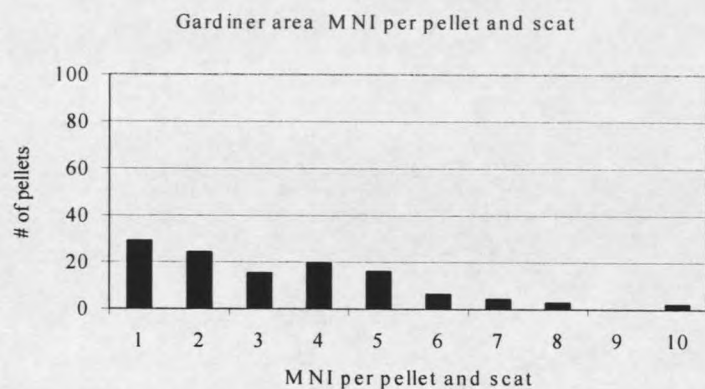


Figure 10.

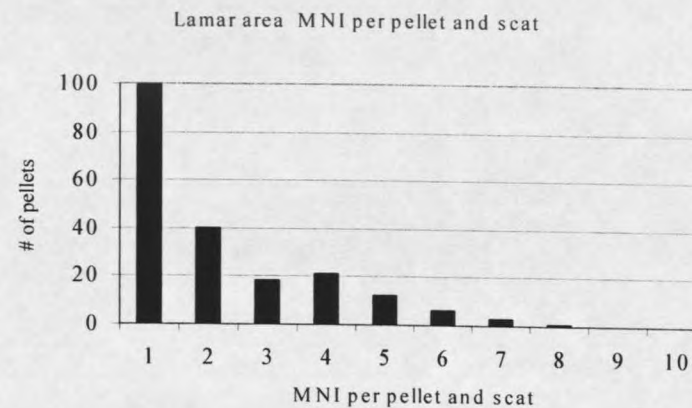


Figure 11.

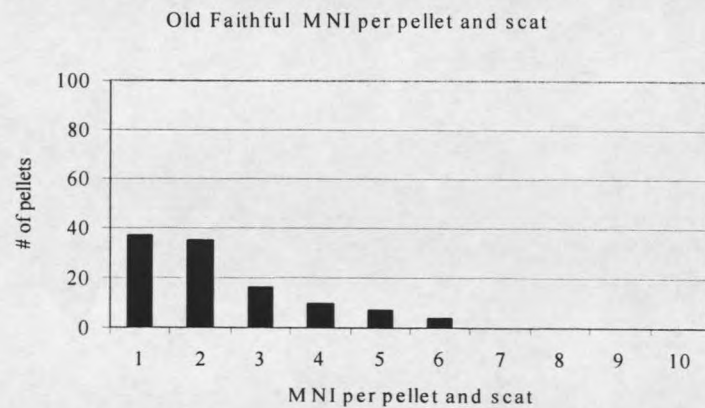


Figure 12.

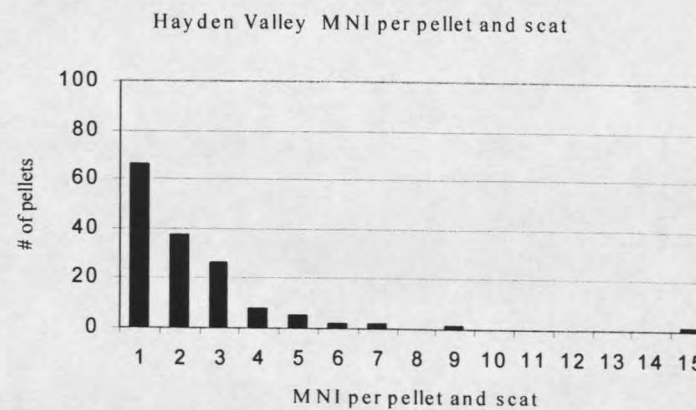


Figure 13.

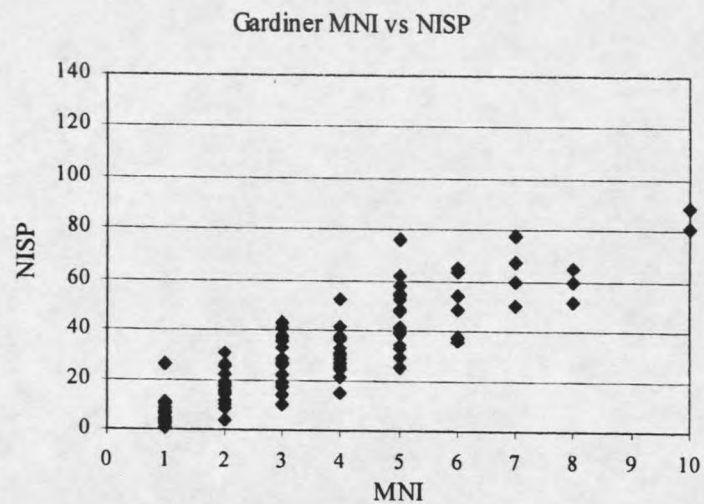


Figure 15.

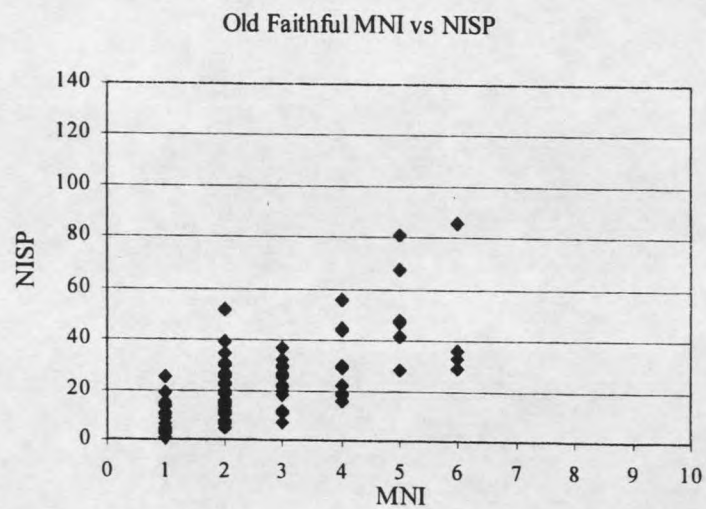


Figure 14.

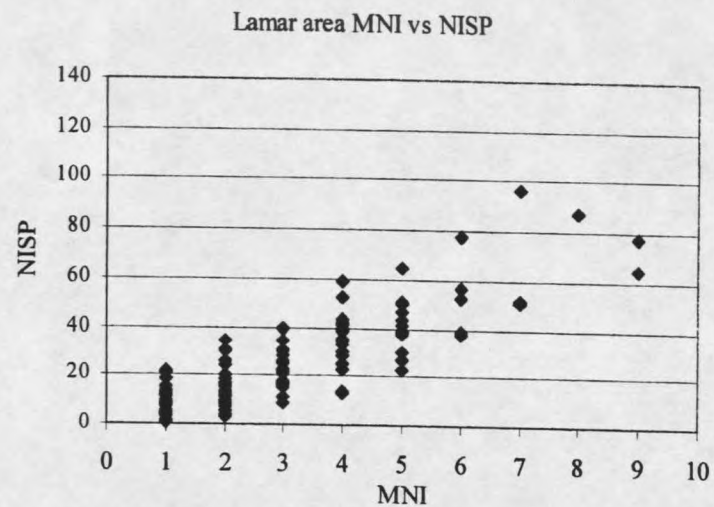
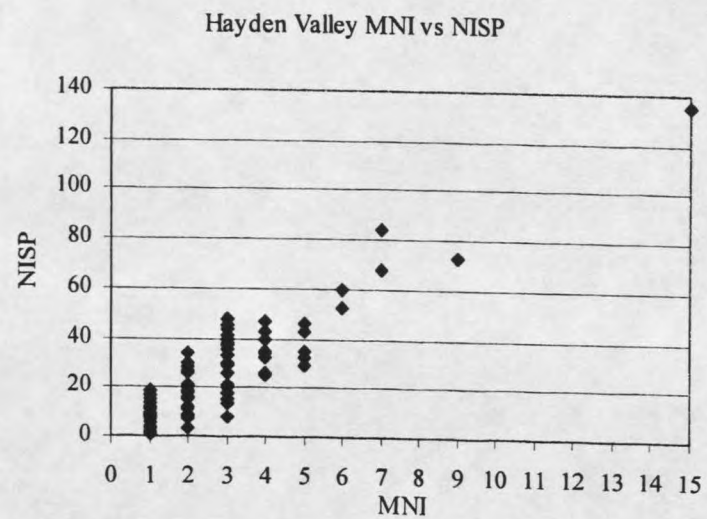


Figure 16.



CHAPTER 4

THE FOOD HABITS OF RAPTORS, RAVENS AND COYOTES FROM FOUR
HABITATS IN YELLOWSTONE NATIONAL PARK

Food habit studies have been conducted on numerous avian predators over a wide range of habitats and various geographic regions. Food habits, or diets, are determined by collecting and examining pellets and prey remains from roosts and nests, and by visual observations of predators. Many food habit studies have compared diets within families (Marti 1976, Marti *et al.* 1993), and between nocturnal and diurnal counterpart species (Craighead and Craighead 1956, Marti and Kochert 1995), between specialist and generalist species and (Steenhof and Kochert 1988, White and Cade 1971), between geographic regions (Jaksic and Marti 1986). Other studies have examined temporal variations in diets (Salamolard *et al.* 2000, Steenhof and Kochert 1988). Results from comparative diet studies reveal information on dietary overlap, life history strategy, differences between ecosystems, and predator-prey cycles. Similar studies have been conducted on mammalian predators by examining scats to determine diet (Bekoff and Wells 1986, Crabtree and Sheldon 1999, Gese *et al.* 1996, Knick 1990, Minta *et al.* 1992, Murie 1940).

The objectives of the diet aspect of this study are three-fold. The first objective was to determine the diets of selected raptors, Ravens (*Corvus corax*), and coyotes (*Canis latrans*), through the collection and examination of pellets and scats from four different habitats within Yellowstone National Park. The second objective was to determine how similar the diets of these predators were between the different habitats. The third

objective was to determine how similar to each other were the diets of raptors, Ravens and coyotes within the same habitats using diet diversity indices. Generalist raptors and Ravens were targeted to provide a sample of the greatest diversity of prey within the four study areas. Coyotes were targeted because they are the most numerous canid predator within the Park.

Avian Predators

Yellowstone National Park has a rich and diverse avian community with over 70 bird species represented (McEneaney 1996). Included in this group are approximately 20 species of raptors (hawks and owls) that are seasonal or resident individuals. Although Ravens are not taxonomically classified as raptors, they fill an ecological role very similar to raptors as their pellet contents reveal. These avian predators feed on a variety of small mammals, birds, amphibians, and reptiles and regulate prey populations to varying degrees (Johnsgard 1988, 1990, Marti 1974, Streubel 1989, White and Cade 1971). They also feed on a variety of invertebrates.

Mammalian Predators

Yellowstone National Park is unique in that it still contains the full suite of large predators found before the first Europeans arrived in the Yellowstone ecosystem (Clark *et al.* 1999). These predators include grizzly bear (*Ursus arctos*), black bear (*Ursus americanus*), gray wolf (*Canis lupus*), coyote (*Canis latrans*), wolverine (*Gulo gulo*), and mountain lion (*Felis concolor*). These predators feed on a variety of ungulates, small mammals and vegetation within Yellowstone and the adjacent national forests lands (Johnson and Crabtree 1999, Streubel 1989).

Methods

The diets of raptors and Ravens were determined by examining 675 pellets collected from four different habitats within Yellowstone National Park during the summers of 1998 and 1999. I collected pellets from Red-tailed Hawks (*Buteo jamaicensis*) representing six different breeding pairs, Swainson's Hawk (*Buteo swainsoni*) representing one breeding pair, Short-eared Owl (*Asio flammeus*) representing at least one breeding pair, Long-eared owls (*Asio otus*) representing one breeding pair, Great Horned Owls (*Bubo virginianus*) representing 3-4 different breeding pairs, and Common Ravens (*Corvus corax*) representing at least six different breeding pairs. Diets of coyotes were determined by examining 44 coyote scats. Pellets and scats were processed in the lab by washing and drying pellets and scats, dissecting them, and determining prey remains underneath a binocular microscope. Minimum number of individuals (MNI), and number of identified specimens (NISP) were determined for pellets and scats using the methods described in Chapter 3.

Diversity Indices

The diversity of a community is described both by the number of species in the community and by the evenness with which individuals are distributed among species. In other words, observations distributed evenly among categories result in high species diversity, whereas observations where the majority of the data occurs in only a few categories results in low diversity (Magurran 1988, Zar 1984).

Common diversity measures include the Shannon-Wiener index and the Brillouin formula (Magurran 1988, Zar 1984). Although both indices are somewhat similar, they

are based on different assumptions. The Shannon-Wiener index assumes that the samples drawn from a population are random and the total number of species is known. Because this is not often the case, and this assumption was not met by our data, the Brillouin index was used. The pellet samples from this study were assumed to have been collected non-randomly by the avian predators. The Brillouin index permits a sample that does not come from a randomly sampled population. The Brillouin diversity index is:

$$H'_B = \frac{\ln N! - \sum \ln n_i!}{N}$$

We calculated H'_B , for each of the four habitats; where N is the total number of prey individuals from all pellets of all predators found in that habitat, and n_i was the total number of individuals of prey species i from all pellets of predators found in that habitat.

We also calculated a Brillouin index, H'_{NM} , for each of the predator species; where N was the total number of prey individuals in all pellets of that predator species and n_i was the total number of individuals of prey species i found in all of pellets of that predator species. This gives an index of diet diversity for each predator species.

Results

Avian Diet

The total diet of the suite of avian predators from four discrete habitats within Yellowstone National Park was determined from a sample of 675 pellets taken from the summers of 1998 and 1999 (Table 2). Small mammals were utilized by all predator species, and were the most numerous class of prey item forming 53% of the diet. Insects were the second most abundant taxon from the total pellet accumulation. The high

percentage of insects (36%) was due primarily to the diets of Ravens (Table 2).

Amphibians, birds, fish and reptiles combined constitute 11% of the total prey items.

Table 2. Total diet composition of 675 pellets from raptors and Ravens within four different habitats within Yellowstone National Park.

	Mammals	Birds	Amphibians	Fish	Reptiles	Insects
MNI	1250	164	45	35	26	845
Percentage of total pellets	52.8	6.9	1.9	1.5	1.1	35.7
Total MNI	2365					

MNI represents the minimum number of individuals identified.

Many previous food habit studies did not identify insect prey. If vertebrates alone are considered (Table 3), then our results are much more consistent with other studies done on similar species (Craighead and Craighead 1956, Engel and Young 1989, England *et al.* 1997, Holt and Leasure 1993, Houston *et al.* 1999, Jaksic and Marti 1984, Marks *et al.* 1994, Marti 1974, Peterson 1979, Preston and Beane 1993).

Table 3. Percent composition of diet from 675 pellets by predator species.

Species	Mammals	Aves	Amphibians	Reptiles	Fish	Insects	Total individuals
RTHA (N=78)	74%	11.6%	3.3%	3.3%	<1%	7.4%	121
SWHA (N=41)	90.1%	0	0	0	0	9.9%	91
SEOW (N=34)	100%	0	0	0	0	0	62
LEOW (N=49)	90%	7.9%	0	0	<1%	2.0%	101
GHOW (N=297)	80.2%	10.2%	3.4%	1.8%	<1%	3.7%	1001
CORA (N=176)	12.8%	5.0%	<1%	<1%	2.7%	78.6%	976

() represents the number of pellets processed.

RTHA = Red-tailed Hawk

SWHA = Swainson's Hawk

SEOW = Short-eared Owl

LEOW = Long-eared Owl

GHOW = Great Horned Owl

CORA = Common Raven

In order to make comparisons between taxa and localities similar minimum numbers of individuals (MNI) and number of identified specimens (NISP) of the prey items were used. Short-eared Owls were the only predators that had a strictly mammalian diet. The diets of Swainson's Hawks were predominately mammals followed by insects. The diets of Long-eared Owls were predominately mammals, followed by birds, fish and insects. The diets of Great Horned Owls and Red-tailed Hawks were heavily dominated with mammals but the diets did include a variety of birds, amphibians, reptiles, fish and insects. Ravens had the most diverse diets with the smallest percent of mammals and the highest percent of insects.

The MNI for all vertebrate prey species from the raptor pellets in each of four habitats is presented in Table 4. Shrews (*Sorex*) were preyed upon in all of the different habitats and by a both nocturnal and diurnal predator species. Uinta ground squirrels (*Spermophilus armatus*), were preyed upon in the all of the habitats except the Hayden Valley and by both nocturnal and diurnal predators. Northern pocket gophers (*Thomomys talpoides*), were preyed upon in all habitats and were found primarily in the diets of owls. Voles (*Microtus montanus*, *M. pennsylvanicus*, and *M. spp.*) were the most numerous prey species found in the diets of the raptors and Ravens. Voles were preyed upon in all habitats and were found primarily in the diets of owls. Water voles (*M. richardsoni*), were preyed upon in all study areas and were heavily preyed upon by Great Horned Owls in the Old Faithful area. Bushy-tailed woodrats (*Neotoma cinerea*) were preyed upon in the Gardiner and Lamar area. Remains from bushy-tailed woodrats were found only in the pellets from Great Horned Owls. Deer mice (*Peromyscus*

maniculatus), were preyed upon in all habitats and by both nocturnal and diurnal predators. Numerically, deer mice were the most important component in the diets of Great Horned Owls in the Gardiner area. Leporidae (rabbits and hares) were found only in the Gardiner area in the diets of Great Horned Owls and Ravens.

The remains from non-mammalian species were found in the diets of all the different predators. Birds were primarily found in the diets of Great Horned Owls. Amphibians, including both salamanders and frogs were preyed upon in the Gardiner, Lamar area and Old Faithful area and were found primarily in the diets of Great Horned Owls. Snakes were preyed upon in all habitats except the Hayden Valley and were found in the diets of both nocturnal and diurnal predators. Fish were preyed upon on in all habitats and were found most often in the diets of Ravens.

Table 4. MNI for all prey species identified from 675 raptor and Raven pellets.

Species	Gardiner		Lamar Area			Old Faithful			Hayden Valley			
	G (99)	C (42)	R (65)	G (93)	C (90)	R (13)	G (105)	C (14)	SW (41)	S (34)	L (49)	C (30)
<i>Sorex</i> (Otisorex) spp.	3	0	1	4	2	0	5	0	1	0	1	0
<i>Myotis</i> spp.	1	0	0	0	0	0	0	0	0	0	0	0
<i>Mustela</i> sp.	0	0	1	1	1	0	1	0	0	0	0	0
<i>Spermophilus armatus</i>	0	3	22	8	18	0	7	4	0	0	0	0
<i>Tamias</i> spp.	1	0	0	0	0	0	1	1	1	0	0	0
<i>Tamiasciurus hudsonicus</i>	1	0	1	5	0	1	3	1	0	0	0	0
<i>Thomomys talpoides</i>	14	1	8	35	5	1	52	0	14	11	12	3
<i>Z. cf. princeps</i>	3	0	1	0	0	0	4	0	0	0	0	0
<i>C. cf. gapperi</i>	1	0	0	1	1	1	3	0	0	0	0	0
<i>M. cf. montanus</i>	14	0	4	14	3	3	10	0	0	19	40	0
<i>M. cf. pennsylvanicus</i>	9	0	2	14	6	0	18	1	1	3	4	0
<i>M. richardsoni</i>	2	0	1	10	0	0	48	1	0	0	0	4
<i>Microtus</i> spp.	103	7	27	83	20	5	46	1	65	29	30	12
<i>O. zibethicus</i>	0	0	0	2	0	0	3	0	0	0	0	0
<i>P. intermedius</i>	1	0	0	0	0	0	4	0	0	0	0	0
<i>N. cinerea</i>	11	0	0	3	0	0	0	0	0	0	0	0
<i>P. maniculatus</i>	145	3	7	60	16	1	16	1	0	0	3	1
Leporidae	33	9	0	0	0	0	0	0	0	0	0	0
Total MNI	342	23	75	240	72	12	221	10	82	62	90	20

Table 5. MNI for all non-mammalian prey species

Non-Mammalian Species	Gardiner		Lamar Area			Old Faithful			Hayden Valley			
	G	C	R	G	C	R	G	C	SW	S	L	C
Birds	19	21	13	44	9	1	38	1	0	0	8	9
Amphibians												
<i>A. tigrinum</i>	5	1	0	24	3	0	0	0	0	0	0	0
Frog	0	0	2	4	4	2	1	0	0	0	0	1
Snake	10	1	3	1	3	1	7	0	0	0	0	0
Fish	6	7	1	1	10	0	0	1	0	0	1	7
Non-Mammalian Total MNI	40	30	19	74	29	4	46	2	0	0	9	17
Grand Total	382	53	94	314	101	16	267	12	82	62	99	37

()= Number of pellets processed

R=Red-tailed Hawk

SW=Swainson's Hawk

S=Short-eared Owl

L=Long-eared Owl

G=Great Horned Owl

C=Common Raven

Table 6. Vertebrate diet composition of 675 pellets from raptors and raven from four different habitats within Yellowstone National Park.

	Mammals	Aves	Amphibians	Fish	Reptiles
MNI	1250	164	45	35	26
Percentage	82.2	10.8	3.0	2.3	1.7
Total MNI	1520				

MNI represents minimum number of individuals identified.

Small mammals comprised 82.2 % of the vertebrate prey items identified (Table 6). While small mammals were the dominant prey items for each of the different predator species, the total percentage for each predator differed (Table 7). They composed 75 % to 79 % of the diet of Red-tailed Hawks with decreasing percentages of birds, amphibians, reptiles and fish. Small mammals composed 100 % of the diet of Swainson's Hawks and Short-eared Owls. Long-eared Owls preyed primarily upon mammals (91 %) and a few birds (8 %). Great Horned Owls had a more diverse diet than other raptors; but small mammals composed 76 % to 89 % of the diet. Ravens had the most diverse diet of all the predator species but small mammals were still the dominant vertebrate prey item (Table 2).

Table 7. Vertebrate prey percentages for raptors and Ravens in four habitats in YNP.

	Gardiner		Lamar Area			Old Faithful			Hayden Valley			
	G	C	R	G	C	R	G	C	SW	S	L	C
Small mammals	89.5% (342)	43.4% (23)	79% (75)	76.2% (240)	72% (72)	75% (12)	82.8% (221)	91% (10)	100% (82)	100% (62)	91% (91)	54.4% (20)
Birds	5.0 % (19)	39.6% (21)	13.7% (13)	14.3% (45)	9% (9)	6.3% (1)	14.2% (38)	9% (9)	0	0	8% (8)	24.3% (9)
Amphibians	1.3% (5)	1.9% (1)	3.2% (3)	8.9% (28)	4% (4)	12.5% (2)	<1% (1)	0	0	0	0	2.7% (1)
Reptiles	2.6% (10)	1.9% (1)	3.2% (3)	<1% (1)	3% (3)	6.3% (1)	2.6% (7)	0	0	0	0	0
Fish	1.6% (6)	13.2% (7)	1.0% (1)	<1% (1)	12% (12)	0	0	0	0	0	1% (1)	19.0% (7)
Total MNI	382	53	95	315	100	16	267	19	82	62	99	37

R=Red-tailed Hawk
 SW=Swainson's Hawk
 S=Short-eared Owl
 L=Long-eared Owl
 G=Great Horned Owl
 C=Common Raven

Insects

Individual insects from seven different families within three different orders of arthropods were identified (N=845) (Table 8). Identifications were determined using heads, mandibles and elytra found within the pellets and scats. Individual insects from the family Scarabaeidae (scarab beetles) constituted 91% of the total insects identified

Table 8. Percent of Insects (Family and Order) found in raptor, Raven, and coyote diet within Yellowstone National Park.

	RTHA	SWHA	LEOW	GHOW	CORA	Coyote	Total Individ.
Scarab	11.1	0	0	8.1	54.9	4.8	426
Silph	22.2	0	0	0	7.3	4.8	59
Acrid	22.2	55.6	100	35.1	20.5	61.9	192
Carab	33.3	33.3	0	8.1	10.6	18.9	94
Curcul	0	11.1	0	21.6	1.3	0	19
Elater	11.1	0	0	27.1	1.6	4.8	24
Formic	0	0	0	0	2.5	4.8	21
Hymenop	0	0	0	0	1.3	0	10
Total Individuals	9	9	2	37	767	21	845

Scarab = Scarabaeidae (scarab beetles), Silph = Silphidae (carrion beetles), Acrid = Acrididae (grasshoppers), Carab = Carabidae (ground beetles), Curcul = Curculionidae (weevils)

Elater = Elateridae (click beetles), Formic = Formicidae (ants), Hymenop = Hymenoptera (bees, wasps, and ants).

Insects proved to be an important component in the diets of Ravens, coyotes, and to a lesser degree, hawks and owls. Raven pellets were composed of 78.6 % insects; most individuals were scarab beetles. Red-tailed Hawk pellets contained 7.4 % insects; mainly click beetles, carrion beetles, and ground beetles. Swainson's Hawks pellets contained 9.9 % insects; mainly weevils, ground beetles and grasshoppers. Insects formed 3.7 % of the diets of Great Horned Owls primarily weevils, click beetles, and

grasshoppers. Only 2.0 % of the diet of Long-eared Owls is comprised of insects; exclusively grasshoppers. Short-eared Owl pellets contained 0% insects.

While insects comprised numerically 35.7 % of the total individuals found in all pellets analyzed they represent a small fraction of the total biomass. For example, the largest most abundant grasshopper weighs approximately 442 mg (wet weight) while the smallest mammal weighs approximately 2 grams (Johnson and Crabtree 1999, Pfadt 1994). The primary focus of this study was to enable numerical comparisons between habitat types and between modern and paleontological data; biomass estimates and other ecological questions are beyond the scope of this thesis.

Coyote Diet

Numerous studies have been conducted on the ecology of coyotes throughout North America. Studies that concentrated on the ecology of coyotes in Yellowstone National Park and surrounding areas determined that coyotes are omnivores that utilize mammals, birds, amphibians, reptiles, insects and a variety of plant material (Bekoff 1978, Bekoff and Wells 1986, Crabtree and Sheldon 1999, Murie 1940). Murie (1940) and Crabtree and Sheldon (1999) found that in Yellowstone small mammals make up over 70 percent of the biomass of the coyote's diet followed by ungulates with 20 % (mainly elk). Results from this study (Table 9) indicated similar trends with higher proportions of small mammals, but we did not try to calculate biomass, and the metrics we used, MNI and NISP, are not applicable to large food items such as elk. The sample size from this study was much smaller (44 scats) but was adequate to indicate the importance of small mammal prey.

Table 9. Diet of coyotes from 44 scats from four different habitats within Yellowstone National Park.

	Small Mammals	Birds	Amphibians	Reptiles	Fish	Insects	Unknown
MNI	178	4	2	0	1	21	7
Percentage	83.5	1.8	<1	0	<1	9.8	3.2
Total MNI	213						

MNI represents minimum number of individuals identified

Samples that were considered unknown contained unidentifiable bone fragments and ungulate hair. If vertebrates alone are considered then the proportion of small mammals in the diets of coyotes comprised 92.7 % of the total. (Table 10).

Table 10. Diet of Coyotes in Yellowstone National Park excluding insects.

	Small Mammals	Aves	Amphibians	Reptiles	Fish	Unknown
MNI	178	4	2	0	1	7
Percentage	92.7	2.0	1.0	0	<1	3.6
Total MNI	192					

MNI represents minimum number of individuals identified.

The dominant small mammal taxa in the diets of coyotes from the four different habitats combined are voles (*Microtus* spp.) 67.4 % followed by northern pocket gophers (*T. talpoides*) at 20.2 % and Uinta ground squirrel (*S. armatus*) at 6.7 % (Table 11).

Table 11. MNI and percent of small mammals in the diets of coyotes from four different habitats in YNP.

Species	MNI	Percent of total
<i>Sorex</i> spp.	1	<1
<i>Spermophilus armatus</i>	12	6.7
<i>Thomomys talpoides</i>	36	20.2
<i>Zapus princeps</i>	1	<1
<i>Microtus pennsylvanicus</i>	20	11.2
<i>Microtus</i> spp.	100	56.2
<i>Peromyscus maniculatus</i>	7	4.0
Leporidae	1	<1
Total	178	100

MNI represents minimum number of individuals identified

Diversity Indices

Due to the small sample size of the coyote scats (N=44) they were not included in the calculation of diversity indices. Results from calculating H'NM for each of the different habitats revealed that diversity was similar in three of the four habitats. The Old Faithful area contained the highest diversity followed by the Lamar area, Gardiner and finally the Hayden Valley areas. (Table 12).

Table 12. Brillouin H'NM index for each habitat.

	Gardiner	Lamar Area	Old Faithful	Hayden Valley
H'NM	1.6	1.9	2.0	1.2
Sample size (pellets)	(364)	(387)	(241)	(255)

When each of the raptors and Ravens were compared within the separate habitats the H'NM values were similar (Table 13). In the Gardiner area, the diets of Great Horned Owls were more diverse than that of Ravens. In the Lamar area, the diets were very similar among the three species of birds. In the Old Faithful area, Great Horned Owls showed greater diet diversity than Red-tailed Hawks or Ravens. In the Hayden Valley all of the birds displayed relatively low diversity within their diets with Long-eared Owls having the greatest diversity followed by Short-eared Owls, Ravens and Swainson's Hawks, respectively.

Table 13. Brillouin diversity index (H'_{NM}) values for raptors and Ravens per habitat.

Habitat	G	C	R	G	C	R	G	C	SW	S	L	C
Gardiner	1.6(342)	1.2(23)	-	-	-	-	-	-	-	-	-	-
Lamar Area	-	-	1.6(75)	1.8(240)	1.6(72)	-	-	-	-	-	-	-
Old Faithful	-	-	-	-	-	1.4(12)	2.0(221)	1.3(11)	-	-	-	-
Hayden Valley	-	-	-	-	-	-	-	-	.58(82)	1.1(62)	1.2(89)	.87(20)

RTHA= Red-tailed Hawk

SW = Swainson's Hawk

S = Short-eared Owl

L = Long-eared Owl

G = Great Horned Owl

C = Common Raven

() represents number of individuals in sample

Discussion

The raptors, Ravens and coyotes from the four different study areas in Yellowstone depend on a variety of small mammals, birds, amphibians, fish, reptiles and invertebrates. Insects form an important component of the Raven and coyote diet including species from seven different families. Scarab, carrion and ground beetles make up 86% of the insects found in the diets of Ravens and are primarily carrion and scavenging beetles. Ravens are known to be scavengers and opportunists and the high percentage of these types of beetles in their diets infer that they were consumed at carcasses.

Small mammals account numerically, and for total biomass, as the most important component in raptor, Raven, and coyote diets. Voles accounted numerically as the most important prey item among all of the predator species studied. Deer mice, pocket gophers, water voles and Uinta ground squirrels were also very important species for all of the bird species and coyotes. Differences were apparent between the nocturnal and diurnal hunters and their associated prey. Great Horned Owls preyed upon more deer mice and northern pocket gophers than did their diurnal counterparts: Red-tailed Hawk, Swainson's Hawk or Ravens. The Uinta ground squirrel, which is a diurnal prey species was found more frequently in the diets of both hawk species and Ravens than in the diets of the owl species. Rabbits and hares are an important component in the diets of Great Horned Owls and Ravens in the Gardiner study area, and provided the most total biomass per individual prey item of any of the small mammals (630 grams to 1.8 kg.) (Johnson

and Crabtree 1999). Numerically they comprised 39.1 % and 9.8 % of the diets of Ravens and Great Horned Owls respectively.

Coyotes, which tend to be crepuscular hunters, take a combination of nocturnal and diurnal species. Their prey included both the nocturnal northern pocket gophers and deer mice as well as the diurnal Uinta ground squirrels and voles. The fact that rabbits or hares only play a minor role numerically (less than one percent) in the diets of coyotes from the Gardiner area is probably due to the small sample size. The absence of rabbit and hare bones from the scats of coyotes could be due to the fragile nature of Leporidae bones and these bones may not remain intact in the digestive system.

Diversity indices for the different habitats suggest that there are important differences in the diets of predator species between the different habitats. However this value needs to be interpreted cautiously because differences among the different H'NM values could be attributed to the differences in habitat and prey availability or the differences in the predator communities.

Diversity indices for the different predator species within a specific habitat help to clarify this problem. If all species of small mammals within a specific habitat are assumed to be available to all predators, we can make some inferences of the differences between predator species within the separate habitats.

A comparison of diversity indices between the different predator species within the same habitat also reveals important differences in diets between the different predator species. Some of these differences could be attributed to the difference in diurnal vs. nocturnal hunters, prey specialists or small sample size. The greatest differences in the

H'NM values between predator species were found in the Old Faithful and Hayden Valley areas. The smallest differences in H'NM values were found in the Lamar area, indicating that the habitat, and thus the type of prey available, has a definite effect on the composition of the diet.

The smallest H'NM values for the different predator species were found in the Hayden Valley. The low diversity values could indicate that all of these predators are specialists or that the habitat does not contain the same diversity of small mammal prey as the other habitats. The answer to this problem may be found in the diets of Ravens. Ravens are found in all of the habitats and have the most diverse diet from the pellets examined (Table 4,6). In the Hayden Valley, diet diversity for Ravens is low (.87) and lies between Swainson's Hawk (.58) and Short and Long-eared Owls (1.1 and 1.2). However the diet diversity for Ravens in the other habitats is higher at 1.2, 1.6, and 1.3 respectively. Ravens are assumed to be generalists and opportunists and the data from this study and other studies indicate they are probably eating the most common prey available. In the case of the Hayden Valley, the diversity of small mammal prey is probably not as high as in the other habitats and the lack in diversity can be seen in the diet diversity indices from the Hayden Valley especially in Ravens.

Diversity indices also indicate that Red-tailed Hawks, Great Horned Owls and Ravens have a broad overlap in diet even though they are nocturnal and diurnal feeders. Great Horned Owls had the most diverse diet, followed by Red-tailed Hawks, Ravens, Long-eared Owls, Short-eared Owls and Swainson's Hawks respectively.

Conclusions

The results from this study are consistent with other studies done on the same raptors, Raven and coyote species from different locations. Diets of these predators are heavily influenced by mammals, insects, birds, amphibians, reptiles and fish. Pellets and scat analysis within the four study areas in Yellowstone National Park for this suite of raptors, Ravens and coyotes can be used as an index to the diversity and relative abundance of small mammals in the predator diet. This analysis suggests that different habitats produce different pellet composition results regardless of the predator species.

CHAPTER 5

DATA ANALYSIS

Introduction

Wildlife observations in natural settings are difficult to analyze statistically because of the number of confounding factors that cannot be controlled. Factors that may confound results include the regional or temporal scale of the problem, the climate, seasonality and the type of environment. Other factors that may complicate analysis are comparisons of different data types that may make analysis difficult to manipulate and analyze.

This study was a challenge in that it contained two different data types: historical data (Lamar Cave) and modern data. Historical data from a paleontological site was compared to a modern study that was based on a planned data collection procedure. Restrictions and methodology that were used for the modern study could not be applied to the historic dataset. Data from Lamar Cave is a faunal composite of bones that originally comprised pellets from raptors, and predator scats (Hadly 1996, 1999). The pellets and scats disaggregate over time and the bones become consolidated into stratigraphic subunits. Data from the modern pellets and scats are based on discrete individual pellets and scats that can also be aggregated for each habitat.

To determine whether data from the modern levels of Lamar Cave most closely resembled one of four current habitats from Yellowstone (Gardiner, Lamar area, Old Faithful, Hayden Valley), the data representing different collection methods needed to be

made compatible for analysis. Two different approaches were used to manipulate the pellet, scat and Lamar Cave data in order to standardize them.

Methods

For both the modern pellet and scat data, and the Lamar Cave data, the analysis was restricted to small mammal data alone. All *Microtus* species were lumped together due to the difficulty in identification from skeletal remains. Up to three species of *Microtus* (*M. longicaudus*, *M. montanus*, and *M. pennsylvanicus*) potentially are included in both modern and fossil data sets. *Microtus* species are difficult to discriminate by isolated teeth. Trapping data, however, indicate that most *Microtus* species in these habitats are *M. montanus*, and *M. pennsylvanicus*, with *M. longicaudus* being very rare (Harter and Crabtree 1991, Johnson and Crabtree 1999). Rabbits and hares were also lumped together as Leporidae due to the difficulty in species identification from dental remains. Initially 15 different species of small mammals were included in the analysis. The 15 species were used in the analysis to determine whether the four habitats could be discriminated between one another. This number was reduced to six and eventually five of the most common taxa found in both the modern and Lamar Cave data. The six most common small mammals species are *Spermophilus armatus* (Uinta ground squirrel), *Thomomys talpoides* (Northern pocket gopher), *Microtus* spp.(voles), *Neotoma cinerea* (bushy-tailed wood rat), *Peromyscus maniculatus* (deer mouse), and Leporidae (rabbits and hares). Analysis that use the five most common small mammal species would exclude Leporidae (rabbits and hares). These six and five taxa were then used to compare the modern and fossil data.

Minimum number of individuals (MNI) and number of identified specimens (NISP) were included in the analysis (Table 14) (Grayson 1978). MNI represents the absolute minimum number of individuals represented in a sample based on the maximum number of elements per specimen. NISP differs from MNI in that each identified element within the sample is included in the total. Teeth and cranial elements are summed together. For detailed description of MNI and NISP see Chapter 3.

Table 14. Mean minimum number of individuals (MNI) and mean number of identified specimens (NISP) per pellet and scat for each of the 4 study areas.

	Gardiner	Lamar Area	Old Faithful	Hayden Valley
MNI	3.27	2.27	2.3	2.19
NISP	26.95	18.29	19.62	21.1
Number of pellets analyzed per site	118	202	109	148

Method 1-Pseudo-pellets

We surmised that if pellets and scats from the cave were to be reconstructed they should have a species composition similar to the raptors, Ravens and coyote scats from the various habitats from where they were originally found. Thus, our objective was to simulate the pellets derived from each habitat by creating "pseudo-pellets". These pseudo-pellets are then added to the modern pellet and scat data and compared between the different habitats. The modern pellet and scat data demonstrated that pellets and scats from the four habitats had different pellet structures; these differing structures correspond to different distributions of MNI and NISP per pellet and scat. Using MATLAB (The Mathworks, Inc. 1997), pellet data from Lamar Cave were then simulated for each of the

four habitats, using the total MNI and NISP from the Lamar Cave data (Level 3) (MNI = 100) and from each of the known distributions of MNI and NISP from the four different habitats (Table 15). The mean MNI per pellet and scat were divided by the total for Level 3 of the Lamar Cave data to produce the appropriate number of pseudo-pellets for each of the habitats. These data are referred to as pseudo-pellets. Thus pseudo-pellets were created for each one of the four different habitats based on the known MNI and NISP from pellets and scats from the modern habitats. The goal was to mimic the pellet structure of MNI and NISP associated with a particular habitat. Five replications were made for each of the four habitats creating 20 different pseudo-pellet simulations. The modern pellet and scat data were not changed in any way, thus individual modern pellets and scats remained unchanged throughout all of the simulations. Pseudo-pellets differed in each simulation based on which habitat they were modeled from (habitats 1-4) and based on randomizations generated within each habitat model.

Table 15. Pseudo-pellets derived and number of observations used in analysis for MNI from modern pellets and scats and Level 3 of Lamar Cave.

	Gardiner	Lamar area	Old Faithful	Hayden	Cave (Level 3) Total
*MNI	3.27	2.27	2.3	2.19	100
Pseudo-pellets Produced	30	44	42	46	
Number of observations used in analysis	607	621	619	623	

* MNI was based on mean number of individuals per pellet and scat of Lamar Cave level.

Modern pellets (N=533) and scats (N=44) from the four habitats were analyzed with a classification tree program (CART, see below) to determine whether the modern habitats could be discriminated from one another based on species distribution across

pellets. If this initial step were successful then the pseudo-pellets would be included in the analysis to see if the Lamar Cave data could be discriminated from the modern habitats using the same discrimination criteria. Ultimately the analysis should indicate which habitat the Lamar Cave data most closely resembled. A schematic way to think of the pseudo-pellet method is:

Lamar Cave data → Form pseudo-pellets based on known distributions of MNI and NISP → Combine with modern pellets and scats → Compare pseudo-pellets, modern pellets and scats to other habitats.

Method 2-Stratigraphic subunits

This method manipulated the modern pellets and scats to make them similar to the original Lamar Cave data so that the modern and historical data would possess similar summary structures. Creation of simulated stratigraphic subunits including both modern and Lamar Cave data was based on the totals of MNI and NISP for Level 3 of the Lamar Cave data (MNI = 85, NISP = 746). Subunits were produced which had the same totals for MNI and NISP for six and five different species from the Lamar Cave data. Unlike the pseudo-pellet method, the process of creating subunits does not involve sampling with replacement. The data were organized into a set of individuals and a set of specimens. The set of individuals (modern pellets and scats) and the set of specimens (Lamar Cave Level 3) were randomized for MNI and NISP analysis. Subunits were fixed in size throughout the analysis. A sufficient number of randomized subunits were created from the totals of MNI and NISP to create enough variability within the units but still retain the overall pattern of species proportionality that exists within the units. In the

case of MNI subunits of size five MNI were produced; and subunits of size twenty NISP were created to simulate NISP (Table 16). Three separate simulations were produced to uncover consistent patterns in the presence of simulations and add greater variability. Data from each simulation was then analyzed using a classification tree program.

Table 16. Number of stratigraphic subunits created for each habitat based on the totals for MNI and NISP using six or five taxa.

Habitat	6 taxa	6 taxa	5 taxa	5 taxa
	Stratigraphic subunits of size 5	Stratigraphic subunit of size 20	Stratigraphic subunits of size 5	Stratigraphic subunit of size 20
	MNI	NISP	MNI	NISP
Gardiner (H1)	74	152	66	138
Lamar area (H2)	85	170	85	170
Old Faithful (H3)	35	72	35	72
Hayden Valley (H4)	63	153	63	153
Lamar Cave (H5)	17	37	14	35

This method differs from the pseudo-pellet method in that any modern pellet structure that might have existed between the different habitats is lost because of the deconstruction of the modern pellets and scats prior to randomization. The randomized pellets and scats are completely different for each simulation. Any MNI and NISP pellet structure among the modern pellets and scats is lost during the creation of the stratigraphic subunits. A schematic way to think of the stratigraphic subunit method is: Combine modern pellets, scats and Lamar Cave data → Combine mixture → Form random uniform size units → Compare units.

Classification and Regression Trees (CART)

Classification and regression trees have been used extensively in other disciplines such as medicine, engineering, economics and marketing (Ahn 1995, Ciampi *et al.* 1995, Spear *et al.* 1994). Recently the use of classification and regression trees has been applied to biology and wildlife studies (Kavanagh and Bamkin 1995, Smith *et al.* 1997). In this study, CART (Classification and Regression Trees. San Diego CA: Salford Systems, 1997) proved to be beneficial because of its capability in handling multiple variables (taxa) and then presenting the results in a concise and easy to understand decision tree format (Figure 18).

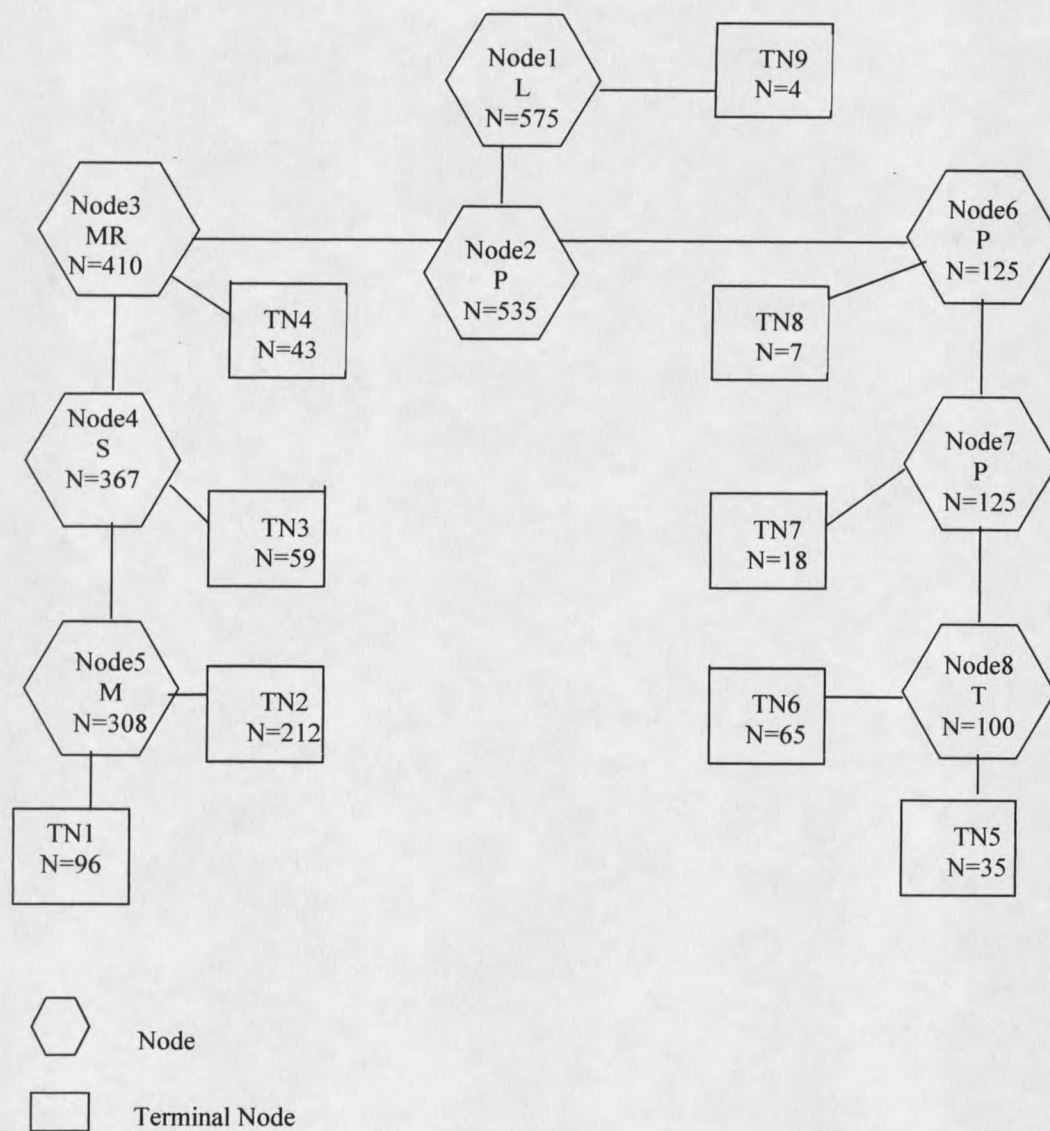
The CART procedure uses a computer intensive algorithm that recursively searches over all variables to produce a sequence of optimal binary splits to best display the structure of the data (Breiman *et al.* 1984). The structure of the data in this case is the relationship between species and habitat. CART looks at the frequency per species in any given line (representing a pellet or stratigraphic subunit), classifies and divides the data in terms of individual taxa (counts of taxa) to display similarities and differences among groups of data. Results from CART are in the form of an inverted tree beginning with a root node (parent) that is repeatedly split into exactly two child nodes based on a series of yes/no questions pertaining to a single variable. Some nodes become terminal, meaning that a final classification has been reached. Other nodes (child) will continue to be split until a terminal node is reached (Steinberg *et al.* 1997). A further refinement that was utilized using CART was the "minchild" option. This function allows a minimum number of individuals to be set. We set the 'minchild' option to require a minimum

number of five individuals within each terminal node. In the initial analysis no other special options were used in CART and the default settings were used.

One of the analytical strengths of CART is that it allows a new or subset of data to be classified using an existing classification tree referred to as 'dropping cases down a tree' (Steinberg et al. 1997). To determine what habitat the Lamar Cave data (H5) most closely resembled it was necessary to have CART classify the Lamar Cave data (H5) so that it displayed the modern habitat it was most closely associated with. Both the pseudo-pellets dataset and the stratigraphic subunit dataset were classified using CART and the results of the model were saved. Then using the resultant tree model, each datum from Lamar Cave (pseudo-pellet for Method 1 or stratigraphic subunits for Method 2) was classified into the habitat that the datum from Lamar Cave most closely resembled.

In the case of this hypothetical tree (Figure 8), there are initially 577 observations; this is stated in Node 1. The 577 observations in Node 1 were split based on L (Leporidae). Based on the binary yes/no questions, the 535 observations containing a threshold of $L < .5$ were moved to the left and the 42 observations containing $L \geq .5$ were moved to the right into terminal node 8 from which no other splits can be made. Threshold values for each variable are determined by the total number of individuals of a specific taxa found in the dataset and threshold values are listed in the output. The next split occurred at node 2 based on P (deer mice) with its 535 observations. The 410 observations containing a threshold of $P < .5$ were split to the left and 125 observations having $P \geq .5$ were split to the right. CART works through all of the variables in a similar manner to produce the inverted tree.

Figure 17. The CART Decision Tree format.



Variable Importance

All variables (taxa) are considered by CART when creating the simplest tree structure. However, relatively few of those variables may ultimately appear as the splitting criteria for nodes in the tree. Variables that initially were expected to be important, however, may not always show up in the tree as primary node splitters. To

calculate a variable importance score, CART looks at the amount of improvement attributed to each variable in its role as a surrogate to the primary split. The improvement values are totaled at each node and scaled relative to the best performing variable. The variable with the highest sum of improvements is scored as 100, with all other variables having scores from 99 to 0 (Steinberg and Colla 1997).

Once variable importance scores have been calculated for a specific model those scores cannot be applied to other models using different variables. Adding or removing a variable from the analysis can result in a completely different tree or can substantially reshuffle the importance scores of the remaining variables (Steinberg and Colla 1997).

Results

Using the modern pellet and scat data, CART was able successfully to discriminate between the four different habitats using the pseudo-pellet method (Table 17). The pseudo-pellet method (Method 1) correctly classified habitats using six and five taxa with varying degrees of accuracy.

Table 17. Mean percent of time that habitats were classified correctly for four habitats using pseudo-pellets MNI and NISP using 6 and 5 taxa.

Habitat	6 taxa		5 taxa	
	Pseudo-pellet MNI	Pseudo-pellet NISP	Pseudo-pellet MNI	Pseudo-pellet NISP
Gardiner (H1)	78.0%	75.4%	61.0%	60.2%
Lamar area (H2)	18.8%	21.3%	24.8%	24.3%
Old Faithful (H3)	38.5%	63.3%	38.5%	63.3%
Hayden Valley (H4)	87.8%	67.6%	87.8%	67.6%

6 variables (taxa) = *Spermophilus armatus* (Uinta ground squirrel), *Thomomys talpoides* (Northern pocket gopher), *Microtus* spp.(voles), *Neotoma cinerea* (bushy-tailed wood rat), *Peromyscus maniculatus* (deer mouse), Leporidae (rabbits and hares).

5 variables (taxa) = *Spermophilus armatus* (Uinta ground squirrel), *Thomomys talpoides* (Northern pocket gopher), *Microtus* spp.(voles), *Neotoma cinerea* (bushy-tailed wood rat) *Peromyscus maniculatus* (deer mouse).

The Lamar area (H2) has a lower mean correct classification probably because it is a combination of habitat types (ecotonal) and therefore is difficult to correctly identify with this method over these spatial and temporal scales. Changing from six variables to five variables using MNI decreased the correct classification percentage in the Gardiner data (H1), increased accuracy in the Lamar area (H2), and there was no change in the Old Faithful (H3) or Hayden Valley (H4) data. When NISP rather than MNI was used there were increases in correct classification for the Old Faithful (H3) data and an almost equal decrease in the correct classification for Hayden Valley (H4) data.

The stratigraphic subunit method (Method 2) had higher correct classification rates overall in comparison with the pseudo-pellet method when using either six or five variables (Table 18).

Table 18. Mean percent of time that habitats were classified correctly for four habitats using stratigraphic subunits MNI and NISP using 6 and 5 taxa.

Habitat	6 taxa		5 taxa	
	Stratigraphic subunit MNI	NISP	Stratigraphic subunit MNI	NISP
Gardiner (H1)	87.0%	97.5%	82.3%	93.7%
Lamar area (H2)	57.2%	89.4%	46.2%	84.1%
Old Faithful (H3)	54.3%	80.1%	49.5%	80.5%
Hayden Valley (H4)	85.7%	91.0%	85.2%	91.9%

The Lamar area had a lower mean classification percentage using MNI. There was a decrease in correct classification percentage when using five variables in the Lamar area (H2) and in the Old Faithful (H3) data. The overall correct classification rates were very high using NISP and there was relatively little change in classification rates when using six or five variables. For the stratigraphic subunits (Method 2), NISP more reliably discriminates habitats than does MNI in all cases.

Classification of five habitats

The pseudo-pellets from Lamar Cave were included with the modern pellets and scats to determine how unique the Lamar Cave data was and how its classification compared with the modern data. The addition of the fifth habitat type will necessarily change the results for the original four habitat types (Table 19).

Table 19. Mean percent of time that habitats were classified correctly for 5 habitats using pseudo-pellets MNI and NISP using 6 and 5 taxa.

Habitat	6 taxa		5 taxa	
	Pseudo-pellet MNI	Pseudo-pellet NISP	Pseudo-pellet MNI	Pseudo-pellet NISP
Gardiner (H1)	66.3%	71.3%	58.6%	57.8%
Lamar area (H2)	21.0%	17.2%	15.0%	13.3%
Old Faithful (H3)	44.1%	64.1%	38.1%	63.3%
Hayden Valley (H4)	85.9%	68.0%	87.3%	66.7%
Lamar Cave (H5)	47.3%	46.5%	43.0%	45.6%

When including the Lamar Cave data (H5) using the pseudo-pellet method, CART was able to successfully classify the Lamar Cave data with higher classification rates than the Lamar area (H2) and lower than the other modern habitats. The classification rates for the Lamar Cave data were consistent for both MNI and NISP.

The stratigraphic subunit method had high classification rates than the pseudo-pellet method for all of the habitats except for the Lamar area (H2) when using either six or five variables. (Table 20) The Lamar Cave (H5) data proved to have high overall correct classification rates. The correct classification rates for NISP were higher than the rates using MNI.

Table 20. Mean percent of time that habitats were classified correctly for 5 habitats using stratigraphic subunits MNI and NISP using 6 and 5 variables.

Habitat	6 taxa		5 taxa	
	Stratigraphic subunit MNI	Stratigraphic subunit NISP	Stratigraphic subunit MNI	Stratigraphic subunit NISP
Gardiner (H1)	79.0%	95.8%	61.0%	60.2%
Lamar area (H2)	44.7%	84.0%	24.8%	24.3%
Old Faithful (H3)	65.0%	81.0%	38.5%	63.3%
Hayden Valley (H4)	69.3%	89.7%	87.8%	67.6%
Lamar Cave (H5)	86.3%	96.4%	71.4%	93.3%

Variable Importance

Simulations using the pseudo-pellet method with 15 different species from all the habitats (H1-H4) were analyzed and each species variable importance score was recorded. The top five variable importance rankings for each species were then averaged across all simulations for both MNI and NISP. This same ranking method was then used for six species and five species to determine an overall ranking of importance.

Overall rank was calculated using the number of times the species was ranked in the top five and was ranked greater than or equal to the sixth ranking. These frequencies were then multiplied by the rank score (1-6) and divided by the maximum sum possible (20) to produce an overall rank. Certain species were found to be important when using six variables (Table 21) or five variables (Table 22) using MNI. Rankings were based on a scale of one to six with one being the best ranking, indicating that the species was important in discriminating between habitats; and six indicating that the species was least important in discriminating between habitats. These overall ranking scores were found to be useful in summarizing variable importance of taxa over multiple simulations.

Table 21. Rank of variable importance scores with six taxa using CART, (MNI).

Rank	Spar	Thta	Microtus spp.	Neci	Pema	Leporidae.
1	(5,3,1,3)	(0,0,0,0)	(0,0,0,0)	(0,0,0,0)	(0,2,3,2)	(0,0,1,0)
Sum	12	0	0	0	7	1
%	60%	0%	0%	0%	35%	5%
2	(0,0,1,1)	(0,0,0,0)	(0,0,1,0)	(2,2,0,0)	(3,0,2,2)	(0,3,1,2)
Sum	2	0	1	4	7	6
%	10%	0%	5%	20%	35%	30%
3	(0,2,1,1)	(0,0,0,0)	(1,0,2,0)	(0,0,1,1)	(1,3,0,1)	(3,0,1,2)
Sum	4	0	3	2	5	6
%	20%	0%	15%	10%	25%	30%
4	(0,0,1,0)	(0,0,0,0)	(1,3,2,1)	(2,1,0,3)	(1,0,0,0)	(1,1,2,1)
Sum	1	0	7	6	1	5
%	5%	0%	35%	30%	5%	25%
5	(0,0,1,0)	(1,0,1,0)	(2,2,0,4)	(1,2,3,1)	(0,0,0,0)	(1,1,0,0)
Sum	1	2	8	7	0	2
%	5%	10%	40%	35%	0%	10%
Overall						
Rank	1.8	5.9	4.2	3.9	2.0	3.05

(H1, H2, H3, H4) represents the frequency of rankings from each of the four habitats.

H1 = Gardiner, H2 = Lamar area, H3 = Old Faithful, H4 = Hayden.

Spar = Uinta ground squirrel, Thta = northern pocket gopher, Microtus spp. = voles, Neci = bushy-tailed woodrat, Pema = deer mice, Leporidae = rabbits and hares.

Table 22. Rank of variable importance with five taxa using CART (MNI).

Rank	Spar	Thta	Microtus spp.	Neci	Pema
1	(4,3,2,1)	(0,0,0,0)	(0,0,0,0)	(1,0,1,0)	(0,2,2,4)
Sum	10	0	0	2	8
%	50%	0%	0%	10%	40%
2	(1,2,1,3)	(0,0,0,0)	(0,0,0,0)	(2,0,1,1)	(2,3,3,1)
Sum	7	0	0	4	9
%	35%	0%	0%	20%	45%
3	(0,0,2,1)	(0,0,0,0)	(1,3,2,2)	(1,2,1,2)	(3,0,0,0)
Sum	3	0	8	6	3
%	15%	0%	40%	30%	15%
4	(0,0,0,0)	(0,0,1,1)	(4,2,3,3)	(1,3,1,1)	(0,0,0,0)
Sum	0	2	12	6	0
%	0%	10%	60%	30%	0%
5	(0,0,0,0)	(5,5,4,4)	(0,0,0,0)	(0,0,1,1)	(0,0,0,0)
Sum	0	18	0	2	0
%	0%	90%	0%	10%	0%
Overall					
Rank	1.6	4.9	3.6	3.8	1.7

(H1, H2, H3, H4) represents the frequency of rankings from each of the four habitats.

H1 = Gardiner, H2 = Lamar area, H3 = Old Faithful, H4 = Hayden.

From these simulations certain species were consistently ranked as important whether 15 variables, six variables or five variables were included. Species that had the highest overall ranking using the pseudo-pellet method for MNI using all 15 species of mammals were: deer mice (2.25), rabbits and hares (2.6), Uinta ground squirrel (3.1), water vole (*Microtus richadsoni*) (3.75), bushy-tailed wood rats (4.4), vole species (5.15) and Northern pocket gophers (6).

Using NISP for 15 species of mammals the overall rankings were only slightly different: deer mice (1.5), Uinta ground squirrels and voles with identical rankings (3.35), rabbits and hares (3.4), water vole (3.6), bushy-tailed wood rat (5.75), and Northern pocket gopher (5.8). Similar species were found to be important when using six variables (Table 23) or five variables (Table 24). These species were also important when using either MNI or NISP. Water voles proved to be important in classifying habitat using all species but this species was excluded from the modern-paleontological comparisons because it was not found in the Lamar Cave (H5) data.

Table 23. Rank of variable importance scores with six taxa using CART, (NISP).

Rank	Spar	Thta	Microtus spp.	Neci	Pema	Leporidae
1	(4,0,0,0)	(0,0,0,0)	(0,1,0,0)	(0,0,0,0)	(1,1,3,4)	(0,3,2,1)
Sum	4	0	1	0	9	6
%	20%	0%	5%	0%	45%	30%
2	(1,2,2,1)	(0,0,0,0)	(0,0,0,1)	(1,1,1,1)	(1,2,0,0)	(3,0,1,2)
Sum	6	0	1	4	3	6
%	30%	0%	5%	20%	15%	30%
3	(0,0,1,3)	(0,0,0,0)	(2,4,2,0)	(1,0,0,0)	(2,0,1,1)	(0,1,1,1)
Sum	4	0	8	1	4	3
%	20%	0%	40%	5%	20%	15%
4	(0,2,2,0)	(0,0,0,4)	(0,0,2,0)	(2,0,1,0)	(1,2,0,0)	(2,1,0,1)
Sum	4	4	2	3	3	4
%	20%	20%	10%	15%	15%	20%
5	(0,1,0,1)	(1,2,2,1)	(3,0,1,0)	(1,2,1,3)	(0,0,0,0)	(0,0,1,0)
Sum	2	6	4	7	0	1
%	10%	30%	20%	35%	0%	5%
Overall Rank	2.7	5.3	4.7	5.4	2.2	2.4

(H1, H2, H3, H4) represents the frequency of rankings from each of the four habitats.

H1 = Gardiner, H2 = Lamar area, H3 = Old Faithful, H4 = Hayden.

Table 24. Rank of variable importance scores with five taxa using CART (NISP).

Rank	Spar	Thta	Microtus spp.	Neci	Pema
1	(5,1,2,1)	(0,0,0,0)	(0,0,0,0)	(0,0,0,0)	(0,4,3,4)
Sum	9	0	0	0	11
%	45%	0%	0%	0%	55%
2	(0,2,1,2)	(0,0,0,0)	(1,2,3,2)	(0,0,1,0)	(4,1,0,1)
Sum	5	0	8	1	6
%	25%	0%	40%	5%	30%
3	(0,1,1,1)	(0,0,0,0)	(1,3,2,3)	(3,1,0,1)	(1,0,2,0)
Sum	3	0	9	5	3
%	15%	0%	45%	25%	15%
4	(0,1,1,1)	(0,1,0,1)	(3,0,0,0)	(2,3,4,3)	(0,0,0,0)
Sum	3	2	3	12	0
%	15%	10%	15%	60%	0%
5	(0,0,0,0)	(5,4,5,4)	(0,0,0,0)	(0,1,0,1)	(0,0,0,0)
Sum	0	18	0	2	0
%	0%	90%	0%	10%	0%
Overall Rank	2.0	4.9	2.7	3.7	1.6

(H1, H2, H3, H4) represents the frequency of rankings from each of the four habitats.

H1 = Gardiner, H2 = Lamar area, H3 = Old Faithful, H4 = Hayden.

Variable importance rankings were carried out for the stratigraphic subunit method and the results were similar to the pseudo-pellet method with Uinta ground squirrels (1.3) and deer mice (2) scoring the highest ranking with six variables using NISP. When using MNI and six variables, voles were ranked highest (1.6) followed by deer mice (2.3). Rabbits and hares were ranked much lower using this method with rankings of 6 and 5 for MNI and NISP respectively. Using five variables, deer mice were ranked (1), voles ranked (2.3) and Uinta ground squirrels were ranked (3.6). Using NISP and five variables Uinta ground squirrels and deer mice are equally ranked at 1.3.

Using Existing Trees to Classify-Dropping Cases

To determine what modern habitat the Lamar Cave (H5) most closely resembled, the method of 'dropping cases down a tree' was utilized using CART. With this method, the initial step is to produce a model and decision tree from the modern dataset (pellet and scat data). After saving the results from this model, the data from Lamar Cave (pseudo-pellets and stratigraphic subunits) were classified using the resultant decision tree model. The results from this classification indicate the number of times that the observations from the Lamar Cave data were classified to each habitat. The results using psuedo-pellet data are found in Table 25.

Table 25. Dropping cases- mean percent of pseudo-pellets classified into each habitat using 6 and 5 model taxa.

Habitat	6 taxa		5 taxa	
	Pseudo-pellet		Pseudo-pellet	
	MNI	NISP	MNI	NISP
Gardiner (H1)	37.6%	35.8%	20.9%	30.6%
Lamar area (H2)	13.9%	22.0%	29.0%	29.5%
Old Faithful (H3)	19.7%	32.0%	27.4%	30.1%
Hayden Valley (H4)	28.7%	10.2%	22.7%	9.8%

Analysis using pseudo-pellets and six taxa indicated that 37.6 % (using MNI) and 35.8 % (using NISP) of the Lamar Cave (H5) pseudo-pellets were classified as being most similar to the Gardiner (H1) habitat type. This stronger relationship with the Gardiner (H1) habitat type is directly related to the presence of rabbits or hares (Leporidae) in both the Lamar Cave (H5) data and the Gardiner (H1) data.

The results using stratigraphic subunits data are found in Table 26. Analysis using stratigraphic subunits and six taxa, indicated that 41.2 % of the Lamar Cave stratigraphic subunits were associated with the Gardiner (H1) habitat type using MNI and 70.3 % with NISP. These results are again tied to the presence of rabbits and hares (Leporidae) within both the Gardiner (H1) and Lamar Cave (H5) data. There is a very low classification of Lamar Cave stratigraphic subunits into the Hayden (H4) habitat type.

Table 26. Dropping cases-mean percent of stratigraphic subunits classified into each habitat using 6 and 5 model taxa.

Habitat	6 taxa		5 taxa	
	Stratigraphic subunit		Stratigraphic subunit	
	MNI	NISP	MNI	NISP
Gardiner (H1)	41.2%	70.3%	9.5%	0.0%
Lamar area (H2)	31.3%	27.0%	54.8%	79.0%
Old Faithful (H3)	25.5%	2.7%	28.6%	21.0%
Hayden Valley (H4)	2.0%	0.0%	7.1%	0.0%

The variable Leporidae (rabbits and hares) was shown to be important in determining which habitat the Lamar Cave data is most closely associated with. To determine how consistent the results of the model were, the data were reanalyzed using only five variables, after rabbits and hares were excluded. Using only five variables, 28.9 % of the Lamar Cave pseudo-pellets were associated with the Lamar area (H2) habitat type data using MNI and 29.4 % with NISP as compared to 13.7 % and 21.9 % respectively when rabbits and hares were included.

When using only five variables with the stratigraphic subunit model, 54.7 % of the Lamar Cave stratigraphic subunits were classified as the Lamar area (H2) habitat type with MNI and 79.0 % with NISP, as compared to 31.3 % and 27.0 % respectively, when rabbits and hares were included. It is interesting to note when using NISP that the Gardiner (H1) habitat type and the Hayden (H4) habitat type are never chosen as being similar to the Lamar Cave stratigraphic subunits.

Discussion

CART was able to provide classification rules that correctly discriminate at a high percentage rate between four different habitats based on the pellets and scats from a predator suite of raptors, Ravens, and coyotes from Yellowstone National Park. Two different approaches were then used to analyze the modern data from the different habitats and the historical data: 1) the pseudo-pellet method based on making the historical cave data similar to the modern distributions of MNI and NISP in pellets and scats from the four different habitats, and 2) the substratigraphic subunit method based on making modern data look similar to the historical Lamar Cave data by disaggregating the

discrete pellets and scats. CART was then able to provide classification rules to allow discrimination between the Lamar Cave data and the modern habitats using either MNI or NISP. Correct classification rates varied depending on the specific habitats, the model used, and whether MNI or NISP were used. In both models NISP produced higher correct classification rates than MNI. The Gardiner (H1), Old Faithful (H3) and Hayden (H4) study areas had the highest correct classification rates while the Lamar area (H2) had the lowest overall correct classification rates using the pseudo-pellet or stratigraphic subunit method. The Lamar Cave (H5) data were correctly classified somewhere in-between the modern habitats. The stratigraphic subunit method had overall higher correct classification rates than did the pseudo-pellet method for both MNI and NISP.

Species that proved to be important overall in determining habitat using CART were deer mice, Uinta ground squirrels, rabbits and hares, voles, and Northern pocket gophers using all, six or five variables for the pseudo-pellet method. These results were consistent using MNI or NISP but the ranking order was slightly different.

The results indicate that historical Lamar Cave data were collected from habitats that were not dissimilar from the modern Lamar or Gardiner areas. The presence of rabbits and hares in both the Gardiner (H1) and Lamar Cave (H5) data but not in the modern Lamar area (H2) data tends to direct CART to associate the Lamar Cave (pseudo-pellets or stratigraphic subunits) with the Gardiner (H1) habitat type. An interesting question emerges as to why no rabbits or hares were found in the modern Lamar area (H2) habitat. Their presence was found in Level 1 and Level 3 of the Lamar Cave data

which is dated as modern and could span as much as 333 years (Hadly 1999). However, no evidence of rabbits or hares were detected in the remains of 248 pellets and 20 scats collected during the two years of this study from the Lamar area (H2). Although rabbits and hares may exist in the modern Lamar area, they probably occur in such low numbers that their remains did not show up in the modern dataset. Their presence in the Lamar Cave (H5) data may indicate higher population numbers in the past or possibly a recent change in the environment.

If rabbits and hares are excluded from the analysis, the Lamar Cave pseudo-pellets were weakly associated with the modern Lamar area (H2) using the pseudo-pellet method with MNI. The stratigraphic subunit method on the other hand makes a strong argument for Lamar Cave stratigraphic subunits to be associated with the Lamar area (H2) habitat type using both MNI and NISP. There is very weak association between the Lamar Cave (pseudo-pellets and stratigraphic subunits) and the Old Faithful (H3) habitat type with both methods using MNI or NISP.

Both methods of analysis (pseudo-pellet and stratigraphic subunit) worked well in discriminating between the different modern habitats and the Lamar Cave data. Correct classification rates differed between the two methods of analysis for the modern habitats and the Lamar Cave data. In trying to determine which habitat the Lamar Cave (H5) data were most closely associated with, the two methods of analysis had similar patterns but the degree of association was higher with the stratigraphic subunit method.

The differences in the results are due to the different assumptions made by each model. The pseudo-pellet method assumes that if pellets from the Lamar Cave data were

to be reconstructed they should have a pellet structure (MNI and NISP) similar to that found in the modern predators from at least one of the different habitats. The pseudo-pellets produced with this model are based on the information that is inherent in the pellet structure (MNI and NISP) from the different habitats. The different MNI and NISP distribution per pellet and scat make classification more rigorous and thus classification rates lower.

The stratigraphic subunit method had higher classification rates than the pseudo-pellet method because it homogenizes the data over many subunits as compared to the pseudo-pellet method (Table 15, 16). This is especially true when a species occurs in the data with high counts but only occurs a few times. It then distributes the large counts of species data over multiple stratigraphic subunits. The species counts are used to associate that species with stratigraphic subunits. The species when present, may be associated with a disproportionate number of stratigraphic subunits. The stratigraphic subunit method has fewer assumptions in that it does not take into consideration the relationship of MNI and NISP that is found in the modern pellets and is therefore less rigorous in analyzing the data.

Conclusions

Trying to determine which modern habitat the Lamar Cave data most closely resembles (linking the present to the past) is not a straightforward analysis. Different data collection methods, data types and the influence of time make this type of analysis challenging. Decision tree software such as CART was chosen for analysis because of the fact that given certain distribution assumptions, it was able to classify the Lamar Cave

data into the modern habitat it was most similar to. This result is given credibility by the fact that CART was able to correctly classify modern data into the habitat it was collected from at a high degree of accuracy.

The stratigraphic subunit model assumes that there is a random distribution between species. This method does not take into account any pellet structure that exists within the modern dataset and only compares MNI totals to other MNI totals. NISP is treated in the same manner and only NISP totals are compared with one another. The stratigraphic subunit model based on five subunits for MNI and 20 subunits for NISP worked well in classifying the Lamar Cave (H5) data as being more closely associated with the Gardiner (H1) area using six species and with the Lamar area (H2) using five species.

Both types of analysis; the pseudo-pellet or the stratigraphic subunit method, contain strengths and weaknesses. Determining which method to use and how many variables to include depends on the perspective and the questions that are being asked. The difficulty in identification of prey remains to the level of species from fossil or pellet samples must be considered when trying to make associations between those samples and habitat. Other issues such as the effects of time within a paleontological site and taphonomy must be considered when interpreting the results from such a study.

CHAPTER 6

PELLET AND SCAT ANALYSIS AS INDICATORS OF PRESENT AND PAST
HABITATS

[This chapter has been written as an independent paper for submission. The discussion and conclusion of this chapter apply to the thesis as a whole.]

Introduction

Raptors have evolved to exploit the prey resources in a wide variety of habitats. A representative sample of their prey communities can be obtained by examining the contents of regurgitated pellets (Errington 1930, Craighead and Craighead 1956, Marti 1974, Salamolard 2000). Raptor pellets have allowed scientists from different scientific fields to unravel the mysteries of raptor diets; to determine species compositions within diverse habitats, to determine prey preferences, and to reconstruct past species communities (Andrews 1990, Craighead and Craighead 1956, Guilday 1969, Guilday and Parmalee 1965, Hadly 1996, 1999, Hockett 2000, Jaksic and Marti 1986, Marti 1974).

Pellets from raptors have been widely used to determine the food habits of raptors within different ecosystems and have been found to be accurate in representing the diets and number of prey eaten in raptors, especially. They are easily collected without being disruptive to the study population (Errington 1930, Craighead and Craighead 1956, Marti 1974).

Scats have similarly been used to determine the food habits of various mammalian predators within diverse ecosystems. The diets of generalist predators such as coyotes have been extensively studied using scat analysis (Bekoff 1977, Crabtree and Sheldon

1999 Murie 1940). Scats have also been used to determine past prey species communities (Andrews 1990, Andrews and Evans 1983, Hadly 1996, 1999, Hockett 2000).

Pellets and scats amassed over time from caves and rock shelters have been used in paleoecological studies to determine species composition and climate from past time periods (Andrews 1990, Brain 1981, Guilday 1969, Guilday and Parmalee 1965, Hadly 1996, Hockett 2000). Modern pellets and scats are usually intact when collected and represent the prey of a single predator's recent meal; paleontological bone assemblages combine the contents of many raptors and mammalian predators over a longer time span into a composite sample.

Many ecological questions arise that may be answered by using both modern and paleontological sources of raptor pellets and predator scats. One such question is whether pellets and scats can be used to discriminate between different habitats within modern ecosystems. A second is whether the predictions from modern pellets and scats can be extrapolated and generalized to determine if paleontological sites represent the habitat from which they were sampled in the past. This study was undertaken to determine whether pellet and scat analysis from different avian predators and coyotes (*Canis latrans*) could discriminate between different modern habitats and whether the results from the modern pellet and scat analysis could be applied to paleontological data.

Research conducted in Yellowstone National Park began to look for the answers to such questions with the excavation and analysis of a late-Holocene cave site in the northern range of Yellowstone National Park (Hadly 1996, 1999). This site, Lamar Cave,

was ideal for studying the past small mammal community in that it 1) contains specimens of still extant species, 2) the modern community can be sampled with limited disturbance, 3) the cave specimens are well-dated with radiocarbon dating and, 4) the cave is composed of many stratigraphic layers (Hadly 1999). The main collecting agents for depositing bones into Lamar cave are the bushy-tailed wood rat (*Neotoma cinerea*) and carnivores, mainly coyote and wolves (*Canis lupus*). Wood rats collect copious amounts of nesting material that includes raptor pellets, plant material, carnivore scats and bones from carcasses.

Lamar cave is a rich paleontological site that contained over 10,597 identified mammalian specimens which showed a high affinity with the local sagebrush grassland habitat (Hadly 1996,1999). To address the question of whether the Lamar cave specimens accurately represent the past communities from which they were sampled, Hadly (1999) collected raptor pellets, carnivore scats and conducted small mammal trapping within the nearby sagebrush grassland to assess the modern small mammal community. Results from this study revealed that the most modern level of Lamar Cave had a similar rank order abundance of species as the modern raptor pellets and carnivore scats.

With these results as a baseline, a more comprehensive analytic approach was undertaken to determine whether the most recent specimens from Lamar Cave more closely resemble the nearby sagebrush grassland or some other habitat within the Park. To assess this, raptor pellets and carnivore scats were collected from different habitats within the Park to determine if the species and numbers of individuals found in the pellets

and scats contained a unique "signature" representative of the different habitat types. Lamar Cave data were then included in the analysis to determine whether the most recent levels (Level 3) of Lamar Cave most resembled those of the modern sagebrush grassland currently found near Lamar Cave or one of the other habitats within the Park.

Study Area

The study area is located in Yellowstone National Park and includes portions of Montana and Wyoming (Fig.1). Yellowstone National Park encompasses 8,892 km² (Knight, 1994). Four primary study areas were selected within the Park to represent varied elevation and vegetation gradients. The study sites were located: 1) near Gardiner, Montana, 2) near the confluence of Slough creek and the Lamar River in the northern part of the Park, within the same vicinity as Lamar Cave 3) the area surrounding Old Faithful in the western part of the Park and 4) within a portion of the Hayden Valley in the central region of the Park. Within these locations, elevation ranges from 1733 meters near Gardiner to 2566 meters in the Hayden Valley. Average annual precipitation ranges from 254 mm near Gardiner to 703 mm in the Hayden Valley.

The vegetation near Gardiner is considered a dry shrubland dominated by bluebunch wheatgrass (*Agropyron spicatum*) and Sandberg's bluegrass (*Poa sandbergii*). Upland areas support big sagebrush (*Artemisia tridentata*). Forested areas are relatively open and are dominated by Juniper (*Juniperus scopalorum*), Douglas fir (*Pseudotsuga menziesii*) and cottonwood (*Populus* spp.) in riparian zones.

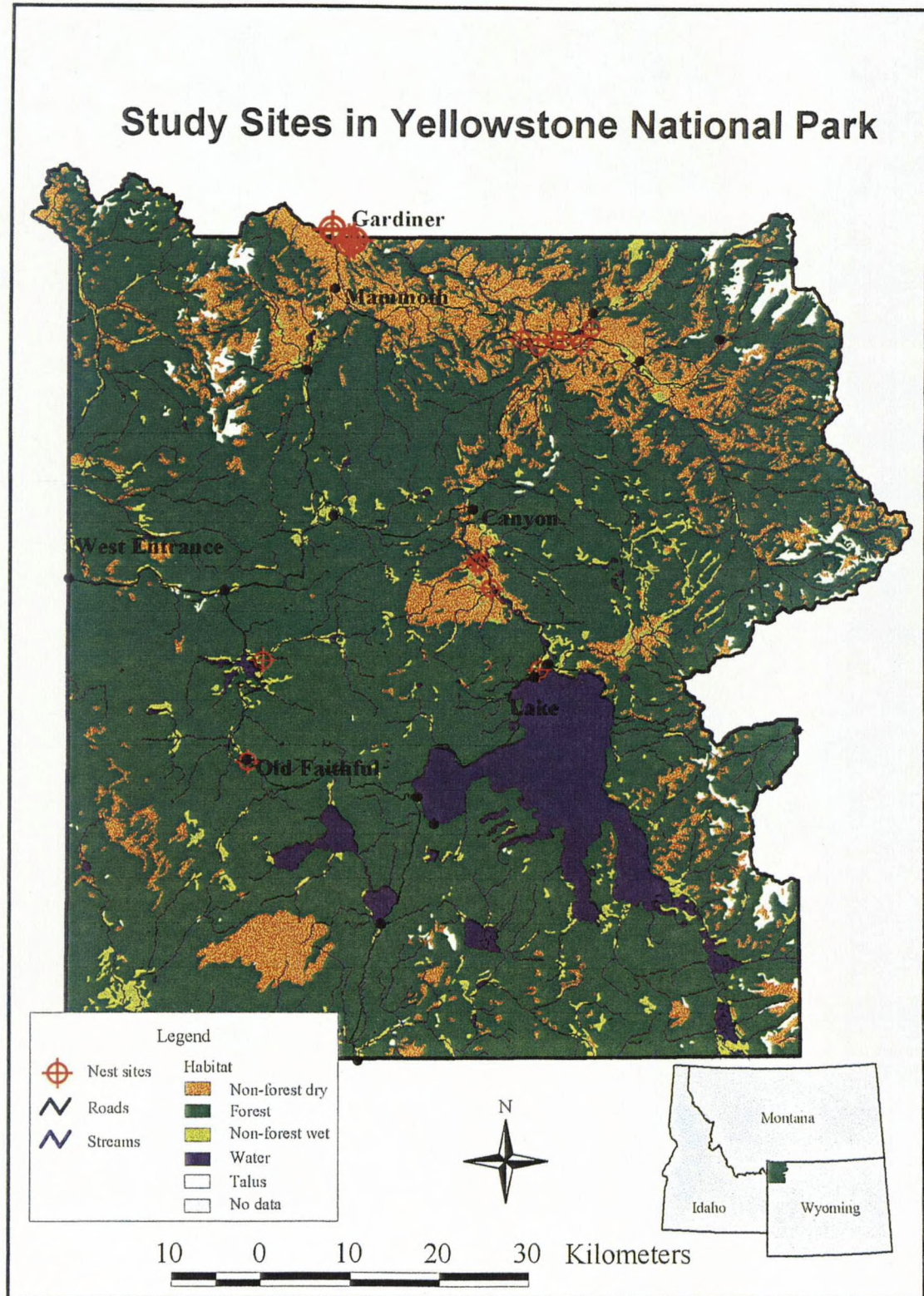
The vegetation in the vicinity of Lamar Cave is a mosaic of sagebrush grassland

and parkland forests. The area is dominated by big sagebrush and Idaho fescue (*Festuca idahoensis*) while forested areas are relatively open and dominated by Douglas fir on north-facing slopes. Moist areas support aspen (*Populus tremuloides*) shrubby cinquefoil (*Potentilla fruticosa*), and sticky geranium (*Geranium viscosissimum*).

The Old Faithful area is dominated by open stands of subalpine fir (*Abies lasiocarpus*), lodgepole pine (*Pinus contorta*), and elk sedge (*Carex geyeri*). Thermally influenced vegetation such as Ross's bentgrass (*Agrostis rossiae*) is prominent within the Old Faithful area and other geyser basins.

The Hayden valley is dominated by silver sage (*Artemesia cana*) and Idaho fescue in meadow areas. Upland areas are dominated by big sagebrush and tufted hairgrass (*Deschampsia cespitosa*). Riparian areas are dominated by sedges (*Carex* spp.). Forested areas are composed of lodgepole pine and subalpine fir and (Despain, 1990).

Figure 18. The Yellowstone Park Study Area.



Methods

Data Collection Methods

Fieldwork was conducted from 15 May – 31 August 1988 and 1 June – 31 August 1999. I collected pellets from roosting and nesting sites of breeding pairs of Red-tailed Hawks (*Buteo jamaicensis*), Great Horned Owls (*Bubo virginianus*) and Common Ravens (*Corvus corax*) throughout the four study areas. In the Hayden valley, pellets were collected from Short-eared Owls (*Asio flameus*) and a pair of Long-eared Owls (*Asio otus*) instead of a Great Horned Owl. Pellets were collected from a Swainson's Hawk (*Buteo swainsoni*) pair instead of a Red-tailed hawk. Coyote scats were collected from the four study areas.

Samples were collected, air-dried, numbered and placed into plastic bags. In the lab 738 pellets were soaked in warm water and soap, and then allowed to dry overnight. Pellets were dissected; bones, teeth, and cranial materials were separated. Fifty-one coyote scats were washed, air-dried and dissected. Teeth and cranial material were used from the pellets and scats to identify samples to the species level when possible. In the case of Leporidae, craniodontal materials were not always present and skeletal elements were used to identify samples to the level of genus.

Comparative materials from the Denver Museum of Natural History and the vertebrate collection at Montana State University were used to aid in identifications. Specimens from this study will be curated at Stanford University and with the National Park Service at Yellowstone National Park.

Twenty species of raptors reside in Yellowstone National Park seasonally or year-round (McEneaney 1996). Of these 20 species the Red-tailed Hawk, Great Horned Owl, and to a lesser degree Swainson's Hawk are the most common generalist raptors in the Park. Ravens are not true raptors, but they are predatory in nature and fill an ecological role similar to raptors (Boarman and Heinrich 1999, Craighead and Craighead 1956, White and Cade 1971). Ravens are common year-round residents in the Park and are found in all habitats.

The diets of generalist raptors, such as, Red-tailed Hawks, Swainson's Hawks, Great Horned Owls, Ravens and coyotes were targeted to represent a wide array of nocturnal and diurnal small mammals from within the four different habitats. Similarly, the Lamar Cave specimens represent an amalgamation of species collected over time by many different types of raptors representing both nocturnal (owls) and diurnal (hawks and Ravens) predators as well as by coyotes (Hadly 1999).

Pellets

Pellets are produced by a number of different species of birds as a normal function of the digestive system (Hoffman 1988). Many studies have investigated the accuracy of using raptor pellets to determine the number of individuals eaten. One study found that owl pellets represented approximately 80% of the individuals eaten (Errington, 1930). Pellets from hawks did not reveal as much information on the number of individuals eaten due to the strength of their gastric juices and eating style (Errington 1930, Dodson and Wexlar 1979, Duke *et al.* 1975, Duke *et al.* 1976).

Degradation of undigested bone depends on the gastric juices produced by each species and the degree to which the bones are disarticulated during the feeding process. Owls eat their prey whole and hawks dismember their prey before swallowing (Dodson and Wexlar 1979, Hoffman 1988, Mayhew 1977). Specific patterns in the fragmentation of specimens are thus distinctive for each group of birds (Dodson and Wexlar 1979, Hoffman, 1988). Owls have a less corrosive acid content with a basal pH of 2.35, while hawks have a more corrosive acid content with a basal pH of 1.6. The weaker acid levels in the digestive systems of owls do not damage bones as much as the digestive systems of hawks. Similar patterns were observed in both the modern Yellowstone samples and in the Lamar Cave samples (Hadly, 1999). The bone assemblages from modern owl pellets contained more intact cranial and postcranial elements. Mammalian teeth from owl pellets had less erosion, etching and pitting and were more intact than teeth from the modern Red-tailed or Swainson's Hawk pellets. Similar patterns were found in the cave specimens so we can assume they were affected by similar processes.

Scats

Mammalian carnivores also produce a unique signature in the remains of scats they produce. Andrews and Evans (1983) found that canids produce distinctive bone assemblages with the bones being excessively damaged and postcranial materials outnumbering cranial fragments. Mandibular and maxillary bones are highly fragmented and teeth are etched and pitted by gastric juices. Similar trends occur in the modern Yellowstone samples.

Data Analysis Methods

Analysis of the data from this study is challenging in that two different types of data were being compared. One dataset is modern (pellets and scats) and is based on a planned collection procedure. The other paleontological dataset from Lamar Cave is a faunal composite of bone that originally comprised pellets from raptors and predator scats (Hadly 1999). The pellets and scats disaggregate over time and the bones become consolidated into stratigraphic subunits. Data from modern pellets and scats are based on individual pellets and scats.

The minimum number of individuals (MNI) and number of identified specimens (NISP) was calculated for each pellet and scat analyzed (Grayson 1978). MNI represents the absolute minimum number of individuals represented in a sample based on the number of dentaries and skulls. NISP differs from MNI in that each identified element within the sample is included in the total. Teeth and cranial elements are summed together.

Diversity Indices

Diversity indices were used to calculate the diet diversity between the different predator (raptor and Raven) species within the four different habitats. The Brillouin index was used to determine diet diversity for each of the different raptors and Ravens because it assumes that species are not randomly sampled within the habitat. The Brillouin formula is:

$$H'_B = \frac{\ln N! - \sum \ln n_i!}{N}$$

We calculated the Brillouin index, H'_{NM} , for each of the predator species, where N represents the number of mammalian individuals in all pellets of that predator species and n_i was the total number of individuals of prey species i found in all pellets of that predator species. This gives an index of diversity of the diet of each predator species.

Data Standardization

To determine whether data from the modern levels of Lamar Cave most closely resembled one of four modern habitats (Gardiner, Lamar area, Old Faithful, Hayden Valley) from Yellowstone, the data representing different collection methods needed to be made compatible for analysis. Two different methodologies were used to manipulate the pellet, scat and Lamar Cave data in order to standardize them. For both the modern and the Lamar Cave data, the analysis was restricted to small mammal data alone. All *Microtus* species were lumped together due to the difficulty in identification from skeletal remains. Up to three species of *Microtus* (*Microtus longicaudus*, *Microtus montanus*, and *Microtus pennsylvanicus*) potentially are included in both modern and fossil data sets. *Microtus* species are difficult to discriminate by isolated teeth. Trapping data, however, indicates that most *Microtus* species in these habitats are *M. montanus*, and *M. pennsylvanicus* with *M. longicaudus* being very rare. Rabbits and hares were also lumped together as Leporidae due to the difficulty in species identification from dental remains. Initially 15 different species of small mammals were included in the analysis. This number was reduced to six and five of the most common species found in both the modern and Lamar Cave data. The six most common small mammals species are *Spermophilus armatus* (Uinta ground squirrel), *Thomomys talpoides* (Northern pocket

gopher), *Microtus* spp.(voles), *Neotoma cinerea* (bushy-tailed wood rat), *Peromyscus maniculatus* (deer mouse), Leporidae (rabbits and hares). The five most common small mammal species would exclude Leporidae (rabbits and hares). These six and five taxa were then used to compare the modern and fossil data.

Method 1- Pseudo-pellets

The pseudo-pellet method is based on reconstructing pellets from the disaggregated cave data. We surmised that if pellets and scats from the cave were to be reconstructed they should have a species composition similar to the raptors, Ravens and coyote scats from the various habitats from where they were originally found. The modern pellet and scat data, determined that pellets and scats from the four habitats had different pellet structures; these differing structures correspond to different distributions of MNI and NISP per pellet and scat (Table 27).

Table 27. Mean minimum number of individuals (MNI) and mean number of identified specimens (NISP) per pellet and scat for each of the 4 study areas.

	Gardiner	Lamar Area	Old Faithful	Hayden Valley
MNI	3.27	2.27	2.3	2.19
NISP	26.95	18.29	19.62	21.1
Number of pellets analyzed per site	118	202	109	148

Using MATLAB (The Mathworks, Inc. 1997), pellet data from Lamar Cave were then simulated for each of the four habitats using the total MNI and NISP from the Lamar Cave data (Level 3) and from each of the known distributions of MNI and NISP from the four different habitats. This data is referred to as pseudo-pellets. Thus pseudo-pellets were created for each one of the four different habitats based on the known MNI and

NISP from pellets and scats from the modern habitats (Table 28). The goal was to mimic the pellet structure of MNI and NISP associated with a particular habitat. Five replications were made for each of the four habitats creating 20 different pseudo-pellet simulations. The modern pellet and scat data were not changed in any way, thus individual modern pellets and scats remained unchanged throughout all of the simulations. Pseudo-pellets differed in each simulation based on which habitat they were modeled from (habitats 1-4) and based on randomizations generated within each habitat model.

Table 28. Pseudo-pellets derived and number of observations used in analysis for MNI from modern pellets and scats and Level 3 of Lamar Cave.

	Gardiner	Lamar area	Old Faithful	Hayden	Cave (Level 3) Total
*MNI	3.27	2.27	2.3	2.19	100
Pseudo-pellets Produced	30	44	42	46	
Number of observations used in analysis	607	621	619	623	

* MNI was based on mean number of individuals per pellet and scat or Lamar Cave level.

Modern pellets (N=533) and scats (N=33) from the four habitats were analyzed with a classification tree program to determine whether the modern habitats could be discriminated from one another based on species distribution across pellets. If this initial step were successful then the pseudo-pellets would then be included in the analysis to see if the Lamar Cave data could be discriminated from the modern habitats using the same discrimination criteria. Ultimately the analysis should indicate which habitat the Lamar Cave data most closely resembled.

Method 2-Stratigraphic Subunit

This method manipulated the modern pellets and scats to make them similar to the original Lamar Cave data so that modern and historical data both possess similar summary structures. Creation of simulated stratigraphic subunits including both modern and Lamar Cave data was based on the totals of MNI and NISP for Level 3 of the Lamar Cave data (MNI = 85, NISP = 746). Subunits were produced which had the same totals for MNI and NISP for six and five different species from the Lamar Cave data. Unlike the pseudo-pellet method, the process of creating subunits does not involve sampling with replacement. The data were organized into a set of individuals and a set of specimens. The set of individuals (modern pellets and scats) and the set of specimens (Lamar Cave Level 3) were randomized for MNI and NISP analysis. Subunits were fixed in size throughout the analysis. A sufficient number of randomized subunits were created from the totals of MNI and NISP to create enough variability within the units but still retain the overall pattern of species proportionality that exists within the units. In the case of MNI, subunits of size five MNI were produced and subunits of size 20 NISP were created to simulate NISP (Table 29). Three separate simulations were produced to uncover consistent patterns in the presence of simulations and add greater variability. Data from each simulation was then analyzed using a classification tree program.

Table 29. Number of stratigraphic subunits created for each habitat based on the totals for MNI and NISP using six or five taxa.

Habitat	6 taxa	6 taxa	5 taxa	5 taxa
	Stratigraphic subunits of size 5	Stratigraphic subunit of size 20	Stratigraphic subunits of size 5	Stratigraphic subunit of size 20
	MNI	NISP	MNI	NISP
Gardiner (H1)	74	152	66	138
Lamar area (H2)	85	170	85	170
Old Faithful (H3)	35	72	35	72
Hayden Valley (H4)	63	153	63	153
Lamar Cave (H5)	17	37	14	35

This method differs from the pseudo-pellet method in that any modern pellet structure that might have existed between the different habitats is lost because of the deconstruction of the modern pellets and scats prior to randomization. The randomized pellets and scats are completely different for each simulation. Any MNI and NISP pellet structure among the modern pellets and scats is lost during the creation of the stratigraphic subunits.

Classification and Regression Trees (CART)

The modern pellets and scats and simulated datasets (pseudo-pellets or stratigraphic subunits) were used in a classification analysis, using CART (classification and regression tree) from Salford Systems. The CART procedure uses a computer intensive algorithm that recursively searches over all variables (taxa) to produce a sequence of optimal binary splits to best display how the data may be classified or predicted (Breiman *et al.* 1984). The structure of the data in this case is relationship between species and habitat. CART classifies and divides the data in terms of individual taxa and their frequency to display similarities and differences among groups of data.

Results from CART are in the form of an inverted tree beginning with a root node (parent) that is repeatedly split into exactly two child nodes based on a series of yes/no questions pertaining to a single variable. Some nodes become terminal, meaning that a final classification has been reached. Other nodes (child) will continue to be split until a terminal node is reached (Steinberg *et al.* 1997). A further refinement that was utilized using CART was the “minchild” option. This function allows a minimum number of individuals to be set within a terminal node. We set the ‘minchild’ option to require a minimum number of five individuals within each terminal node. In the initial analysis no other special options were used in CART and the default settings were used.

One of the analytical strengths of CART is that it allows a new or subset of data to be classified using an existing classification tree. This is referred to as ‘dropping cases down a tree’ (Steinberg *et al.* 1997). To determine what habitat the Lamar Cave data (H5) most closely resembled it was necessary to have CART classify the Lamar Cave data (H5) with the modern habitat it was most closely associated with. Both the pseudo-pellet and stratigraphic subunit datasets were classified using CART and the results of the model were saved. Then using the resultant model tree, each datum from Lamar Cave (pseudo-pellets and stratigraphic subunits) was classified to determine the habitats that the pseudo-pellet or stratigraphic subunit from Lamar Cave most closely resembled.

Results

Data Collection Results

The prey species whose remains were identified from modern pellets and scats, and from the historical Lamar Cave data are presented in Table 30.

Table 30. Mammalian faunal list from raptors and Raven pellets from four habitats within Yellowstone National Park and Levels 1-3 of Lamar Cave.

Taxon	Gardiner	Lamar Area	Old Faithful	Hayden Valley	Level 1 Lamar Cave	Level 3 Lamar Cave
Insectivora						
Soricidae						
<i>Sorex merriami</i>						1-4
<i>Sorex palustris</i>						1-5
<i>Sorex (Otisorex) spp.</i>	3-55	7-74	5-56	2-43		
<i>Sorex spp.</i>						1-4
Chiroptera						
Vespertilionidae						
<i>Myotis spp.</i>	1-11	0	0	0	0	1-8
Carnivora						
Mustelidae						
<i>Mephitis mephitis</i>						1-7
<i>Mustela cf. frenata</i>						1-8
<i>Mustela sp.</i>	0	3-16	1-15	0	0	
Rodentia						
Sciuridae						
<i>Spermophilus cf. armatus</i>	3-10	48-275	11-49	0	3-32	18-225
<i>Tamias spp.</i>	1-12	0	2-5	0		2-6
<i>Tamiasciurus hudsonicus</i>	1-3	6-40	5-10	0		1-1
Geomyidae						
<i>Thomomys talpoides</i>	15-163	48-492	53-480	40-374	4-15	14-142
Zapodidae						
<i>Zapus cf. princeps</i>	3-20	1-12	3-44	0		
Muridae						
<i>Clethrionomys cf. gapperi</i>	1-5	2-17	4-33	0		1-4
<i>Microtus cf. montanus</i>	14-171	21-215	13-167	59-788	0	0
<i>Microtus cf. pennsylvanicus</i>	9-98	22-193	19-201	8-103	3-11	3-17
<i>Microtus richardsoni</i>	2-26	11-118	49-460	4-19	0	0
<i>Microtus spp.</i>	110-974	130-1124	52-387	137-1169	3-18	21-179
<i>Ondatra zibethicus</i>	0	2-8	3-9	0		3-18
<i>Phenacomys intermedius</i>	1-3	0	3-54	0		3-16
<i>Neotoma cinerea</i>	11-67	3-26	0	0	1-4	9-87
<i>Peromyscus maniculatus</i>	148-1141	83-587	18-90	4-38		9-54
Lagomorpha						
Leporidae						
<i>Lepus cf. americanus</i>						2-2
<i>Lepus cf. townsendii</i>					1-5	4-27
<i>Sylvilagus cf. nuttallii</i>						2-6
<i>Sylvilagus spp.</i>						1-4
Leporidae	42-279	0	0	0		2-3
Total	365-3038	387-3197	241-2060	255-2535	15-85	100-827

The minimum number of individuals (MNI) of non-volant mammalian species identified from 675 pellets and 44 scats was 1,428 and the number of identified specimens (NISP) within the study areas was 12,170. The mean MNI and mean NISP are presented in Table 31.

Table 31. Mean minimum number of individuals (MNI) and mean number of identified specimens (NISP) per pellet and scat for each of the 4 study areas.

	Gardiner	Lamar Area	Old Faithful	Hayden Valley
MNI	3.27	2.27	2.3	2.19
NISP	26.95	18.29	19.62	21.1
Number of pellets analyzed per site	118	202	109	148

Results from the pellet analysis indicate that the avian raptor community preys upon a diverse mammalian and non-mammalian prey base. Small mammals make up the bulk of the avian predators diets (82.3 %), with birds (10.8%), amphibians (3.0%), fish (2.3%), and reptiles (1.7%), respectively comprising smaller percentages (MNI= 1,520). These results are comparable with other food habit studies conducted on similar raptor species (Boarman and Heinrich 1999, Craighead and Craighead 1956, England *et al.* 1997, Houston *et al.* 1999, Johnsgaard 1990, Marks *et al.* 1994, Marti 1974, Preston and Beane 1993).

The minimum number of individuals (MNI) of non-volant mammalian specimens identified from 51 coyote scats was 178 and the total number of identified specimens (NISP) was 1,340. The small mammal component of the coyote's diet within this sample was very high (91.2%), with birds (2.0%), amphibians (1.0%), and fish (<1.0%) respectively comprising smaller percentages (MNI=195, NISP = 1,369). The relative

frequency for small mammals is higher than in other coyote studies done within the Park (Murie, 1940, Crabtree and Sheldon, 1999) but these differing results could be attributed to our small sample size.

Data Analysis Results

When each of the predator species (raptors and Ravens) were compared within the separate habitats the Brillouin Diversity Index, H'_{NM} , values were similar (Table 32). In the Gardiner area, the diet of Great Horned Owls was more diverse than that of Ravens. In the Lamar area, the diets were very similar between the three species of birds. In the Old Faithful area, Great Horned Owls showed greater diet diversity than Red-tailed Hawks or Ravens. In the Hayden Valley all of the birds displayed relatively low diversity in their diets with Long-eared Owls having the greatest diversity followed by Short-eared Owls, Ravens and Swainson's Hawk respectively.

Table 32. Brillouin diversity index (H'_{NM}) values for raptors and Ravens per habitat.

Habitat	G	C	R	G	C	R	G	C	SW	S	L	C
Gardiner	1.6(342)	1.2(23)	-	-	-	-	-	-	-	-	-	-
Lamar Area	-	-	1.6(75)	1.8(240)	1.6(72)	-	-	-	-	-	-	-
Old Faithful	-	-	-	-	-	1.4(12)	2.0(221)	1.3(11)	-	-	-	-
Hayden Valley	-	-	-	-	-	-	-	-	.58(82)	1.1(62)	1.2(89)	.87(20)

RTHA= Red-tailed Hawk

SW = Swainson's Hawk

S = Short-eared Owl

L = Long-eared Owl

G = Great Horned Owl

C = Common Raven

() represents number of individuals in sample

Pseudo-pellets were simulated using MNI and NISP data from the modern dataset (pellets and scats) from the four different habitats to determine their structure (Table 33). Similarly, stratigraphic subunits were simulated from the modern and the Lamar Cave data using totals from both five and six taxa. CART processed individual habitats based on the pseudo-pellet or stratigraphic subunit models and calculated the percent of observations that were classified correctly into the correct habitat. CART was able to discriminate between the four habitats with varying degrees of accuracy using either the pseudo-pellet or the stratigraphic subunit method (Table 34). The Lamar area (H2) had the lowest classification rates overall using the pseudo-pellet method and stratigraphic subunit method. The lower classification rates for the Lamar area (H2) are due to the fact that it is a mixture of habitat types including sagebrush grasslands and coniferous forests.

Classification rates were considerably higher for more discrete habitats: the Gardiner area (H1) and the Hayden Valley area (H4) with the pseudo-pellet and stratigraphic subunit methods using MNI or NISP. Classification rates for the Old Faithful area (H3) were somewhere in between the other three habitats; greater than the Lamar area (H2) and less than either the Gardiner area (H1) or Hayden Valley (H4).

Table 33. Pseudo-pellets derived and number of observations used in analysis for MNI from modern pellets and scats and Level 3 of Lamar Cave.

	Gardiner	Lamar area	Old Faithful	Hayden	Cave (Level 3) Total
*MNI	3.27	2.27	2.3	2.19	100
Pseudo-pellets Produced	30	44	42	46	
Number of observations used in analysis	607	621	619	623	

* MNI was based on mean individual per pellet and scat.

Table 34. Mean percent of habitats classified correctly for four habitats using pseudo-pellets and stratigraphic subunit methods with MNI and NISP using 6 and 5 taxa.

Habitat	Pseudo-pellets				Stratigraphic subunit			
	6 taxa		5 taxa		6 taxa		5 taxa	
	MNI	NISP	MNI	NISP	MNI	NISP	MNI	NISP
Gardiner (H1)	78.0	75.4	61.0	60.2	87.0	97.5	82.3	93.7
Lamar area (H2)	18.8	21.3	24.8	24.3	57.2	89.4	46.2	84.1
Old Faithful (H3)	38.5	63.3	38.5	63.3	54.3	80.1	49.5	80.5
Hayden Valley (H4)	87.8	67.6	87.8	67.6	85.7	91.0	85.2	91.9

6 variables = *Spermophilus armatus* (Uinta ground squirrel), *Thomomys talpoides* (Northern pocket gopher), *Microtus* spp.(voles), *Neotoma cinerea* (bushy-tailed wood rat), *Peromyscus maniculatus* (deer mouse), Leporidae (rabbits and hares).

5 variables = *Spermophilus armatus* (Uinta ground squirrel), *Thomomys talpoides* (Northern pocket gopher), *Microtus* spp.(voles), *Neotoma cinerea* (bushy-tailed wood rat) *Peromyscus maniculatus* (deer mouse).

The simulated pseudo-pellets from the Lamar Cave (H5) data (Table 33) were then included with the modern pellets and scats to determine how unique the Lamar Cave data was and how its classification compared with the modern data. The Lamar Cave data was considered to represent another habitat type. The addition of the fifth habitat type will necessarily change the results for the original four habitat types, since in the new scenario there is an additional possibility for classifying them as another habitat type. The results of this classification are found in Table 35.

Table 35. Mean percent of habitats classified correctly for five habitats using pseudo-pellets and stratigraphic subunit methods with MNI and NISP using 6 and 5 taxa.

Habitat	Pseudo-pellets				Stratigraphic subunit			
	6 taxa		5 taxa		6 taxa		5 taxa	
	MNI	NISP	MNI	NISP	MNI	NISP	MNI	NISP
Gardiner (H1)	66.3	71.3	58.6	57.8	79.0	95.8	61.0	60.2
Lamar area (H2)	21.0	17.2	15.0	13.3	44.7	84.0	24.8	24.3
Old Faithful (H3)	44.1	64.1	38.1	63.3	65.0	81.0	38.5	63.3
Hayden Valley (H4)	85.9	68.0	87.3	66.7	69.3	89.7	87.8	67.6
Lamar Cave (H5)	47.3	46.5	43.0	45.6	86.3	96.4	71.4	93.3

6 variables = *Spermophilus armatus* (Uinta ground squirrel), *Thomomys talpoides* (Northern pocket gopher), *Microtus* spp.(voles), *Neotoma cinerea* (bushy-tailed wood rat), *Peromyscus maniculatus* (deer mouse), Leporidae (rabbits and hares).

5 variables = *Spermophilus armatus* (Uinta ground squirrel), *Thomomys talpoides* (Northern pocket gopher), *Microtus* spp.(voles), *Neotoma cinerea* (bushy-tailed wood rat) *Peromyscus maniculatus* (deer mouse).

When including the Lamar Cave (H5) data using the pseudo-pellet method, CART was able to correctly classify the Lamar Cave (H5) data with higher classification rates than the Lamar area (H2) and lower than the other modern habitats. The classification rates for the Lamar Cave data were consistent for both MNI and NISP.

When using the stratigraphic subunits method CART had relatively high classification rates for all of the habitats except for the Lamar area (H2) when using either six or five variables (taxa). The Lamar Cave (H5) data proved to have high overall correct classification rates. The correct classification rates for NISP were higher than the rates using MNI.

To determine what modern habitat the Lamar Cave (H5) data most closely resembled the method of 'dropping cases down a tree' was utilized using CART. With this method, the initial step is to produce a model and decision tree from the modern pellet and scat data. After saving the results from this model, the data from Lamar Cave (pseudo-pellets and stratigraphic subunits) were classified using the resultant decision

tree model. The results from this classification indicate the number of times that the observations from the Lamar Cave data were classified to each habitat. These data are found in Table 36.

Table 36. Dropping cases-mean percent of pseudo-pellets and stratigraphic subunit classified into each habitat using 6 and 5 model taxa.

Habitat	Pseudo-pellets				Stratigraphic subunit			
	6 taxa		5 taxa		6 taxa		5 taxa	
	MNI	NISP	MNI	NISP	MNI	NISP	MNI	NISP
Gardiner (H1)	37.6	35.8	20.9	30.6	41.2	70.3	9.5	0.0
Lamar area (H2)	13.9	22.0	29.0	29.5	31.3	27.0	54.8	79.0
Old Faithful (H3)	19.7	32.0	27.4	30.1	25.5	2.7	28.6	20.5
Hayden (H4)	28.7	10.2	22.7	9.8	2.0	0.0	7.1	0.0

Analysis using pseudo-pellets and six variables indicated that 37.6% of the Lamar Cave (H5) pseudo-pellets were classified as being most similar to the Gardiner (H1) habitat type using MNI and 35.8% with NISP. This stronger relationship with the Gardiner (H1) habitat type is directly related to the presence of rabbits or hares (Leporidae) in both the Lamar Cave (H5) data and the Gardiner (H1) data.

Analysis using stratigraphic subunits and six variables, indicated that 41.2% of the Lamar Cave stratigraphic subunits were associated with the Gardiner (H1) habitat type using MNI and 70.3% with NISP. These results are again tied to the presence of rabbits and hares (Leporidae) within both the Gardiner (H1) and Lamar Cave (H5) data. There is also a strong negative association towards classifying the Lamar Cave stratigraphic subunits with the Hayden (H4) habitat type.

Leporidae (rabbits and hares) was shown to be an important variable in determining which habitat the Lamar Cave data is most closely associated with. To see how consistent the results of the model were, the data were reanalyzed after rabbits and hares were excluded. Using only five variables, 29.0% of the Lamar Cave pseudo-pellets were classified as the Lamar area (H2) habitat type data using MNI and 29.5% with NISP as compared to 13.9% and 22.0% respectively when rabbits and hares were included.

When using only five variables with the stratigraphic subunit model, 54.8% of the Lamar Cave stratigraphic subunits were classified as the Lamar area (H2) habitat type with MNI and 79.0% with NISP, as compared to 31.3% and 27.0% respectively when rabbits and hares were included. It is interesting to note when using NISP that the Gardiner (H1) habitat type and the Hayden (H4) habitat type are never chosen as being similar to the Lamar Cave stratigraphic subunits.

Discussion

CART was able to provide classification rules that correctly discriminated between the four different habitats based on the pellets and scats from a predator suite of raptors, Ravens, and coyotes from Yellowstone National Park. Two different approaches were then used to analyze the modern data from the different habitats and the historic data: 1) the pseudo-pellet method based on making the historic data similar to the modern distributions of MNI and NISP in pellets and scats from the four different habitats, and 2) the substratigraphic subunit method based on making modern data look similar to the historical Lamar Cave data by disaggregating the discrete pellets and scats. CART was then able to provide classification rules to allow discrimination between the Lamar Cave

data and the modern habitats using either MNI or NISP. Correct classification rates varied depending on the specific habitats, the model used, and whether MNI or NISP were used. In both models NISP produced higher correct classification rates than MNI. The Gardiner (H1), Old Faithful (H3) and Hayden (H4) study areas had the highest correct classification rates while the Lamar area (H2) had the lowest overall correct classification rates using the pseudo-pellet or stratigraphic subunit method. The Lamar Cave (H5) data were correctly classified somewhere in-between the modern habitats. The stratigraphic subunit method had overall higher correct classification rates than did the pseudo-pellet method for MNI and NISP.

Two sources of bias are possible in the data. These can be broadly viewed as either historical biases or modern biases.

Historical Biases

The term taphonomy means the process of how animals are culled from the environment, deposited, and accumulated over time into fossils (Behrensmeyer 1984, Hadly 1999, Korth 1979). Several taphonomic sources of bias may be occurring within fossil assemblages such as Lamar cave. These include 1) collection bias by wood rats, 2) variation in predator ranges, 3) change in predators and, 4) prey selection by predators. Wood rats do not collect raptor pellets and carnivore scat as dietary items the way that they collect plants. Instead they use pellets, scats and other odd items in the construction of their middens (Hadly, 1999). Wood rat remains were found to be constant and abundant throughout the Lamar cave deposits indicating that habitat preferences had not

changed over time and that the major taphonomic processes (collection by wood rats) was constant over time (Hadly, 1999).

Variation in predator ranges could bias the fossil fauna by inclusion of extralocal mammals not representative of the local habitat. Biases could be reflected by the collecting agent (wood rats), or by contributors (raptors, Ravens, and mammalian carnivores). Wood rats collect materials from approximately 50 meters from their nests (Hadly 1999). Home ranges vary greatly between various raptors. However, Red-tailed Hawks and Great Horned Owls tend to have smaller home ranges ($< 5 \text{ km}^2$) depending on habitat and densities of small mammals (Johnsgaard 1989, 1990). Territory size for coyotes in Yellowstone varied, but on average territories ranged from 7 to 12 km^2 prior to wolf reintroduction (Crabtree and Sheldon 1999). After the reintroduction of wolves to Yellowstone, the mean average home range was slightly smaller (J. Sheldon pers. comm.) Results from other studies have shown that coyotes may maintain territories up to 70 km^2 but move an average of 4 km^2 a day (Bekoff 1977). Hadly (1999) therefore estimated that the contents of Lamar Cave were probably being sampled from a 5 km radius around the cave.

Change in predators over time could potentially bias the Lamar Cave deposits by overrepresenting one type of raptor species over another (ie: nocturnal vs. diurnal). Throughout Lamar Cave both the nocturnal deer mouse (*Peromyscus maniculatus*) and diurnal species Uinta ground squirrel (*Spermophilus armatus*) are represented. Characteristic erosion and pitting of these specimens by different types of raptors is

evident throughout the Lamar Cave samples (Hadly, 1999). [See pellet section, Chapter 3].

All of the predator species are territorial during the breeding season. Territoriality tends to smooth out any bias caused by changes in predators over time for the following reasons. Breeding pairs return to the same territories year after year. This is especially true of Red-tailed Hawks, Swainson's hawk, Great Horned Owls, and Ravens (Boarman and Heinrich 1999, England *et al.* 1997, Houston *et al.* 1999, Preston and Beane 1993, Heinrich 1999, Ratcliffe 1997). Breeding site fidelity is not as strong in Short-eared Owls or Long-eared Owls (Marks *et al.* 1994, Holt and Leasure 1993). Hawks and Ravens return to the previous year's nest or erect new nests within close proximity to the old nest (England *et al.* 1997, Preston and Beane 1993, Ratcliffe 1997). Great Horned Owls and Long-eared Owls do not construct their own nests but utilize different types of existing nests or natural cavities (Houston *et al.* 1999, Marks *et al.* 1994). Short-eared Owls are usually ground nesters and construct new nests every breeding season (Holt and Leasure 1993).

Many of these species of predators nest in close proximity to one another and turnover rates of nests can be quite high since owls utilize abandoned hawk nests (Boarman and Heinrich 1999, Dunstan 1973, Hansen and Flake 1995, White and Cade 1971). Even if nests are not reused or usurped, territory boundaries tend to remain stable year after year especially in Red-tailed Hawks, Great Horned Owls and Ravens (Houston *et al.* 1999, Janes 1984, Ratcliffe 1997).

Coyote territories within the area of Lamar Cave remained very stable prior to the reintroduction of wolves (Crabtree and Sheldon 1999). After reintroduction, coyote territory size was reduced in most cases, or shifted outside of wolf core areas (Crabtree and Sheldon 1999). Even though coyote territories have shifted they still inhabit the area near Lamar Cave where they overlap with wolves.

Territory stability is an important aspect to the Lamar Cave deposits; pellets that end up in Lamar Cave come from the combined territories of different species of predators that remain stable over time (hawks, owls and Ravens). The arrival and establishment of new species is unlikely and even if this happened the area sampled would not change greatly. The Lamar cave specimens are thus a generalization of a suite of raptors over time; it is unlikely that any single species of raptor would be overrepresented in Lamar cave.

Modern biases

Similar biases could potentially affect the modern pellet and scat samples. Biases in the data from modern pellets could include variation within home range sizes of the predators, and prey selection by predators.

Variation in home ranges

Burt (1943) defined home range as the area normally traversed by an individual in its normal activities of foraging, mating, and caring for young. Home range size of predators varies greatly depending upon species, sex, habitat type, prey base, and season of the year (Johnsgard 1989, 1990, Preston and Beane 1993). Results from telemetry studies done on the same species from various habitats indicate that home range size

varies between individuals of the same species. The range of variation is discussed below.

Anderson and Rongstad (1989) estimated the mean home range size for breeding Red-tailed Hawks to be 7.73 km^2 in southeastern Colorado. Peterson (1979) estimated mean home range for Red-tailed Hawks in southeastern Wisconsin to be much smaller during the summer with mean home range at 1.17 km^2 .

Swainson's hawks have home range sizes comparable to Red-tailed hawks. Fitzner (1978) estimated mean home range size during the breeding season to be 6.21 km^2 in southeastern Washington. Another study in the same region estimated mean home range to be 8.86 km^2 for breeding males (Bechard 1982). In the Central Valley in California, mean home range size was estimated to be much larger at 40.38 km^2 (Babcock 1995).

On the breeding grounds, Short-eared owls tend to have small breeding ranges (Johnsgard 1988). Territory size from four European studies indicated that territory size varied from 0.15 km^2 to 2.0 km^2 (Mikokola 1983 as cited in Johnsgard 1988). Holt and Melvin (1986) estimated that mean territory size was 0.55 km^2 in Massachusetts (as cited in Johnsgard 1988).

Long-eared owls also tend to have small home ranges. Thurlow and White (1984) estimated that home range size to be 0.65 km^2 in southcentral Idaho. Craig *et al.* (1988) estimated home range size during the breeding season to be 1.02 km^2 .

Great Horned Owls typically have small home ranges during the breeding season. Fuller (1979) determined the mean home range of three breeding individuals to be 2.38

km² in Minnesota. Mean home range size for territorial Great Horned Owls in Kluane Park, Alberta was 2.48 km² (Rohner 1997). Peterson (1979) determined the mean home range size for Great Horned Owls during the summer (July-September) in southeastern Wisconsin to be 3.43 km² for adult males and 3.16 km² for females.

When food and nesting resources are plentiful, Ravens tend to have smaller home ranges. Linz *et al.* (1992) determined the median home range for Ravens in southern California to be 5.1 km². Smith and Murphy (1973) determined that four pairs of Ravens in Utah used a mean home range size of 6.6 km² during the breeding season.

Even though this suite of generalist predators have varied home range sizes in different habitats, they all tend to have relatively small home ranges during the breeding season. Many of them migrate or disperse to winter habitat outside the study areas, and winter-deposited pellets tend to become fragmented by the following summer, so that all intact pellets collected can be assumed to have been deposited during the breeding season. Thus it can be assumed that the habitat in which these predator species forage (and the area sampled by pellets) is within a relatively small radius around their nests or dens. The habitat within the home ranges of these predator species varies locally from mesic to xeric conditions, and from forested to non-forested areas. The local differences in habitats are reflected in the diets of predators with prey taxa being represented from open and forested areas, xeric and dry conditions. The food habits of this suite of predators did not indicate that these predator species were foraging in habitats radically different from what is near their nesting areas. For example, raptors and Ravens from the

Gardiner area do not appear to be foraging in the Lamar area according to the signature in their pellets.

Prey selection by predators

Red-tailed hawks, Swainson's hawk, Great Horned Owls, and Ravens are all considered generalist and opportunistic feeders. Depending on habitat, the diet composition and relative proportions of prey vary greatly for these species. All of these species prey upon a variety of small mammals, birds, amphibians, reptiles, and insects (Boarman and Heinrich 1999, England *et al.* 1997, Houston *et al.* 1999, Preston and Beane 1993, Ratcliffe 1997). Short-eared owls are considered to be small mammal specialists in certain habitats, particularly where vole species are present (Holt and Leasure 1993). Results from recent studies indicate that Long-eared Owls are more opportunistic feeders than originally considered and they feed on a variety of small mammals < 100 grams (Marks *et al.* 1994). Results from this study found 15 taxa of small mammals represented in the pellets.

In general, all of these predators prey opportunistically upon the most available species within any given habitat. Prey selection appears to be tied to body size, activity and vulnerability of prey species (Houston *et. al* 1999, Preston and Beane 1993). Pellet analysis from the modern habitats revealed that predators were preying on both juveniles and adults, and both diurnal and nocturnal species.

Conclusions

Trying to determine which modern habitat the Lamar Cave data most closely resembles (linking the present to the past) was not a straightforward analysis. Different

data collection methods, data types and the influence of time make this type of analysis challenging. Decision tree software such as CART was chosen for analysis because the fact that, given certain distribution assumptions, it was able to classify the Lamar Cave data into the modern habitat it was most similar to. This result is given credibility by the fact that CART was able to correctly classify modern data into the habitat it was collected from at a high degree of accuracy.

The results indicate that historical Lamar Cave data were collected from habitats that were not dissimilar from the modern Lamar area or Gardiner areas. The presence of rabbits and hares in both the Gardiner (H1) and Lamar Cave (H5) data but not in the modern Lamar area (H2) data tends to direct CART to associate the Lamar Cave (pseudo-pellets or stratigraphic subunits) with the Gardiner (H1) habitat type. An interesting question emerges as to why no rabbits or hares were found in the modern Lamar area (H2) habitat. Their presence was found in Level 1 and Level 3 of the Lamar Cave data which is dated as modern and could span as much as 333 years (Hadly 1999). However, no evidence of rabbits or hares was detected in the remains of 214 pellets and 20 scats collected during the two years of this study from the Lamar area (H2). Although rabbits and hares may exist in the modern Lamar area, they probably occur in such low numbers that their remains did not show up in the modern pellets processed from raptors, Ravens or coyotes. Rabbits and hares have been well-documented to exhibit cyclic population increases and declines (Chapman 1990). Their presence in the Lamar Cave (H5) data may indicate higher population numbers in the past or possibly a recent change in the environment. The disappearance of the Leporidae from the modern pellets and scats may

be due to a low population cycle. Because of this possibility and because of the more restricted habitat requirements of some Leporidae (Clark and Stromberg 1987) the data were examined with and without their inclusion.

If rabbits and hares are excluded from the analysis, the Lamar Cave pseudo-pellets were weakly associated with the modern Lamar area (H2) using the pseudo-pellet method with MNI. The stratigraphic subunit method on the other hand makes a strong argument for Lamar Cave stratigraphic subunits to be associated with the Lamar area (H2) habitat type using both MNI and NISP. There is very weak association between the Lamar Cave (pseudo-pellets and stratigraphic subunits) and the Old Faithful (H3) habitat type with both methods using MNI or NISP.

Both methods of analysis (pseudo-pellet and stratigraphic subunit) worked well in discriminating between the different modern habitats and the Lamar Cave data. Correct classification rates differed between the two methods of analysis for the modern habitats and the Lamar Cave data. In trying to determine which habitat the Lamar Cave (H5) data were most closely associated with, the two methods of analysis had similar patterns but the degree of association was higher with the stratigraphic subunit method.

The differences in the results are due to the different assumptions made by each model. The pseudo-pellet method assumes that if pellets from the Lamar Cave data were to be reconstructed they should have a pellet structure (MNI and NISP) similar to that found in the modern predators from at least one of the different habitats. The pseudo-pellets produced with this model are based on the information that is derived from the pellet structure (MNI and NISP) from the different habitats.

The stratigraphic subunit model assumes that there is a random distribution between species. This method does not take into account any pellet structure that exists within the modern dataset and only compares MNI totals to other MNI totals. NISP is treated in the same manner and only NISP totals are compared with one another. The stratigraphic subunit model based on five subunits for MNI and 20 subunits for NISP worked well in classifying the Lamar Cave (H5) data as being more closely associated with the Gardiner (H1) area using six species and with the Lamar area (H2) using five species.

Both types of analysis; the pseudo-pellet or the stratigraphic subunit method, contain strengths and weaknesses. Determining which method to use and how many variables to include depends on the perspective and the questions being asked. The difficulty in identification of prey remains to the level of species from fossil or pellet samples must be considered when trying to make associations of those samples to habitat. Other issues such as the effects of time within a paleontological site and taphonomy must be considered when interpreting the results from such a study.

When all of these uncertainties are taken into account, the results of this analysis indicate that the recent deposits from Lamar Cave came from habitats and prey communities that were similar to modern conditions near the Cave. Food habit results, home range size estimates, and territory stability all indicate that the generalist predators in the different habitats are preying upon the most common small mammals, within small home ranges, and that the populations of predators have remained stable through time. These factors indicate that any current pellets and scats that end up in Lamar Cave are

indeed sampled from the local sagebrush grassland near Lamar Cave. This indicates that modern stratigraphic layers found within the cave were sampled from similar habitats.

The results indicate that pellet and scat remains, either modern or historical, can be used to differentiate between clearly different habitats; forested versus open, or mesic versus xeric. Distinction between more similar habitats such as the open types found in the Lamar area, Gardiner area and Old Faithful area are less accurate and may be beyond the resolution of these methods. The results however support the conclusion that habitat near Lamar Cave was not much different over the past 300 years than it is today.

Lamar Cave provides paleoecologists and ecologists with a unique perspective on changes in climate and faunal assemblages during the past 3,000 years. The cave provides an accurate representation of the habitat from which it was sampled. Some of the reasons for this accuracy are due to the fact that Lamar Cave is a late Holocene site contained within a large relatively intact ecosystem. All the species within the fossil assemblage are still extant. The processes of taphonomy are similar today as they were in the past. The Cave is well-dated using radiocarbon dating (Hadly 1999). Other paleontological sites that do not reflect similar conditions may not be accurate recorders of the surrounding habitat and faunal assemblages.

APPENDIX A

Systematic Species Account

This appendix provides a compilation of mammalian species from cataloged raptor pellets and coyote scats from four different habitats in Yellowstone National Park collected during 1998-1999. Nomenclature, specific order, and terminology follow Wilson and Reeder (1993), unless otherwise noted. Minimum number of individuals (MNI) and number of identified specimens (NISP) are calculated for each individual taxon within each pellet and scat. Specimens were identified to species whenever possible.

For each taxon a description of identification procedures is followed by a current geographic distribution and brief discussion on the ecology and behavior of the taxon identified. Other taxa recovered from pellets and scats but not fully identified and not covered in this appendix include birds, fish and freshwater invertebrates.

The following is a list of abbreviations used in this appendix:

(xxx) = AC catalog number of pellet or scat. The first two numbers refers to the year the pellet or scat was collected followed by the numerical number in which it was collected.

R = right L = left I = upper incisor

i = lower incisor C = upper canine c = canine

P = upper premolar p = lower premolar M = molar

m = lower molar d = deciduous U = unicuspid

Raptor and Raven species pellets were collected from:

RTHA = Red-tailed Hawk

SWHA = Swainson's Hawk

SEOW = Short-eared Owl

LEOW = Long-eared Owl

GHOW = Great horned Owl

CORA = Common Raven (Raven)

Pellets and scats were collected within four different habitats: specific locations within the general areas are as follows:

Gardiner:

Gardiner, Little Rattlesnake, Town

Lamar Cave area:

**Junction Butte, Lamar Bridge, Lower Owl Alley, Old Red-tail, E. Slough and
Lamar**

Old Faithful:

Old Faithful, Porcupine

Hayden Valley:

Alum Ck., Trout Ck., Lake

Insectivora

Comparative Materials for the genus *Sorex* was limited to *S. cinereus*, *S. hoyi*, *S. monticolus* and *S. palustris* (Carraway 1995). Identification to species was not done for this study due to the lack of comparative material, and diagnostic characters in collected specimens, however, identification was determined to subspecies (*Otisorex*) based on the absence of the post-mandibular foramen on the lingual side of the dentary (Junge and Hoffmann 1981).

Streubel (1989) lists seven species that have been recorded in or have the

potential for being found in Yellowstone National Park. These include: *Sorex cinereus* (Masked Shrew) *S. hoyi* (Pygmy Shrew), *S. merriami* (Merriam's Shrew), *S. monticolus* (Dusky Shrew), *S. nanus* (Dwarf Shrew), *S. palustris* (Water Shrew) and *S. preblei* (Preble's Shrew). Species identified from Lamar Cave include *S. cf. hoyi*, *S. merriami*, *S. palustris*, *S. (Otisorex)* spp. and *S. spp.*

Sorex spp. Linnaeus, 1758

Referred Materials:

Sorex (Otisorex) spp.

Gardiner

1998

GHOW: (98-190) 1 skull with RI1, RU1, RU2, RU3, RU4, RU5, RP4, RM1, RM2, LI1, LU1, LU2, LU3, LU4, LU5, LP4, LM1, 1 R mandible with Rc1, Rp4, Rm1, Rm2, Rm3, 1 L mandible with Lc1, Lp4, Lm1, Lm2, Lm3, MNI=1, NISP=30; (98-192) 1 R mandible with Rc1, Rp4, Rm1, Rm2, Rm3, 1 L mandible with Lp4, Lm1, Lm2, Lm3, MNI=1, NISP=11;

1999

GHOW: (99-35) 1 palatine with LP4, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lp4, Lm1, Lm2, Lm3, MNI=1, NISP=14;

1998

Junction Butte

GHOW: (98-446) 1 R mandible with Rp4, Rm1, Rm2, MNI=1, NISP=4;

Lower Owl Alley

GHOW: (98-290) 1 skull with RU5, RP4, LU5, LP4, LM1, LM2, 1 L mandible with Lm2, Lm3, MNI=1, NISP=10; (98-391) 1 skull with RU3, RP4, RM1, LP4, LM1, LM2, 1 R mandible with Rp4, Rm1, Rm2, Rm3, 1 L mandible with Lp4, Lm1, Lm2, Lm3, MNI=1, NISP=17;

1999

Lower Owl Alley

GHOW: (99-502) 1 L maxilla with LP4, LM1, LM2, LM3, 1 R mandible with Ri1, Rp4, Rm1, Rm2, Rm3, 1 L mandible with Li1, Lp4, Lm1, Lm2, Lm3, MNI=1, NISP=17;

1999

Lamar Bridge

CORA: (99-132) 1 R mandible with Ri1, Rp4, Rm1, Rm2, Rm3, 1 L mandible with Li1, Lc1, Lp4, Lm1, Lm2, Lm3, MNI=1, NISP=13; (99-149) 1 R mandible with Ri1, Rp4, Rm1, Rm2, MNI=1, NISP=5;

E. Slough

RTHA: (99-182) 1 L mandible with Li1, Lp4, Lm1, Lm2, Lm3, MNI=1, NISP=6;

Old Faithful

GHOW: (98-31) 1 skull with RI1, RU1, RU2, RU3, RU4, RU5, RP4, RM1, RM2, RM3, LI1, LU1, LU2, LU3, LU4, LU5, LP4, LM1, LM2, LM3, 1 R mandible with Rp4, Rm1, Rm2, Rm3, 1 L mandible with Lp4, Lm1, Lm2, Lm3, MNI=1, NISP=31;

1999

GHOW: (99-259) 1 R mandible with Rp4, Rm1, Rm2, Rm3, MNI=1, NISP=5;

(99-287) 1 R mandible with Rp4, Rm1, Rm2, Rm3, MNI=1, NISP=5; (99-551) 1 R mandible with Ri1, Rc1, Rp4, Rm1, Rm2, Rm3, MNI=1, NISP=7; (99-552) 1 skull with RU3, RU4, RU5, RP4, RM1, RM2, RM3, LU4, LU5, 1 R mandible with Ri1, Rp4, Rm1, Rm2, 1 L mandible with Li1, Lp4, Lm1, Lm2, Lm3, MNI=1, NISP=24;

1999

Alum Ck.

SWHA: (99-362) 1 palatine with RI1, RU1, RU2, RU3, RU4, RU5, LI1, LU1, LU2, 1 R mandible with Ri1, Rc1, Rp4, Rm1, Rm2, Rm3, 1 L mandible with Li1, Lc1, Lp4, MNI=1, NISP=22;

Trout Ck.

LEOW: (99-175) 2 R maxilla with RU3, RU4, RU5, 2 RP4, 2 RM1, 2 RM2, RM3, 2 L mandibles with Lp4, 2 LM1, 2 LM2, 2 LM3, MNI=2, NISP=21;

Sorex spp.

1999

Lower Owl Alley

Coyote: (99-19S) RI1, LI1, LM1, LM2, 1 L mandible with Lp4, Lm1, Lm2, Lm3, MNI=1, NISP=9;

Identification: Shrews are distinctive by their very small size and undifferentiated sharp and red pigmented teeth. The skull lacks both a zygomatic arch and tympanic bulla (Vaughan 1986). Behind the incisor is a series of unicuspid teeth numbered U1-U5 (Junge and Hoffmann 1981, Vaughan 1986).

Sorex cinereus Kerr, 1792 (masked shrew)

Comparative Materials: Montana State University Vertebrate Collection #7456.

Present Distribution: The masked shrew is distributed throughout the boreal regions of North America south to Washington and along the intermountain west to central Utah and Colorado. It ranges east from Minnesota towards Virginia and the Appalachians (Pattie and Hoffmann 1990).

Ecology: Masked shrews are active throughout the day and night and do not hibernate (Pattie and Hoffmann 1990). Like other shrews they have a high metabolism and must feed constantly and can be found foraging underneath rocks, downed logs and leaf litter. They are insectivores and eat a variety of insects, amphibians and small mammals. In Yellowstone they can be found in wet coniferous and deciduous forests, and along ponds, lakes and streams (Pattie and Hoffmann 1990, Streubel 1989).

Sorex hoyi Baird, 1857 (pygmy shrew)

Comparative Materials: Montana State University Vertebrate Collection # 5961.

Present Distribution: While range maps do not include the pygmy shrew in and around the Yellowstone ecosystem, it has been found in western Montana, the Medicine Bow Mountains in Wyoming and an isolated population in Colorado (Pattie and Hoffmann, 1990, Steubel 1989). The pygmy shrew ranges from Alaska east throughout Canada and south to Georgia (Pattie and Hoffmann 1990).

Ecology: The pygmy shrew is the smallest of all mammals in the Yellowstone ecosystem with an average weight of 2.2-3.8 grams (Streubel 1989). It occupies similar habitats as the masked shrew and can be found foraging in dry upland forests and grassy meadows. The pygmy shrew eats butterfly larvae, grasshoppers, spiders and earthworms (Streubel

1989).

Sorex merriami Dobson, 1890 (Merriam's shrew)

Present Distribution: Merriam's shrew is distributed in the more arid regions of the intermountain west and portions of the Great Plains. It ranges from eastern Washington and Oregon eastward into Montana and North Dakota. The rest of its range includes portions of Nebraska, New Mexico, Arizona and Nevada (Pattie and Hoffmann 1990).

Ecology: Merriam's shrews are adapted to arid environments including sagebrush desert, sagebrush grasslands and grasslands. This shrew uses the runways of other small rodents for hunting and eats a variety of insects including caterpillars, larval and adult beetles, cave crickets and spiders (Clark and Stromberg 1987, Pattie and Hoffmann 1990).

Sorex monticolus Merriam 1890 (dusky shrew)

Comparative Materials: Montana State University Vertebrate Collection #6628, # 5396.

Present Distribution: The dusky shrew is distributed from Alaska through the central and western regions of Canada south through the northwest and Rocky Mountains to New Mexico. There are isolated populations in northern California, Arizona and in the southern Rocky Mountains of Mexico (Pattie and Hoffmann 1990).

Ecology: Dusky shrews are active year round and can be found in the moist coniferous forests or alpine tundra. Occasionally they can be found in lodgepole and Douglas fir forests (Clark and Stromberg 1987). Their diet includes a variety of insects, earthworms, and spiders (Pattie and Hoffmann 1990).

Sorex palustris Richardson, 1828 (water shrew)

Comparative Materials: Montana State University Vertebrate Collection # 5159, #

5390.

Present Distribution: The water shrew ranges from southern Alaska east throughout Canada to Labrador, south along the Appalachians to Georgia. It ranges south from Alaska to central California, and along the Rocky Mountains to New Mexico (Clark and Stromberg 1987, Pattie and Hoffmann 1990).

Ecology: As the name implies, water shrews can be found near streams, ponds and lakes. Water shrews are at home in the water and can be seen floating, diving and even walking across water. They eat a variety of aquatic insects, spiders and small fish (Clark and Stromberg 1987, Pattie and Hoffmann 1990). In Yellowstone they can be found in a variety of habitats including the Lamar Valley (Clark and Stromberg 1987).

Sorex preblei Jackson 1922 (Preble's shrew)

Present Distribution: This shrew is usually found in the arid and semi-arid regions of the Columbia Plateau, west through the Snake River in Idaho through the mountains and grasslands of Montana (Pattie and Hoffmann 1990).

Ecology: Preble's shrews are usually associated with sagebrush and bunchgrass communities. Only one specimen has been found in Yellowstone near the Lamar Ranger station (Streubel 1989). Little is known on the life history of this shrew.

Sorex nanus Merriam, 1895 (dwarf shrew)

Present Distribution: The dwarf shrew ranges throughout the central part of Montana and into northern Wyoming. Its range also includes portions of South Dakota south through Nebraska, Colorado and into Arizona and New Mexico (Pattie and Hoffmann 1990).

Ecology: Dwarf shrews are usually associated with rock rubble and talus slopes of alpine and subalpine zones (Pattie and Hoffmann 1990). Occasionally they can be found in grasslands at lower elevations. They prey primarily on insects and spiders that inhabit rock and rubble areas (Pattie and Hoffmann 1990).

Chiroptera

Streubel (1989) lists five different species of bats that have been recorded in the Yellowstone ecosystem including *Eptesicus fuscus* (Big brown bat), *Lasiurus cinereus* (Hoary bat), *Myotis evotis* (Long-eared myotis), *Myotis lucifugus* (Little brown bat) and *Plecotus townsendi* (Townsend's big-eared bat). Four other species of bats are thought to occur in the Yellowstone ecosystem, however, they have never been trapped.

Myotis spp. Kaup 1829

Comparative Materials: Montana State University Vertebrate Collection # 401.

Referred Materials:

Gardiner

GHOW: (98-206) 1 separated maxilla with RM1, RM2, RM3, LP4, LM1, LM2, 1 R mandible with Rm2, Rm3, 1 L mandible, MNI=1, NISP=11;

Identification: Family Vespertilionidae has the widest distribution and greatest number of species within the New World. Characteristics that define bats within this family are tuberculosectorial teeth with well developed upper molars, the skull lacks postorbital processes, the palatal parts of the premaxillaries are missing and the front of the palate is emarginate (Vaughan 1986). Even though sample (98-206) is not complete, the emarginate palate is very apparent. Within this family, the genus *Myotis* has a broad

geographic distribution and is one of the most common bats within the region (Clark and Stromberg 1987, Streubel 1989).

Present Distribution: Bats are wide-ranging mammals and are distributed throughout the United States and Canada. Some species including *Plecotus townsendi* and *Myotis evotis* are limited in their distribution and are only found in the western United States (Streubel 1989).

Ecology: Bats can be found in a variety of habitats within Yellowstone including areas near water, coniferous forests, sagebrush grasslands, rocky outcrops and human habitations. Roosting areas are very important to bats and their populations and distribution may be limited to areas where they can acquire suitable roosting sites. In Yellowstone bats can be found roosting in caves, abandoned buildings and dense forests (Streubel 1989). Many species of bats migrate in the fall, however a few species may overwinter in caves in Montana and North Dakota (Pattie and Hoffmann 1990). Bats eat a variety of insects.

Carnivora

Mustela sp. Linnaeus 1758

Streubel (1989) lists two small mustelids that inhabit the Yellowstone ecosystem. They are *Mustela erminea* (ermine) and *Mustela frenata* (long-tailed weasel). Designation to species is difficult for these two species without having the entire skeleton and hide. These species overlap in their distribution and while *M. frenata* is larger overall than *M. erminea*, sexual dimorphism between the sexes or juveniles make species identification difficult (Jones, Jr. and Manning 1992). The dental formula for Mustelids

are 3/3 incisors, 1/1 canines, 3/3 premolars, 1/2 molars.

Comparative Materials: Montana State University Vertebrate Collection # 6086, # 6082.

Referred Materials:

Lower Owl Alley

GHOW: (98-52) 1 skull with RI1, RP2, RP3, RP4, RM1, LI1, LP2, LP3, LP4, LM1, 1 R mandible with Rp4, Rm1, Rm2, MNI=1, NISP=15; (98-303) 1 R mandible with Rp3, Rp4, Rm1, MNI=1, NISP=4;

1999

Tower

RTHA: (99-668) 1 R mandible with Rm2, Rm3, 1 L mandible with Lm2, MNI=1, NISP=5;

Lamar Bridge

CORA: (99-143) 1 R maxilla with RC1, RP2, RP3, RP4, RM1, LC1, MNI=1, NISP=7;

Identification: In general, mustelids can be identified by their skull with its long braincase and a short rostrum. Their teeth are similar to other carnivores and they have a distinctive M1 that is transversely placed and dumbbell-shaped (Jones, Jr. and Manning 1992).

Mustela erminea Linnaeus 1758 (ermine)

Comparative Materials: Montana State University Vertebrate Collection # 6086, # 6120.

Present Distribution: The ermine has a wide distribution and its range is Holarctic from Arctic tundra, boreal taiga, montane, subalpine, and coastal coniferous forests (Pattie and Hoffmann 1990). It ranges as far south as New Mexico (Clark and Stromberg 1987).

Ecology: Ermines are quick, effective predators that prey on a variety of rodents, shrews, birds, amphibians and insects (Clark and Stromberg 1987). They are distinctive for their white pelage in winter. While they are effective predators, they may also end up as prey for owls and hawks. Ermines can be found in a variety of habitats ranging from coniferous and mixed forests to tundra. They are found near the boundaries of meadows and shrubby river banks (Banfield 1974, Clark and Stromberg 1987).

Mustela frenata Lichtenstein, 1831 (long-tailed weasel)

Comparative Materials:

Present Distribution: Long-tailed weasels occur from British Columbia south throughout the United States and into central and South America (Clark and Stromberg 1987, Pattie and Hoffmann 1990).

Ecology: The long-tailed weasel can be found in a variety of habitats, including open fields, willows, grasslands and forests (Banfield 1974). Weasels are carnivorous and eat rodents, shrews, rabbits, birds, eggs, chicks, insects and carrion. Long-tailed weasels are active at any time of the day or night (Clark and Stromberg 1987).

Rodentia

Spermophilus cf. armatus Kennicott 1863 (Uinta ground squirrel)

Comparative Materials: Denver Museum of Natural History #2468, # 2467, Montana State University Vertebrate Collection # 121, # 31.

Referred Materials:**Little Rattlesnake**

CORA: (98-273) 1 L mandible with Lp4, Lm1, Lm2, Lm3, MNI=1, NISP=5;
 (98-515) 1 R mandible, MNI=1, NISP=1;

1999

CORA: (99-683) 1 L mandible with Lp4, Lm1, Lm2, MNI=1, NISP=4;

Coyote: (99-40S) 1 LM3, Lp4, Lm1, Lm3, MNI=1, NISP=4;

Junction Butte

GHOW: (98-444) 1 skull with RP3, RP4, RM1, RM2, RM3, LP3, LP4, LM1, MNI=1, NISP=9;

RTHA: (98-244) 1 RM1, RM2, 2 RM3, 1 L maxilla with 2 LP4, 2 LM2, LM3, 2 R mandibles with 2 Rm1, 2 Rm2, 2 Rm3, MNI=2, NISP=20; (98-245) 1 L maxilla with LP3, LP4, LM1, LM2, LM3, 1dLp4, 2 Lp4, 2 Lm1, 2 Lm2, MNI=2, NISP=13; (98-246) 1 RM2, MNI=1, NISP=1; (98-383) 1 Rm1, MNI=1, NISP=1, (98-385) 1 Rm2, Rm3, MNI=1, NISP=2; (98-388) 1 LM1, LM3, Lm2, Lm3, MNI=1, NISP=4; (98-389) 1 skull with RP3, RP4, RM1, RM2, RM3, LP3, LM4, LM1, LM2, LM3, MNI=1, NISP=11;

1999

CORA: (99-283) 1 palatine with RP4, RM1, RM2, RM3, LP4, LM1, LM2, LM3, MNI=1, NISP=9; (99-284) 1 RM1, RM2, LP4, LM1, 1 R mandible with Rp4, Rm1, Rm2, Rm3, MNI=1, NISP=9;

Lamar Bridge

CORA: (98-8) 1 L maxilla with LP3, LP4, LM1, LM2, MNI=1, NISP=5; (98-9) Rp4, Lp4, MNI=1, NISP=2; (98-10) 1R mandible with Rm1, Rm2, MNI=1, NISP=3; (98-11) 1 R maxilla with RP4, RM1, RM3, Lm3, MNI=1, NISP=5; (98-14) 1 separated maxilla with RP3, RP4, RM1, RM2, RM3, LP4, LM1, LM2, LM3, Rp4, MNI=1. NISP=11; (98-99) 1 RM1, 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lp4, Lm3, MNI=1, NISP=8; (98-101) 1 RM1, 1 L maxilla with LP3, LP4, Lm2, MNI=1, NISP=5; (98-234) 1 L maxilla with LP4, LM1, LM2, LM3, MNI=1, NISP=5; (98-235) 1 R maxilla with RP3, RP4, LP4, 1 R mandible with Rp4, Rm1, Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=12; (98-360) 1 R mandible with Rp4, Rm1, Rm2, Rm3, MNI=1, NISP=5; (98-362) 1 Lp4, MNI=1, NISP=1; (98-498) 1 R mandible with Rp4, MNI=1, NISP=2;

1999

Lamar Bridge

CORA: (99-325) 1 Rp4, Rm1, 1 L mandible with Lp4, Lm1, Lm2, MNI=1, NISP=6; (99-328) 2 L mandibles with Lp4, Lm1, 2 Lm2, Lm3, MNI=2, NISP=7; (99-331) 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=4;

Tower

RTHA: (99-467) 1 R mandible with Rp4, Rm1, Rm2, Rm3, MNI=1, NISP=5;

Coyote: (99-18S) 1 RM3, 1 R mandible with Rp4, Rm1, Rm2, 1 L mandible with Lp4, Lm1, Lm2, Lm3, MNI=1, NISP=10; (99-28S) 1 RM1, RM2, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, Rm3, MNI=1, NISP=9;

Lamar

CORA: (99-280) 1 LM2, Rm2, Lm3, MNI=1, NISP=3;

Institute

RTHA: (99-662) 1 R mandible with Rp4, Rm1, Rm2, Rm3, MNI=1, NISP=5; (99-664) 1 skull with RP3, RP4, RM1, RM2, RM3, LP3, LP4, LM1, LM2, LM3, MNI=1, NISP=11;

Lamar Cave

RTHA: (98-371) 1 RP3, RP4, RM1, RM2, RM3, 1 L mandible with Lp4, Lm1, Lm2, Lm3, MNI=1, NISP=10;

1999

Lamar Cave

RTHA: (99-700) 2 palatines with RP4, RM3, LP3, 2 LP4, 2 LM1, 2 LM2, MNI=2, NISP=12; (99-702) 1 Lm1, MNI=1, NISP=1;

Coyote: (98-3S) 1 RP4, RM1, RM2, 2 RM3, LM1, LM3, Rm1, Rm3, Lp4, Lm3, MNI=2, NISP=11; (98-7S) 1 R maxilla with RP3, RP4, RM1, RM2, RM3, 1 R mandible with Rm1, Rm2, Rm3, MNI=1, NISP=10; (98-8S) 1 L maxilla with LP3, LP4, LM1, LM2, LM3, 1 R mandible with Rp4, Rm1, Rm2, Rm3, 1 L mandible with Lp4, Lm1, Lm3, MNI=1, NISP=14;

Old Red-tail nest

RTHA: 1 R mandible with Rp4, Rm1, Rm2, Rm3, 1 L mandible with Lp4, Lm1, Lm2, Lm3, MNI=1, NISP=10;

1999

Old Red-tail Nest

RTHA: (99-550) 1 Rm2, MNI=1, NISP=1;

Lower Owl Alley

Coyote: (98-6S) 1 R maxilla with RP3, RP4, RM1, RM2, RM3, LP4, LM1, LM2, 2 LM3, 1 R mandible with Rp4, Rm1, Rm2, Rm3, 1 L mandible with 2 Lp4, 3 Lm1, Lm2, Lm3, MNI=3, NISP=24;

1999

Coyote: (99-21S) 1 RP4, RM1, RM2, RM3, 2 LM3, Rp4, 2 L mandibles with Lp4, Lm1, 2 Lm2, 2 Lm3, MNI=2, NISP=15;

Lower Owl Alley

GHOW: (99-652) 1 skull with RP3, RP4, RM1, RM2, RM3, LP3, LP4, LM1, LM2, LM3, 1 R mandible with Rp4, Rm1, Rm2, Rm3, 1 L mandible with Lp4, Lm1, Lm2, Lm3, MNI=1, NISP=21;

E. Slough

RTHA: (98-143) 1 R maxilla RP3, RP4, RM1, RM2, RM3, 1 L mandible with Lp4, Lm1, Lm2, Lm3, MNI=1, NISP=11; (98-144) 1 Rm3, 1 L mandible with Lp4, Lm1, Lm2, Lm3, MNI=1, NISP=5; (98-145) 1 Rm1, Rm2, Lm3, MNI=1, NISP=3; (98-146) 1 R mandible, Lm1, Lm2, Lm3, MNI=1, NISP=4; (98-348) 1 Lm3, MNI=1, NISP=1; (98-350) 1 Lp4, Lm1, Lm3, MNI=1, NISP=3; (98-351) 1 L mandible with Lp4, Lm1, Lm2, Lm3, MNI=1, NISP=4; (98-352) 1 Rp4, MNI=1, NISP=1;

Old Faithful

GHOW: (98-58) 1 R mandible with Rp4, Rm1, MNI=1, NISP=3; (98-82) 1 skull with RP3, RP4, RM2, RM3, LM1, LM2, LM3, 1 L mandible with Lp4, Lm1, Lm2, Lm3, MNI=1, NISP=14;

1999

Old Faithful

GHOW: (99-451) 1 separated maxilla with RP3, RP4, RM1, LP3, LP4, LM1, LM2, 1 Rm1, Rm2, 1 L mandible, MNI=1, NISP=11;

CORA: (99-247) 1 L mandible with Lp4, Lm1, Lm2, Lm3, MNI=1, NISP=5; (99-267) 1 R mandible with Rp4, Rm1, Rm2, Rm3, 1 L mandible with Lp4, Lm1, Lm2, Lm3, MNI=1, NISP=10; (99-295) 1 palatine, MNI=1, NISP=1; (99-302) 1 R mandible with Rm1, Rm2, MNI=1, NISP=3; (99-303) 1 L maxilla with RM2, MNI=1, NISP=2;

Identification: *S. armatus*, *S. richardsoni* and *S. elegans* overlap in distributions in the western states and have similar habitat requirements (Banfield 1974, Clark and Stromberg 1987). However trapping studies indicate the *S. armatus* is the only ground squirrel of these three species to be found in the Park (Crabtree et al. 1997, Streubel 1989). Cheek teeth are cuspidate, brachydont and rooted and higher crowned than tree squirrels. Mandibular molars have four roots while the maxillary molars have three roots. The upper tooth rows tend to be parallel or to converge slightly in the rear. Maxillary teeth are characterized by having ridges curving up from low cusps on the lingual side to high cusps on the buccal side. There are two main ridges with smaller ridges on the distal and mesial side (Hillson 1986). M3 is much larger than M2, and the posterior cingulum of M3 bends posteriad from the protcone (Chomko 1980). P3 is distinctive from other squirrels in its peglike appearance (Jones Jr. and Manning 1992).

Lower cheek teeth are basin-like with a high rim on the lingual side (Hillson 1986). The mandibular molars (m1, m2) are narrowly triangular in cross section

(Chomko 1980)

Present Distribution: The Uinta ground squirrel has a limited distribution and is found in areas of western Wyoming, southern Montana, eastern Idaho to northern and central Utah (Clark and Stromberg 1987, Eshelman and Sonnemann 2000, Pattie and Hoffmann 1990, Struebel 1989).

Ecology: Uinta ground squirrels hibernate for six to seven months of the year, usually from late July to mid-April. They are found in a variety of habitats but are mainly associated with areas of heavily grazed grasslands, sagebrush grasslands, mountain meadows, open areas and forests. It ranges from the lowest elevations in the Park near Gardiner at 1766 meters up to 3666 meters in some of the mountain meadows (Clark and Stromberg 1987, Pattie and Hoffmann 1990). Uinta ground squirrels are the most frequently seen ground squirrel in the Park (Pattie and Hoffmann 1990). These ground squirrels eat a variety of grasses, forbs, shrubs, and mushrooms, as well as other ground squirrels (Clark and Stromberg 1987, Eshelman and Sonnemann 2000).

Tamias spp. Illiger, 1811

Comparative Materials: *Tamias minimus* Denver Museum of Natural History #8848, #8846, Montana State University Vertebrate Collection # 6380, # 6530.

Referred Materials:

Gardiner

GHOW: (98-152) 1 palatine with RP4, RM1, RM2, RM3, LP4, LM1, 1 L mandible with Lp4, Lm1, Lm2, Lm3, MNI=1, NISP=12;

Old Faithful

GHOW: (98-69) 1 R mandible with Rp4, Rm2, MNI=1, NISP=3;

1999

Old Faithful

CORA: (99-301) 1 L maxilla, 1 L mandible, MNI=1, NISP=2,

Porcupine

CORA: (99-545) 1 RP3, 1 L maxilla with LP3, 1 L mandible, MNI=1, NISP=4;

Alum Ck.

SWHA: (99-167) 1 L maxilla with LP4, MNI=1, NISP=2;

Identification: Identification of this species within the genus is difficult. Samples from raptor pellets were not identified to species. In general *Tamias* teeth are smaller than *Tamiasciurus* but similar in structure. The teeth are small in relative size, cuspidate, brachyodont and rooted. In the Yellowstone samples, teeth from *Tamias* were slightly larger than that of *Peromyscus maniculatus*. Maxillary molars have three roots, while mandibular molars have four roots (Chomko 1980).

Present Distribution: *Tamias* ranges across Canada into the northern Rocky Mountains and as far south as New Mexico and Arizona. Its east-west distribution in the U.S extends from the Cascade Mountains east to North Dakota (Clark and Stromberg 1987, Pattie and Hoffmann 1990).

Ecology: The least chipmunk is widely distributed and is found in a variety of habitats from sagebrush-grasslands to coniferous forests to alpine regions. Local populations and distribution depend on the presence or absence of other species of chipmunks (Pattie and Hoffmann 1990). They eat a variety of foods including roots, nuts, fruits, berries and

fungus (Clark and Stromberg 1987).

Tamiasciurus hudsonicus (Erxleben, 1777) (red squirrel)

Comparative Materials: Denver Museum of Natural History # 1086, # 1091, Montana State University Vertebrate Collection, # 240, #242.

Referred Materials:

1999

Gardiner

GHOW: (99-58) 1 skull with RP4, LP4, MNI=1, NISP=3;

Junction Butte

GHOW: (98-432) 1 LM3, Rm2, MNI=1, NISP=2; (98-447) 1 L mandible with Lm2, MNI=1, NISP=2;

1999

Junction Butte

GHOW: (99-80) 1 skull with RP3, RP4, RM1, RM2, RM3, LP3, LP4, LM1, LM2, LM3, 1 R mandible with Rp4, Rm1, Rm2, Rm3, 1 L mandible with Lp4, Lm1, Lm2, Lm3, MNI=1, NISP=20;

RTHA: (98-383) 1 Lp4, Lm2, Lm3, MNI=1, NISP=3;

1999

Lower Owl Alley

GHOW: (99-498) 1 skull with LP4, LM1, LM2, LM3, MNI=1, NISP=6; (99-526) 1 skull, 1 R mandible with Rp4, Rm1, Rm2, Rm3, 1 L mandible, MNI=1, NISP=7;

Old Faithful

GHOW: (98-32) 1 R mandible with Rp3, MNI=1, NISP=2; (98-39) 1 RM1, 1 Rm1, 1 Lm1, MNI=1, NISP=3; (98-87) 1 skull with RP4, LM2, MNI=1, NISP=3; 1 Rm3, MNI=1, NISP=1;

1999

Old Faithful

CORA: (99-298) 1 dLp4, MNI=1, NISP=1;

Identification: As with other species in the Family Sciuridae, teeth from *T. hudsonicus* are cuspidate, brachyodont and rooted. Mandibular molars have four roots and maxillary teeth have three roots. P3 is very small and non-functional or may be absent altogether (Chomko 1980). *T. hudsonicus* teeth are larger than *Tamias* but smaller than *S. armatus*. *T. hudsonicus* are more bunodont than *S. armatus*.

Present Distribution: Red squirrels occur across Alaska and northern Canada, and south along the Rocky Mountains into New Mexico. They range east through the midwestern states to the Appalachian Mountains (Clark and Stromberg 1987).

Ecology: This squirrel is found in a variety of conifer to mixed forest type habitats. It is mainly diurnal and is unusual in that it defends large territories up to two hectares in size. Red squirrels eat evergreen buds, seeds, fungi and occasionally insects and small birds (Clark and Stromberg 1987).

Thomomys talpoides (Richardson, 1828) (northern pocket gopher)

Comparative Materials: Denver Museum of Natural History # 7844, # 8183, Montana State University Vertebrate Collection # 6393, # 6375.

Referred Materials:

Gardiner

GHOW: (98-147) 1 LM3, 1 L mandible with Lp4, Lm1, Lm2, Lm3, MNI=1, NISP=6; (98-148) 1 L mandible with Lp4, Lm1, Lm2, Lm3, MNI=1, NISP=5; (98-149) 1 skull with RP4, RM1, RM3, LP4, LM1, LM2, LM3, 1 R mandible with Rp4, Rm1, Rm2, Rm3, MNI=1, NISP=13; (98-156) 1 skull with RP4, RM1, RM2, RM3, LP4, LM1, LM2, MNI=1, NISP=8; (98-163) 1 L mandible with Lp4, Lm1, Lm2, MNI=1, NISP=4; (98-168) 1 skull with RP4, RM1, RM2, RM3, LP4, LM1, LM2, LM3, 1 R mandible with Rp4, Rm1, Rm2, Rm3, 1 L mandible with Lp4, Lm1, Lm2, Lm3, MNI=1, NISP=19; (98-170) 1 skull with RP4, RM1, RM2, LP4, LM1, LM2, LM3, MNI=1, NISP=8; (98-172) 1 Lp4, MNI=1, NISP=1; (98-173) 1 skull with RP4, RM1, RM2, RM3, LP4, LM1, LM2, LM3, 1 R mandible with Rp4, Rm1, Rm2, Rm3, 1 L mandible with Lp4, Lm1, Lm2, Lm3, MNI=1, NISP=19; (98-184) 1 palatine with RP4, RM1, RM2, RM3, LP4, LM1, LM2, LM3, 1 R mandible with Rp4, Rm1, Rm2, 1 L mandible with Lp4, Lm1, Lm2, MNI=1, NISP=17; (98-188) 1 skull with RM1, RM2, RM3, LP4, LM1, LM2, 1 R mandible with Rp4, Rm1, Rm2, Rm3, MNI=1, NISP=12; (98-192) 1 L maxilla with LM1, LM2, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=7; (98-203) 1 skull with RP4, RM1, RM2, RM3, LP4, LM1, LM2, LM3, 1 R mandible with Rp4, Rm1, Rm2, 1 L mandible with Lp4, Lm1, Lm2, Lm3, MNI=1, NISP=18;

1999**Gardiner**

GHOW: (99-35) 1 skull with RP4, RM1, RM2, RM3, LP4, LM1, LM2, LM3, 1 R mandible with Rp4, Rm1, Rm2, Rm3, 1 L mandible with Lp4, Lm1, Lm2, Lm3,

MNI=1, NISP=19; (99-691) 1 R mandible with Rp4, Rm1, Rm2, Rm3, 1 L mandible with Lp4, Lm1, Lm2, Lm3, MNI=1, NISP=10;

Coyote: (99-24S) 1 RP4, 1 R mandible with Rm1, Rm2, Rm3, Lp4, MNI=1, NISP=6; (99-30S) 1 palatine with RM1, RM2, LP4, LM1, LM2, 2 R mandibles with 2 Rp4, 2 Rm1, 2 Rm2, 2 Rm3, 2 L mandibles with 2 Lp4, 2 Lm1, 2 Lm2, 2 Lm3, MNI=2, NISP=26;

Town

CORA: (99-241) 1 L mandible with Lp4, Lm1, Lm2, MNI=1, NISP=4;

Tower

RTHA: (99-471) 1 palatine with RP4, RM1, RM3, LP4, LM1, MNI=1, NISP=6; (99-473) 2 palatines with RP4, RM1, RM2, 2 LP4, 2 LM1, 2 LM2, LM3, 1 R mandible with Rp4, 2 L mandibles with 2 Lp4, 2 Lm1, 2 Lm2, MNI=2, NISP=22;

Junction Butte

Coyote: (99-38S) 1 Lm3, MNI=1, NISP=1;

Junction Butte

GHOW: (98-424) 1 skull with RP4, RM1, RM2, RM3, LP4, LM1, LM2, LM3, 1 R mandible with Rp4, Rm1, Rm2, 1 L mandible with Lp4, Lm1, Lm2, Lm3, MNI=1, NISP=18; (98-425) 1 R mandible with Rp4, Rm1, Rm2, Rm3, 1 L mandible with Lp4, Lm1, Lm2, Lm3, MNI=1, NISP=10; (98-429) 1 palatine with RP4, RM1, LP4, LM1, LM2, LM3, 1 R mandible with Rp4, Rm1, Rm2, Rm3, 1 L mandible with Lp4, Lm1, Lm2, Lm3, MNI=1, NISP=17; (98-444) 1 skull with RM1, RM2, RM3, LP4, LM1, LM2, LM3, 1 R mandible with Rp4, Rm1, Rm2, Rm3, MNI=1, NISP=13; (98-446) 1 skull with

RP4, RM1, RM2, RM3, LP4, LM1, LM2, LM3, MNI=1, NISP=9; (98-452) 1 skull with RP4, RM1, RM2, LP4, LM1, MNI=1, NISP=6;

Lower Owl Alley

GHOW: (98-280) 1 R mandible with Rp3, Rm1, Rm2, 1 L mandible with Lp4, MNI=1, NISP=6; (98-282) 1 L mandible with Lp4, Lm1, Lm2, MNI=1, NISP=4; (98-283) 1 skull, 1 palatine with 2 RP4, 2 RM1, 2 RM2, 2 RM3, 2 LP4, 2 LM1, 2 LM2, LM3, 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lp4, Lm1, Lm2, Lm3, MNI=2, NISP=26; (98-284) 2 R mandibles with Rp4, 2 Rm1, 2 Rm2, Rm3, MNI=2, NISP=8; (98-286) 1 skull with RP4, RM1, RM2, RM3, LP4, LM1, LM2, LM3, 1 R mandible with Rp4, Rm1, Rm2, MNI=1, NISP=13; (98-287) 1 skull with RP4, RM1, RM2, RM3, LP4, LM1, LM2, LM3, 2 R mandibles with 2 Rp4, 2 Rm1, 2 Rm2, 2 Rm3, MNI=2, NISP=19; (98-289) 2 palatines with 2 RP4, 2 RM1, RM2, RM3, 2 LP4, LM1, LM2, LM3, 1 R mandible with Rp4, Rm1, Rm2, Rm3, 1 L mandible with Lp4, 2 Lm1, Lm2, MNI=2, NISP=23; (98-290) 1 skull with RP4, RM1, RM2, RM3, LP4, LM1, LM2, LM3, 2 R mandibles with 2 Rp4, 2 Rm1, Rm2, 2 L mandibles with 2 Lp4, 2 Lm1, 2 Lm2, MNI=2, NISP=24; (98-303) 1 skull with RP4, RM1, RM2, RM3, LM1, LM2, LM3, 1 L mandible with Lp4, Lm1, Lm2, Lm3, MNI=1, NISP=13; (98-376) 1 palatine with RP4, RM1, RM2, RM3, LP4, LM1, LM2, LM3, 1 R mandible with Rp4, Rm1, Rm2, 1 L mandible with Lp4, Lm1, Lm2, Lm3, MNI=18; (98-377) 1 skull with RP4, RM1, RM2, RM3, LP4, LM1, LM2, LM3, 1 L mandible with Lp4, Lm1, Lm2, Lm3, MNI=1, NISP=15; (98-392) 1 skull with RM1, RM2, RM3, LP4, LM1, LM2, LM3, MNI=1, NISP=8; (98-393) 1 L mandible with Lp4, Lm1, Lm2, Lm3, MNI=1, NISP=5; (98-395) 1

skull with RP4, RM1, RM2, RM3, LP4, LM1, LM2, LM3, 2 R mandibles with 2 Rp4, 2 Rm1, 2 Rm2, 2 Rm3, MNI=2, NISP=19; (98-396) 1 R mandible with Rp4, Rm1, Rm2, Rm3, 1 L mandible with Lp4, Lm1, Lm2, Lm3, MNI=1, NISP=10; (98-398) 1 RM2, LM1, 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lp4, Lm1, Lm2, MNI=1, NISP=10;

1999

Lower Owl Alley

GHOW: (99-482) 1 skull with RM1, RM2, RM3, LP4, LM1, LM2, LM3, MNI=1, NISP=8; (99-484) 1 skull with RP4, RM1, RM2, RM3, LP4, LM1, LM2, LM3, 1 R mandible with Rp4, Rm1, Rm2, Rm3, MNI=1, NISP=13; (99-507) 1 skull with RP4, RM1, RM2, RM3, LP4, LM1, LM2, LM3, MNI=1, NISP=9; (99-522) 1 skull with RP4, RM1, RM2, RM3, LP4, LM1, LM2, LM3, MNI=1, NISP=9; (99-636) 2 skulls with 2 RP4, 2 RM1, 2 RM2, 2 RM3, 2 LP4, 2 LM1, 2 LM2, 2 LM3, 2 R mandibles with 2 Rp4, 2 Rm1, 2 Rm2, 1 L mandible with Lp4, Lm1, Lm2, Lm3, MNI=2, NISP=31; (99-640) 1 R mandible with Rp4, Rm1, Rm2, Rm3, MNI=1, NISP=5; (99-646) 1 skull with RP4, RM1, RM2, RM3, LP4, LM1, LM2, LM3, MNI=1, NISP=9;

Coyote: (98-6S) 2 RP4, 2 RM1, RM2, RM3, LM1, 1 R mandible with 2 Rp4, 2 Rm1, 3 Rm2, 2 Rm3, 1 L mandible with 4 Lp4, 2 Lm1, 2 Lm2, Lm3, MNI=4, NISP=27; (98-7S) 1 RM1, MNI=1, NISP=1;

1999

Coyote: (99-20S) 1 RM1, 2 LP4, LM1, LM3, Rm2, 1 L mandible with Lp4, Lm1, 2 Lm2, Lm3, MNI=2, NISP=12; (99-27S) 1 RP4, RM1, 2 RM2, 2 RM3, 2 LP4, LM1,

LM2, 1 R mandible with Rp4, Rm1, 1 L mandible with 2 Lp4, Lm1, Lm2, Lm3, MNI=2, NISP=19; (99-28S) 1 Lm2, MNI=1, NISP=1;

Lamar Bridge

CORA: (99-130) 1 palatine with RMP4, RM1, RM2, LP4, LM2, LM3, 1 R mandible with Rp4, Rm1, Rm2, rm3, 1 L mandible with Lp4, MNI=1, NISP=14; (99-150) 1 skull with RP4, RM1, RM2, RM3, LP4, LM1, LM2, LM3, 1 R mandible with Rp4, Rm1, Rm2, Rm3, 1 L mandible with Lp4, Lm1, Lm2, Lm3, MNI=1, NISP=19; (99-325) 1 skull with RP4, RM1, RM2, RM3, LP4, LM1, LM2, LM3, 1 L mandible with Lp4, Lm1, Lm2, MNI=1, NISP=13; (99-327) 1 RM3, 1 R mandible with Rp4, Rm1, Rm2, 1 L mandible with Lp4, Lm1, Lm2, MNI=1, NISP=9;

E. Slough

RTHA: (98-348) 1 R mandible with Rp4, Rm1, 1 L mandible with Lp4, MNI=1, NISP=5; (98-352) 2 R mandibles with 2 Rp4, 2 Rm1, 2 Rm2, Rm3, MNI=2, NISP=9;

1999

E. Slough

RTHA: (99-184) 1 palatine with RP4, RM1, RM2, RM3, LP4, MNI=1, NISP=6;

Lamar

CORA: (99-279) 1 palatine with RP4, RM1, RM2, RM3, LP4, LM1, MNI=1, NISP=7;

Institute

RTHA: (99-663) 1 skull with RP4, RM1, LP4, MNI=1, NISP=4;

Old Faithful

GHOW: (98-31) 2 partial skulls with 2 RP4, 2 RM1, 3 RM2, RM3, 2 LP4, 2 LM1, 3 LM2, LM3, 1 R mandible with Rp4, Rm1, Rm2, Rm3, 1 L mandible with Lp4, Lm1, Lm2, Lm3, MNI=3, NISP=28; (98-32) 2 R mandibles with Rp4, 2 Rm1, 2 Rm2, 1 L mandible with Lp4, Lm1, Lm2, Lm3, MNI=2, NISP=12; (98-33) 1 skull with RP4, RM1, RM2, RM3, LP4, LM1, 1 R mandible, MNI=1, NISP=8, (98-35) 1 R mandible with Rp4, Rm1, Rm2, Rm3, 1 L mandible with Lp4, Lm1, Lm2, MNI=1, NISP=9; (98-38) 1 skull with RP4, RM1, RM2, RM3, LP4, LM1, LM2, LM3, 1 R mandible with Rp4, Rm1, Rm3, 1 L mandible with Lm3, MNI=1, NISP=15; (98-42) 1 skull with RP4, RM1, RM2, RM3, LP4, LM1, LM2, LM3, 2 L mandibles with 2 Lp2, 2 Lm1, 2 Lm2, 2 Lm3, MNI=2, NISP=18; (98-47) 1 skull with RP4, RM1, RM2, RM3, LP4, LM1, LM2, LM3, 1 R mandible with Rp4, Rm1, Rm2, Rm3, 1 L mandible with Lp4, Lm1, Lm2, Lm3, MNI=1, NISP=18; (98-49) RM1, 1 R mandible with Rp4, Rm1, Rm2, 1 L mandible with Lp4, Lm1, Lm2, Lm3, MNI=1, NISP=10; (98-52) 1 R mandible with Rp4, Rm1, Rm2, 1 L mandible with Lp4, Lm3, MNI=1, NISP=7; (98-58) 1 L mandible with Lp4, Lm1, Lm2, MNI=1, NISP=4; (98-59) Rm3, MNI=1, NISP=1; (98-62) 1 R mandible with Rp4, Rm1, Rm2, MNI=1, NISP=4; (98-69) 1 skull with RP4, RM1, RM2, LP4, LM1, LM2, LM3, 1 L mandible with Lp4, Lm1, Lm2, Lm3, MNI=1, NISP=13; (98-76) 1 palatine with RP4, RM1, RM2, RM3, 1 L mandible, MNI=1, NISP=6; (98-79) 1 palatine with RP4, RM1, RM2, RM3, LP4, LM2, LM3, 1 R mandible with Rp4, Rm1, Rm2, Rm3, MNI=1, NISP=13; (98-81) 1 skull with RP4, 2 RM1, RM3, LP4, LM1, LM3, 2 R mandibles with 2 Rp4, 3 Rm1, 3 Rm2, 2 Rm3, 1 L mandible with Lp4, Lm1, Lm2, Lm3, MNI=3, NISP=25; (98-82) 1 skull with RP4, RM2, RM3, LP4, LM1, LM2, LM3, 1 R

mandible with Rp4, Rm1, Rm2, 1 Lp4, Lm1, Lm2, Lm3, MNI=1, NISP=17; (98-83) 1 skull with RP4, RM1, RM2, RM3, LP4, LM1, LM2, LM3, Lm3, MNI=1, NISP=10; (98-85) 1 skull with RP4, RM1, RM2, RM3, LP4, LM1, LM2, LM3, 1 Rm3, MNI=1, NISP=10; (98-86) 1 R mandible with Rp4, Rm1, Rm2, Rm3, MNI=1, NISP=5; (98-88) 1 R mandible with Rp4, Rm1, Rm2, Rm3, 1 L mandible with Lp4, Lm1, Lm2, Lm3, MNI=1, NISP=10; (98-89) 1 R mandible with Rp4, Rm2, Rm3, MNI=1, NISP=4; (98-90) 1 LP4, LM1, Rp4, Rm3, Lm1, MNI=1, NISP=5; (98-91) 1 palatine with RP4, RM1, RM2, RM3, LP4, LM1, LM2, LM3, 1 R mandible with Rp4, Rm1, Rm2, MNI=1, NISP=13; (98-102) 2 partial skulls with RP4, RM1, RM2, 2 RM3, 2 LP4, 2 LM1, 2 LM2, 2 LM3, 1 R mandible with Rp4, 1 Rm1, Rm2, Rm2, 1 L mandible with Lp4, Lm1, Lm2, Lm3, MNI=2, NISP=25; (98-103) 1 skull with RP4, RM1, RM2, RM3, LP4, LM1, LM2, LM3, 1 R mandible with Rp4, Rm1, Rm2, Rm3, MNI=1, NISP=14; (98-104) 1 skull, 1 palatine with RP4, 2 RM1, 2 RM2, Rm3, LP4, 2 LM1, 2 LM2, LM3, 2 R mandibles with 2 Rp4, Rm1, Rm2, Rm3, 1 L mandible with 2 Lp4, Lm1, Lm2, MNI=2, NISP=25; (98-105) 1 skull with RP4, RM1, RM2, RM3, LP4, LM1, LM2, LM3, Rm2, MNI=1, NISP=11; (98-107) 1 skull with LM1, LM2, MNI=1, NISP=3; (98-109) 2 L mandibles with Lp4, Lm1, 2 Lm2, Lm2, MNI=2, NISP=7; (98-110) 2 R mandibles with Rp4, 2 Rm1, 2 Rm2, Rm3, 1 L mandible with Lp4, Lm1, Lm2, Lm3, MNI=2, NISP=13; (98-111) 1 skull, 2 palatine with 3 RP4, 3 RM1, 3 RM2, RM3, LP4, LM1, LM2, 1 R mandible with Rp4, Rm1, Rm2, MNI=3, NISP=20;

Old Faithful

GHOW: (99-110) 1 skull with LP4, LM2, LM3, 1 R mandible with Rp4, Rm1, Rm2, Rm3, MNI=1, NISP=9; (99-253) 1 skull with RP4, RM1, RM2, RM3, LP4, LM1, LM2, LM3, 1 R mandible with Rp4, Rm1, Rm2, Rm3, 1 L mandible with Lp4, Lm1, Lm2, Lm3, MNI=1, NISP=19; (99-291) 1 R maxilla with RP4, RM1, RM2, RM3, 1 R mandible with Rp4, Rm1, Rm2, Lp4, MNI=1, NISP=10; (99-306) 1 skull with RP4, RM1, RM2, RM3, LP4, LM1, LM2, LM3, 1 R mandible with Rp4, Rm3, 1 L mandible with Lp4, Lm1, Lm2, Lm3, MNI=1, NISP=17; (99-449) 2 skulls with 2 RP4, 2 RM1, 2 RM2, RM3, LP4, 2 LM1, LM2, LM3, 2 L mandibles with 2 Lp4, 2 Lm1, 2 Lm2, Lm3, MNI=2, NISP=23; (99-454) 2 R mandibles with 2 Rp4, 2 Rm1, 2 Rm2, Rm3, 2 L mandibles with 2 Lp4, 2 Lm1, 2 Lm2, Lm3, MNI=2, NISP=18;

Coyote: (99-34S) 1 RM2, LP4, LM2, MNI=1, NISP=3;

Porcupine

RTHA: (99-560) 1 Lp4, MNI=1, NISP=1;

Alum Ck.

SEOW: (98-292) 1 palatine with RP4, RM2, RM3, LM1, LM2, LM3, 1 R mandible with Rp4, Rm1, Rm2, Rm3, 1 L mandible with Lp4, Lm1, Lm2, Lm3, MNI=1, NISP=17; (98-295) 1 skull with RP4, RM1, RM2, RM3, LP4, LM1, LM2, LM3, 1 R mandible with Rp4, Rm1, Rm2, Rm3, 1 L mandible with Lp4, Lm1, Lm2, Lm3, MNI=1, NISP=19; (98-296) 1 LM1, 1 L mandible with Lp4, Lm1, Lm2, MNI=1, NISP=5; (98-297) 1 skull with RP4, RM1, RM2, RM3, LP4, LM1, LM2, LM3, 1 R mandible with Rp4, Rm1, Rm2, Rm3, 1 L mandible with Lp4, Lm1, Lm2, Lm3, MNI=1, NISP=19; (98-

312) 1 skull with RP4, RM1, RM2, RM3, LP4, LM1, LM2, LM3, 1 R mandible with Rp4, Rm1, Rm2, Rm3, 1 L mandible with Lp4, Lm1, Lm2, Lm3, MNI=1, NISP=19; (98-313) 1 palatine with RP4, RM1, RM2, LP4, MNI=1, NISP=5; (98-318) 1 palatine with LM3, MNI=1, NISP=2; (98-319) 1 partial skull with RM3, LM1, 1 R mandible with Rp4, Rm1, Rm2, Rm3, 1 L mandible with Lp4, Lm1, Lm2, MNI=1, NISP=12; (98-503) 1 palatine with RM1, RM3, LP4, LM1, LM2, LM3, Rp4, 1 L mandible with Lm1, Lm2, LM3, MNI=2, NISP=13; (98-504) 1 R mandible with Rp4, Rm1, Rm2, MNI=1, NISP=5;

1999

Alum Ck.

SWHA: (99-356) 1 RM1, LP4, LM2, 1 L mandible with Lp4, MNI=1, NISP=5; (99-357) 1 RM2, RM3, LP4, LM1, LM2, LM3, 1 R mandible with Rp4, Rm1, MNI=1, NISP=9; (99-358) 1 skull with RP4, RM1, RM2, RM3, LP4, LM1, LM2, LM3, 3 R mandibles with 3 Rp4, 2 Rm1, Rm2, Rm3, 2 L mandibles with 2 Lp4, 2 Lm1, Lm2, Lm3, MNI=3, NISP=27; (99-365) 1 RP4, RM1, RM2, Lp4, Lm2, Lm3, MNI=1, NISP=6; (99-369) 1 R mandible with Rp4, Rm1, 1 L mandible with Lp4, Lm1, Lm2, MNI=1, NISP=7; (99-589) 1 LM2, Lm2, MNI=1, NISP=2; (99-590) 1 RM2, MNI=1, NISP=1; (99-593) 1 Rm3, MNI=1, NISP=1; (99-595) 1 skull with RP4, RM1, RM2, RM3, LP4, LM1, LM2, LM3, 1 R mandible with Rp4, Rm1, Rm2, Rm3, 1 L mandible with Lp4, Lm1, Lm2, Lm3, MNI=1, NISP=19; (99-598) 1 skull with RP4, 2 RM1, RM2, LP4, LM1, LM2, 1 R mandible with Rp4, Rm1, Rm2, 1 L mandible with Lp4, Lm1, Lm2, MNI=1, NISP=16; (99-601) 1 palatine with RP4, RM1, LP4, MNI=1, NISP=4;

Coyote: (99-1S) 1 RP4, 2 RM2, LP4, 2 LM2, 1 R mandible with Rp4, Rm2,

Rm3, 1 L mandible with 2 Lp4, Lm1, Lm2, MNI=2, NISP=15; (99-2S) 2 palatines with 3 RP4, 3 RM1, 2 RM2, 2 RM3, 3 LP4, 2 LM1, 3 LM2, 2 LM3, 4 R mandible with 5 Rp4, 6 Rm1, 4 Rm2, 3 Rm3, 7 L mandibles with 6 Lp4, 5 Lm1, 3 Lm2, 3 Lm3, MNI=7, NISP=68; (99-3S) 1 palatine with RM1, RM2, RM3, LP4, LM1, LM2, LM3, 1 R mandible with Rp4, Rm1, Rm2, Rm3, 1 L mandible with Lp4, Lm1, Lm2, Lm3, MNI=1, NISP=18; (99-4S) 3 palatines with 3 RP4, 4 RM1, 4 RM2, 3 RM3, 2 LP4, 6 LM1, 4 LM2, 5 LM3, 4 R mandibles with 3 Rp4, 3 Rm1, 5 Rm2, 3 Rm3, 3 L mandibles with 3 Lp4, 3 Lm1, 4 Lm2, 2 Lm3, MNI=6, NISP=67; (99-8S) 2 RP4, 2 RM3, LP4, 1 R mandible with Rp4, Rm1, 2 Rm2, Rm3, 3 L mandibles with 2 Lp4, 3 Lm1, 2 Lm2, Lm3, MNI=3, NISP=22; (99-12S) 1 LM2, MNI=1, NISP=1; (99-13S) 1 RM1, RM2, RM3, LP4, LM2, LM3, 1 R mandible with Rp4, Rm1, Rm2, 1 L mandible with Lp4, Lm2, Lm3, MNI=1, NISP=14;

Trout Ck.

LEOW: (99-174) 1 skull with RP4, RM1, RM2, RM3, LP4, LM1, LM2, LM3, 1 L mandible with Lp4, Lm1, Lm2, Lm3, MNI=1, NISP=14; (99-175) 1 palatine with RP4, RM1, LP4, LM1, 1 L mandible with Lp4, Lm1, Lm2, MNI=1, NISP=9; (99-377) 1 L mandible with Lp4, Lm1, Lm2, Lm3, MNI=1, NISP=5; (99-379) 2 skulls with 2 RP4, 2 RM1, 2 RM2, 2 RM3, LP4, 2 LM1, 2 LM2, 2 LM3, 2 R mandibles with 2 Rp4, 2 Rm1, 2 Rm2, 2 Rm3, 2 L mandibles with 2 Lp4, 2 Lm1, 2 Lm2, 2 Lm3, MNI=2, NISP=37; (99-387) 1 L mandible with Lp4, Lm1, Lm2, Lm3, MNI=1, NISP=5; (99-405) 1 skull with LM3, MNI=1, NISP=2; (99-411) 1 skull with RP4, RM1, RM2, RM3, LP4, LM1, LM2, LM3, 2 R mandibles with 2 Rp4, 2 Rm1, 2 Rm2, 2 Rm3, 1 L mandible with Lp4, Lm1,

Lm2, Lm3, MNI=1, NISP=23; (99-602) 1 palatine with RM1, RM2, LM1, LM2, 1 L mandible with Lp4, Lm1, Lm2, Lm3, MNI=1, NISP=10; (99-607) 1 palatine with RP4, RM1, RM2, RM3, LP4, LM1, LM2, LM3, 1 L mandible with Lp4, Lm1, Lm2, Lm3, MNI=1, NISP=14; (99-610) 1 skull with RP4, RM1, RM2, RM3, LP4, LM1, LM2, LM3, 1 R mandible with Rp4, Rm1, Rm2, Rm3, 1 L mandible with Lp4, Lm1, Lm2, Lm3, MNI=1, NISP=19;

Lake

CORA: (99-424) 1 skull with RP4, RM1, RM2, RM3, LP4, LM1, LM2, LM3, 1 R mandible with Rp4, Rm1, Rm2, Rm3, 1 L mandible with Lp4, Lm1, Lm2, Lm3, MNI=1, NISP=19; (99-428) 1 Lm3, MNI=1, NISP=1; (99-571) 1 RM3, LM2, LM3, MNI=1, NISP=3;

Identification: Northern pocket gophers have simplified teeth with tall cylindrical crowns with broad folds from the sides (Hillson 1986). The teeth are rootless and kernal-shaped. P4 is triangular and has a distinct anteriomedial notch (Chomko 1980).

Present Distribution: Northern pocket gophers are widely distributed and are found in the northern Great Plains and central Rocky Mountains from Manitoba to Alberta south to New Mexico and northern Arizona (Pattie and Hoffmann 1990).

Ecology: Northern pocket gophers are found in a variety of habitats from meadows to sagebrush to alpine areas but seem to avoid dense forests and areas of wet or waterlogged soils (Pattie and Hoffmann 1990, Streubel 1989). Northern pocket gophers are prodigious diggers and their work can be seen in piles of mounded soil and worm-like cores (Struebel1989). Pocket gophers eat primarily forbs, herbs and grasses. They feed in

underground tunnels where they can chew on roots (Clark and Stromberg 1987).

Zapus cf. princeps Allen, 1893 (western jumping mouse)

Comparative Materials: Denver Museum of Natural History # 9582, # 8841, Montana State University # 265, # 269.

Referred Materials:

Gardiner

GHOW: (98-150) 1 skull with RP4, RM1, RM2, RM3, 1 L mandible with Lm1, Lm2, MNI=1, NISP=8; (98-160) 1 R mandible with Rm1, Rm2, Rm3, MNI=1, NISP=4; (98-184) 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=8;

Junction Butte

RTHA: (98-244) 1 RI1, R maxilla with RP4, RM1, RM2, LI1, LM1, Rm2, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=12;

1999

Lower Owl Alley

Coyote: (99-20S) 1 L maxilla with LP4, LM1, LM2, LM3, Lm1, Lm2, MNI=1, NISP=7;

Old Faithful

GHOW: (98-113) 1 R mandible with Rm1, Rm2, 1 RI, 1 LI, MNI=1, NISP=5;

1999

Old Faithful

GHOW: (99-431) 2 RI1, 1 R maxilla with RP4, RM1, RM2, RM3, 2 L maxilla

with LP4, 2 LM1, LM2, LM3, 2 R mandibles with 2 Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=2, NISP=23; (99-552) 1 separated maxilla with RP4, RM1, RM2, RM3, LP4, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=16;

Identification: The molars are brachydont, with two parallel mesiodistal rows of cusps (Hillson 1986). There are three maxillary roots and two mandibular roots. The upper incisors are deeply grooved. P4 is peglike, M2 is smaller than M1, M3 has two labial re-entrant folds of equal length and is nearly circular in cross section (Chomko 1980).

Present Distribution: The western jumping mouse ranges from southern Yukon south along the Rocky Mountains to Arizona and New Mexico. It occurs eastward into South Dakota and west into central California (Pattie and Hoffmann 1990).

Ecology: Western jumping mice inhabit wet, lush streamside vegetation, marshes and ponds. They are omnivores and eat a variety of insects and seeds. Unlike other rodents within Yellowstone, western jumping mice spend up to nine months of the year hibernating in underground burrows (Clark and Stromberg 1987, Streubel 1990).

Clethrionomys cf. gapperi (Vigors, 1830) (red-backed vole)

Comparative Materials: Denver Museum of Natural History # 7354, # 7183, Montana State University Vertebrate Collection # 6402, # 7205.

Referred Materials:

Gardiner

GHOW: (98-147) 1 separated maxilla with LM3, 1 R mandible with Rm1, 1 L mandible, MNI=1, NISP=5;

Lower Owl Alley

GHOW: (98-289) 1 separated maxilla with RM1, RM2, LM2, LM3, 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm2, MNI=1, NISP=12;

Lamar Bridge

CORA: (99-147) 1 LM1, 1 R mandible, 1 L mandible with Lm1, Lm2, MNI=1, NISP=5;

Old Faithful

GHOW: (98-88) 1 separated maxilla with RM1, RM2, RM3, LM1, 1 L mandible with Lm1, Lm2, Rm3, MNI=1, NISP=9;

1999

Old Faithful

GHOW: (99-256) 1 R maxilla with RM1, RM2, 1 R mandible with Rm1, Rm2, 1 L mandible with Lm1, Lm2, MNI=1, NISP=9; (99-259) 1 RM1, 1 R mandible with 2 Rm1, Rm2, MNI=2, NISP=5;

Porcupine

RTHA: (99-567) 1 RM3, LM3, 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=10;

Identification: The subfamily Microtinae share similar teeth with long angular molars consisting of multiple prismatic elements. *Clethrionomys* teeth differ from other Microtinae in the Yellowstone ecosystem. Adult teeth are rooted, and have rounded infolds which do not meet in the center of the occlusal surface (Hillson 1986).

Clethrionomys teeth from Yellowstone tended to be slightly smaller than other voles.

Present Distribution: This species ranges from across Canada south along the Rocky and Appalachian mountains (Clark and Stromberg 1987).

Ecology: Red-backed voles are usually associated with cool, forested habitats having adequate litter and brush but they can also be found in dry brushy aspen forests (Pattie and Hoffmann 1990, Streubel 1989). In Yellowstone, highest densities can be found in spruce-fir forests although they can also be found in lodgepole pine, mixed aspen and Douglas fir forests (Streubel 1989). Red-backed voles eat a variety of shoots, grasses and flowers in the spring and then switch to berries in the summer. In the fall and winter they eat seeds, nuts and evergreen shrubs as well as twigs and roots (Pattie and Hoffmann 1990).

Microtus longicaudus (Merriam, 1888) (long-tailed vole)

Comparative Materials: Denver Museum of Natural History # 7913, # 7911, # 7912, Montana State University Vertebrate Collection # 397, # 398.

Referred Materials:

Identification: Identification to species is not possible for *M. longicaudus* using only teeth. Where this species coexists with *M. montanus* designation to species should be done with the skull and skin. *M. longicaudus* can be determined by having a longer tail, and lighter pelage (Clark and Stromberg 1987, Streubel 1989).

Cranial attributes that can be useful for the designation to species include the fact that the area between the orbits is smooth as opposed to forming a ridge as with *M. montanus*. The upper incisors do not protrude beyond the nasal and premaxilla bones (Maser and Storm 1970).

Present Distribution: The long-tailed vole ranges from eastern Alaska into the Yukon and from British Columbia south along the west coast to southern California. It ranges south along the Rocky Mountains to Arizona and New Mexico. Its eastward distribution extends into Montana, Wyoming and parts of Colorado (Pattie and Hoffmann 1990).

Ecology: Long-tailed voles can be found in a variety of habitats including moist meadows, sagebrush grasslands and riparian habitats (Clark and Stromberg 1987, Streubel 1989). Like other voles, they eat a variety of grasses, forbs and bulbs. They are active year round but they do not construct runways similar to meadow and montane voles. In Yellowstone long-tailed voles are sympatric with meadow and montane voles but are usually present in lower densities (Crabtree et al. 1997, Pattie and Hoffmann 1990).

Microtus montanus (Peale, 1848) (montane vole)

Comparative Materials: Denver Museum of Natural History # 7726, # 8990, # 8988, Montana State University Vertebrate Collection # 5150, # 6106.

Referred Materials:

Gardiner

GHOW: (98-160) 1 skull with RM1, RM2, RM3, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=15; (98-162) 1 skull with RM1, RM2, RM3, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=14; (98-164) 1 skull with RM1, RM2, RM3, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, Rm3, MNI=1, NISP=11; (98-168) 1 skull with RM1, RM2, RM3, LM1, LM2, MNI=1, NISP=6; (98-

181) 1 skull with RM1, RM2, RM3, LM1, LM2, LM3, MNI=1, NISP=7; (98-205) 2 skulls with 2 RM1, 2 RM2, 2 RM3, 2 LM1, 2 LM2, 2 LM3, 1 L mandible with Lm1, Lm2, Lm3, MNI=2, NISP=18;

1999

Gardiner

GHOW: (99-30) 1 skull with RM1, RM2, RM3, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=15; (99-60) 1 skull with RM1, RM2, RM3, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=15; (99-192) 2 skulls with 2 RM1, 2 RM2, 2 RM3, 2 LM1, 2 LM2, LM3, 2 R mandibles with 2 Rm1, 2 Rm2, 2 Rm3, 2 L mandibles with 2 Lm1, 2 Lm2, 2 Lm3, MNI=2, NISP=29; (99-205) 2 skulls with 2 RM1, 2 RM2, 2 RM3, 2 LM1, 2 LM2, 2 LM3, 1 R mandible with Rm1, Rm2, Rm3, 2 L mandibles with 2 Lm1, 2 Lm2, 2 Lm3, MNI=2, NISP=26; (99-218) 1 skull with RM1, RM2, RM3, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=15;

Junction Butte

GHOW: (98-428) 2 skulls with 2 RM1, 2 RM2, 2 RM3, 2 LM1, 2 LM2, LM3, MNI=2, NISP=13; (98-434) 1 skull with RM1, RM2, LM1, LM2, MNI=1, NISP=5; (98-437) 1 skull with RM1, RM2, RM3, LM1, LM2, LM3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=11; (98-442) 1 skull with RM1, RM2, LM1, LM2, MNI=1, NISP=5;

1999

Junction Butte

GHOW: (99-64) 2 skulls with 2 RM1, 2 RM2, 2 RM3, 2 LM1, 2 LM2, LM3, 2 R mandibles with 2 Rm1, 2 Rm2, 2 Rm3, 2 L mandibles with 2 Lm1, 2 Lm2, 2 Lm3, MNI=2, NISP=29; (99-65) 2 skulls with RM1, 2 RM2, 2 RM3, 2 LM1, 2 LM2, 2 LM3, 2 R mandibles with 2 Rm1, 2 Rm2, 2 Rm3, 2 L mandibles with 2 Lm1, 2 Lm2, 2 Lm3, MNI=2, NISP=30; (99-78) 1 skull with RM1, LM1, LM2, 1 R mandible with Rm1, Rm2, 1 L mandible with Lm1, MNI=1, NISP=9;

Tower

RTHA: (99-473) 1 skull with RM1, RM2, RM3, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=15;

Lower Owl Alley

GHOW: (99-489) 1 skull with RM1, RM2, RM3, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=15; (99-502) 1 skull with RM1, RM2, RM3, LM1, LM2, LM3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=11; (99-512) 1 skull with RM1, RM2, RM3, LM1, LM2, LM3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=11; (99-515) 1 skull with RM1, RM2, LM1, LM2, Rm3, MNI=1, NSIP=6;

Lamar Bridge

CORA: (99-148) 1 skull with RM1, RM2, RM3, LM1, LM2, 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=14;

E. Slough

RTHA: (99-476) 1 skull with RM1, RM2, RM3, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=15;

Lamar

CORA: (99-177) 2 skulls with 2 RM1, 2 RM2, RM3, 2 LM1, 2 LM2, 2 R mandibles with 2 Rm1, 2 Rm2, 2 Rm3, 2 L mandibles with 2 Lm1, 2 Lm2, Lm3, MNI=2, NISP=26;

Old Faithful

GHOW: (99-86) 2 skulls with 2 RM1, 2 RM2, 2 RM3, 2 LM1, 2 LM2, 2 LM3, 1 R mandible with Rm1, Rm2, Rm3, 2 L mandibles with 2 Lm1, 2 Lm2, 2 Lm3, MNI=2, NISP=26; (99-97) 1 skull with RM1, RM2, RM3, LM1, LM2, LM3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=11; (99-102) 3 skulls with 3 RM1, 3 RM2, 3 RM3, 3 LM1, 3 LM2, 3 LM3, 3 R mandibles with 3 Rm1, 3 Rm2, 2 Rm3, 3 L mandibles with 3 Lm1, 3 Lm2, 3 Lm3, MNI=3, NISP=44; (99-119) 2 skulls with 2 RM1, 2 RM2, 2 RM3, 2 LM1, 2 LM2, 2 LM3, 2 R mandibles with 2 Rm1, 2 Rm2, 2 Rm3, 2 L mandibles with 2 Lm1, 2 Lm2, MNI=2, NISP=28; (99-445) 1 skull with RM1, RM2, RM3, LM1, LM2, LM3, 1 R mandible with Rm1, Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=14;

CORA: (99-249) 1 skull with RM1, RM2, RM3, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, Rm3, MNI=1, NISP=11;

Porcupine

RTHA: (99-531) 2 skulls with 2 RM1, 2 RM2, 2 RM3, 2 LM1, 2 LM2, 2 LM3, 1 R mandible with Rm1, Rm2, Rm3, 2 L mandibles with 2 Lm1, 2 Lm2, 2 Lm3, MNI=2,

NISP=26; (99-567) 1 skull with RM1, RM2, RM3, LM1, LM2, LM3, MNI=1, NISP=7;

Alum. Ck.

SEOW: (98-291) 1 skull with RM1, RM2, RM3, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=15; (98-295) 1 skull with RM1, RM2, RM3, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=15; (98-309) 1 skull with RM1, RM2, RM3, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=15; (98-310) 1 skull with RM1, RM2, RM3, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=15; (98-311) 1 skull with RM1, RM2, RM3, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=15; (98-314) 1 skull with RM1, RM2, RM3, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=15; (98-315) 2 skulls with 2 RM1, 2 RM2, 2 RM3, 2 LM1, 2 LM2, 2 LM3, 2 R mandibles 2 Rm1, 2 Rm2, 2 Rm3, 2 L mandibles with 2 Lm1, 2 Lm2, 2 Lm3, MNI=2, NISP=30; (98-318) 2 skulls with RM1, RM2, 2 RM3, 2 LM1, 2 LM2, 2 LM3, 1 L mandible with Lm1, Lm2, Lm3, MNI=2, NISP=16; (98-504) 1 skull with RM1, RM2, RM3, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=15; (98-508) 1 skull with RM1, RM2, RM3, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=15;

1999

Alum Ck.

SEOW: (99-152) 2 skulls with RM1, LM1, LM2, LM3, 2 R mandibles with 2 Rm1, Rm2, Rm3, 2 L mandibles with 2 Lm1, 2 Lm2, 2 Lm3, MNI=2, NISP=20; (99-153) 1 skull with RM1, RM2, RM3, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=15; (99-154) 1 skull with RM1, RM2, RM3, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=15; (99-342) 1 skull with RM1, RM2, RM3, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=15; (99-345) 1 skull with RM1, RM2, RM3, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=15;

Trout Ck.

LEOW: (99-371) 1 skull with RM1, RM2, RM3, LM1, LM2, LM3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=11; (99-373) 2 skulls with 2 RM1, 2 RM2, 2 RM3, 2 LM1, 2 LM2, 2 LM3, 2 R mandibles with 2 Rm1, 2 Rm2, 2 Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=2, NISP=19; (99-375) 1 skull with RM1, RM2, RM3, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=15; (99-377) 1 skull with RM1, RM2, RM3, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=15; (99-378) 1 skull with RM1, RM2, RM3, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=15; (99-379) 1 skull with RM1, RM2, RM3, LM3, MNI=1, NISP=4; (99-381) 1 skull with RM1, RM2, RM3, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, Rm3, MNI=1, NISP=11; (99-383) 1 skull with RM1, RM2, RM3, LM1, LM2, LM3, MNI=1, NISP=7; (99-384) 1 skull with

RM1, RM2, RM3, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=15; (99-385) 1 skull with RM1, RM2, RM3, LM1, LM2, LM3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=11; (99-387) 1 skull with RM1, RM2, RM3, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=15; (99-388) 1 skull with RM1, RM2, RM3, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=15; (99-389) 1 skull with RM1, RM2, RM3, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=15; (99-390) 1 skull with RM1, RM2, RM3, LM1, LM2, LM3, MNI=1, NISP=15; (99-391) 2 skulls with 2 RM1, 2 RM2, Rm3, 2 LM1, 2 LM2, LM3, 2 R mandibles with 2 Rm1, 2 Rm2, 2 Rm3, 2 L mandibles with Lm1, 2 Lm2, 2 Lm3, MNI=2, NISP=27; (99-393) 1 skull with RM1, RM2, RM3, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=15; (99-395) 2 skulls with 2 RM1, 2 RM2, 2 RM3, 2 LM1, 2 LM2, 2 LM3, 2 R mandibles with 2 Rm1, 2 Rm2, Rm3, 2 L mandibles with 2 Lm1, 2 Lm2, Lm3, MNI=2, NISP=28; (99-401) 1 skull with RM1, RM2, RM3, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, Rm3, MNI=1, NISP=11; (99-405) 3 skulls with 3 RM1, 3 RM2, 3 RM3, 3 LM1, 3 LM2, 3 LM3, 1 R mandible with Rm1, Rm2, Rm3, 2 L mandibles with 2 Lm1, 2 Lm2, 2 Lm3, MNI=3, NISP=33; (99-407) 1 skull with RM1, RM2, RM3, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=15; (99-409) 1 skull with RM1, RM2, RM3, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=15; (99-411) 1 skull with RM1, RM2, RM3, LM1,

LM2, LM3, 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=15; (99-413) 3 skulls with 3 RM1, 3 RM2, 3 RM3, 3 LM1, 3 LM2, 3 LM3, 3 R mandibles with 3 Rm1, 3 Rm2, 3 Rm3, 3 L mandibles with 3 Lm1, 3 Lm2, 2 Lm3, MNI=3, NISP=44; (99-416) 1 skull with RM1, RM2, RM3, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, Rm3, MNI=1, NISP=11; (99-603) 1 skull with RM2, RM3, LM1, LM2, LM3, MNI=1, NISP=6; (99-607) 2 skulls with 2 RM1, 2 RM2, 2 RM3, 2 LM1, 2 LM2, 2 LM3, 2 R mandibles with 2 Rm1, 2 Rm2, 2 Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=2, NISP=26; (99-610) 1 skull with RM1, RM2, RM3, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=15; (99-616) 2 skulls with 2 RM1, 2 RM2, 2 RM3, 2 LM1, 2 LM2, 2 LM3, 2 R mandibles with 2 Rm1, 2 Rm2, 2 Rm3, 2 L mandibles with 2 Lm1, 2 Lm2, 2 Lm3, MNI=2, NISP=30; (99-618) 2 skulls with 2 RM1, 2 RM2, 2 RM3, 2 LM1, 2 LM2, 2 LM3, 2 R mandibles with 2 Rm1, 2 Rm2, 2 Rm3, 2 L mandibles with 2 Lm1, 2 Lm2, 2 Lm3, MNI=2, NISP=30;

Identification: Designation to species was made by cranial attributes, specifically by a ridge that forms between the orbits in adults. The upper incisors protrude slightly from the nasal and premaxilla bones (Maser and Storm 1970). Therefore, juvenile *M. montanus* that did not have a distinctive ridge between the orbits were identified as *M. spp.*

Present Distribution: The montane vole ranges from British Columbia south along the Rocky Mountains to Arizona and New Mexico. In the west, it ranges from the eastern Cascades along to the Sierra Nevada to central California. To the east, its range extends

along the southern edge of Montana through portions of Wyoming and Colorado (Pattie and Hoffmann 1990).

Ecology: Montane voles can be found in a variety of habitats but they prefer drier habitats than those of meadow voles. They can be found from mountain meadows to sagebrush grasslands and occasionally in riparian zones (Streubel 1989).

As with other voles, montane voles eat grasses, forbs and sedges. They are active year round and their extensive runways can be seen early in the spring when greenup first appears. In winter, they tend to eat the bark of willows and other woody vegetation (Pattie and Hoffmann 1990). While the montane vole is sympatric with other voles, it utilizes slightly different habitats. In areas of overlap, the meadow vole will displace the montane vole for preferred sites (Clark and Stromberg 1987).

Microtus pennsylvanicus (Ord, 1815) (meadow vole)

Comparative Materials: Denver Museum of Natural History # 7532, # 7533, Montana State University Vertebrate Collection # 6042, #6249.

Referred Materials:

Gardiner

GHOW: (98-164) 1 skull with RM1, RM2, RM3, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, Rm3, MNI=1, NISP=11; (98-165) 1 skull with RM1, RM2, RM3, LM1, LM2, 1 R mandible with Rm1, Rm2, 1 L mandible with Lm1, Lm2, MNI=1, NISP=12; (98-166) 1 skull with RM1, RM2, RM3, LM1, LM2, 1 L mandible with Lm1, Lm2, MNI=1, NISP=9; (98-177) 1 skull with RM1, RM2, RM3, LM1, LM2, 1 R mandible with Rm1, Rm2, Rm3, MNI=1, NISP=8; (98-182) 1 skull with RM1, RM2,

RM3, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=15; (98-189) 1 skull with RM1, RM2, LM1, LM2, 1 R mandible with Rm1, Rm2, 1 L mandible with Lm1, Lm2, MNI=1, NISP=11; (98-205) 1 skull with RM1, RM2, LM1, LM2, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=9; (98-212) 1 skull with RM1, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=12;

1999

Gardiner

GHOW: (99-30) 1 skull with RM1, RM2, RM3, LM1, LM2, LM3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=11;

Junction Butte

GHOW: (98-423) 1 palatine with RM1, LM1, LM2, MNI=1, NISP=4; (98-429) 1 palatine with RM1, RM2, LM1, LM2, 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm2, MNI=1, NISP=12;

1999

Junction Butte

GHOW: (99-74) 1 skull, 1 palatine with RM1, 2 RM2, 2 LM1, 2 LM2, 2 LM3, 2 R mandibles with 2 Rm1, 2 Rm2, 2 Rm3, MNI=2, NISP=19;

Tower

RTHA: (99-472) 1 RM1, RM2, 1 R mandible with Rm1, Rm2, 2 L mandibles with 2 Lm1, Lm2, MNI=2, NISP=10;

South-side Lamar River

Coyote: (98-5S) 1 palatine with RM1, RM2, RM3, LM1, LM2, LM3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=11; (98-8S) 1 palatine with LM2, LM3, 1 R mandible with Rm1, Rm2, MNI=1, NISP=6;

Lower Owl Alley

GHOW: (98-280) 1 palatine with RM1, RM2, RM3, LM1, LM2, LM3, MNI=1, NISP=7; (98-376) 1 skull with RM1, RM2, RM3, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=15; (98-398) 1 skull with RM1, RM2, RM3, LM1, LM2, LM3, MNI=1, NISP=7;

1999

Lower Owl Alley

GHOW: (99-482) 1 skull with RM1, RM2, RM3, LM2, LM3, 1 L mandible with Lm1, Lm2, MNI=1, NISP=9; (99-494) 1 skull with RM1, RM1, RM3, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=15; (99-504) 1 skull with RM1, RM2, RM3, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=15; (99-515) 2 skulls with 2 RM1, 2 RM2, RM3, 2 LM1, 2 LM2, 2 LM3, 1 R mandible with Rm1, Rm2, Rm3, 2 L mandibles with Lm1, Lm2, Lm3, MNI=2, NISP=22; (99-654) 1 skull, 1 palatine with 2 RM1, 2 RM2, 2 RM3, 2 LM1, 2 LM2, 2 LM3, 1 L mandible with Lm1, Lm2, Lm3, MNI=2, NISP=18;

Lamar Cave

Coyote: (99-18S) 2 RM1, 2 RM2, 2 RM2, 2 LM1, LM2, 2 R mandibles with 2 Rm1, 2 Rm2, Rm3, 1 L mandible with Lm1, Lm2, MNI=2, NISP=19; (99-28S) 1 palatine

with RM1, RM2, RM3, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=14;

Lamar Bridge

CORA: (99-132) 1 skull with RM1, RM2, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, 1 L mandible with Lm1, Lm2, MNI=1, NISP=12; (99-135) 1 skull with RM1, RM2, RM3, LM1, LM2, LM3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=11; (99-327) 1 palatine with RM1, RM2, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, Rm3, Lm1, MNI=1, NISP=11;

Lamar

CORA: (99-178) 2 skulls with 2 RM1, 2 RM2, RM3, 2 LM1, 2 LM2, LM3, 2 R mandibles with 2 Rm1, 2 Rm2, 2 Rm3, 2 L mandibles with 2 Lm1, 2 Lm2, 2 Lm3, MNI=2, NISP=28; (99-181) 1 skull with RM1, RM2, RM3, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=15;

Old Faithful

GHOW: (98-37) 1 skull with RM1, RM2, RM3, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=15; (98-80) 1 skull with RM1, RM2, LM1, LM2, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=9; (98-83) 1 skull with RM1, RM2, LM1, LM2, MNI=1, NISP=5; (98-87) 1 skull with RM1, RM2, RM3, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm2, Lm3, MNI=1, NISP=14; (98-88) 1 LM2, 1 R mandible with Rm1, Rm2, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=8; (98-107) 1 RM1, 1 L maxilla with LM1, LM2, LM3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=8;

1999

Old Faithful

GHOW: (99-97) 2 skulls with 2 RM1, 2 RM2, 2 RM3, 2 LM1, 2 LM2, 2 LM3, 2 R mandibles with 2 Rm1, 2 Rm2, 2 Rm3, 2 L mandibles with 2 Lm1, 2 Lm2, 2 Lm3, MNI=2, NSIP=30; (99-116) 1 skull with RM1, RM2, RM3, LM1, LM2, LM3, MNI=1, NISP=7; (99-119) 1 skull with RM1, RM2, RM3, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=15; (99-125) 1 skull with RM1, RM2, RM3, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=15; (99-256) 3 skulls with 3 RM1, 3 RM2, 3 RM3, 3 LM1, 3 LM2, 3 LM3, 3 R mandibles with 3 Rm1, 3 Rm2, 2 Rm3, 3 L mandibles with 3 Lm1, 3 Lm2, 3 Lm3, MNI=3, NISP=44; (99-261) 1 skull with RM1, RM2, LM1, LM2, LM3, 1 L mandible with Lm1, Lm2, MNI=1, NISP=9; (99-451) 1 RM1, RM2, MNI=1, NISP=2; (99-551) 1 skull with RM1, RM2, RM3, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm2, MNI=1, NISP=14;

CORA: (99-246) 1 LM1, LM2, 1 R mandible with Rm1, Rm2, Lm3, MNI=1, NISP=6;

Coyote: (99-33S) 2 palatine, 1 R maxilla with 2 RM1, 3 RM2, 3 RM3, 3 LM1, 2 LM2, 2 LM3, 3 Rm2, 2 Rm3, 2 L mandibles with 2 Lm1, 2 Lm2, Lm3, MNI=3, NISP=29; (99-34S) 1 R maxilla with RM1, 2 RM2, 2 RM3, 1 R mandible with 2 Rm1, Rm2, Rm3, MNI=2, NISP=11;

Alum Ck.

SWHA: (99-599) 1 skull with RM1, RM2, RM3, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=15;

SEOW: (99-151) 1 skull with RM1, RM2, RM3, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=15; (99-155) 1 skull with RM1, RM2, RM3, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=15; (99-344) 1 skull with RM2, RM3, LM1, LM2, LM3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=10;

Coyote: (99-4S) 1 RM1, RM2, LM1, LM2, 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=12; (99-7S) 1 R maxilla with RM1, 2 RM2, 2 RM3, LM1, LM3, Rm1, Rm3, MNI=2, NISP=10; (99-10S) 1 palatine with RM1, RM2, RM3, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=15; (99-11S) 1 RM1, RM2, LM1, LM2, Rm1, Lm1, Lm3, MNI=1, NISP=7; (99-12S) 1 RM, LM2, 1 R mandible with Rm1, Rm2, Lm1, Lm3, MNI=1, NISP=7; (99-14S) 1 RM1, 2 RM2, RM3, 2 LM1, 2 Rm1, 2 Rm2, 2 Rm3, 2 Lm1, Lm2, MNI=2, NISP=15; (99-23S) 2 palatines with 2 RM1, 2 RM2, 2 RM3, 2 LM1, 2 LM2, 2 LM3, 2 R mandibles with 2 Rm1, 2 Rm2, 2 Rm3, 2 L mandibles with 2 Lm1, 2 Lm2, 2 Lm3, MNI=2, NISP=30;

Trout Ck.

LEOW: (99-373) 1 skull with RM1, RM2, RM3, LM1, LM2, LM3, MNI=1, NISP=7; (99-376) 1 skull with RM1, RM2, RM3, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=15; (99-403) 1 skull with RM1, RM2, RM3, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, Rm3, 1 L

mandible with Lm1, Lm2, Lm3, MNI=1, NISP=15; (99-407) 1 skull with RM1, RM2, RM3, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, Rm3, MNI=1, NISP=11;

Identification: Meadow vole teeth can be distinguished from other vole species by an extra rounded posterior inner loop on M2.

Present Distribution: Meadow voles are the most widely distributed voles in North America. They range from Alaska south along the Rocky Mountains to Arizona. Their range extends eastward through Newfoundland, and in the east they range south along the Appalachian Mountains to Georgia (Pattie and Hoffmann 1990, Streubel 1989).

Ecology: The meadow vole is sympatric with other vole species but tends to be less abundant than montane voles in the Yellowstone ecosystem (Streubel 1989). When sympatric with other voles, they prefer more mesic sites. It prefers riparian area communities as compared to drier areas preferred by the montane vole (Streubel 1989). Meadow voles are active year round and eat a variety of grasses, leaves and sedges (Clark and Stromberg 1987, Streubel 1989). Their finely clipped runways can be observed in dense vegetation and are used as pathways of travel.

Similar to other species of voles, meadow voles exhibit population cycles that usually occur every three to four years (Streubel 1989). During these cycles, populations can increase three to six times their original population numbers (Krebs and Myers 1974).

Microtus richardsoni- (DeKay, 1842) (water vole)

Junction Butte

GHOW: (99-65) 1 skull with RM1, RM2, RM3, LM1, LM2, LM3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=11;

Tower

RTHA: (99-468) 1 skull with RM1, RM2, RM3, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=15;

Old Faithful

GHOW: (99-92) 1 skull with RM1, RM2, RM3, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, Rm3, MNI=1, NISP=11; (99-116) 1 palatine with RM1, RM2, RM3, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=15; (99-122) 2 skulls, 1 palatine with 2 RM1, 3 RM2, 2 RM3, 3 LM1, 3 LM2, 2 LM3, 3 R mandibles with 3 Rm1, 3 Rm2, 3 Rm3, 3 L mandibles with 3 Lm1, 3 Lm2, 2 Lm3, MNI=3, NISP=41; (99-125) 1 skull with RM1, RM2, RM3, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=15; (99-128) 1 R maxilla with RM1, RM3, LM3, MNI=1, NISP=4; (99-255) 1 skull, 1 palatine with RM1, RM2, RM3, 2 LM1, 2 LM2, LM3, 3 L mandibles with 2 Lm1, 2 Lm2, Lm3, MNI=3, NISP=18; (99-287) 2 skulls with 2 RM1, 2 RM2, 2 RM3, LM1, 2 LM2, LM3, MNI=2, NISP=12; (99-291) 2 skulls with 2 RM1, 2 RM2, 2 RM3, 2 LM1, 2 LM2, LM3, 2 L mandibles with 2 Lm1, 2 Lm2, 2 Lm3, MNI=2, NISP=21; (99-436) 2 skulls with 2 RM1, 2 RM2, 2 RM3, 2 LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=2, NISP=20; (99-442) 1 skull with RM1, RM2, RM3, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=15; (99-451) 1 LM1, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=5; (99-454) 1 skull with RM1, RM2, RM3, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, Rm3, MNI=1, NISP=11;

CORA: (99-558) 1 palatine with RM1, RM2, LM1, LM2, LM3, 1 R mandible Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=14;

Lake

CORA: (99-425) 1 LM3, MNI=1, NISP=1; (99-426) 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=4; (99-430) 1 skull with RM2, LM1, LM2, 1 R mandible with Rm1, Rm2, 1 L mandible with Lm1, Lm2, MNI=1, NISP=10; (99-573) 1 R mandible with Rm1, Rm2, Rm3, MNI=1, NISP=4;

Identification: Water vole teeth are very similar to other vole species, however, the large size and robust nature of the teeth is a very good indicator of this species. The lower m1 usually contains a posterior transverse loop followed anteriorly by five closed triangles and a transverse loop that is constricted in the middle (Ludwig 1984).

Cranial attributes that aid in species designation, include the upper incisors which protrude noticeably and the incisive foramina is sharply restricted posteriorly (Ludwig 1984, Maser and Storm 1970).

Present Distribution: Water voles can be found in two distinct populations, one population can be found in the Cascade mountains from central British Columbia south to southern Oregon. The other population ranges from southern Alberta along the Rocky Mountains to Utah (Pattie and Hoffmann 1990).

Ecology: As its name implies the water vole is associated with water and can be found near mountain lakes and swiftly flowing streams. It constructs conspicuous runways near the edges of stream banks (Streubel 1989). Like other voles it is active year round and eats a variety of grasses, stems, roots and flowers.

Water voles are adapted to water and can be seen swimming and diving underwater. Because of its dependence on water and riparian habitat the water vole is only found in the proximity to perennial streams, ponds or lakes (Pattie and Hoffmann 1990).

Microtus spp. Shrank 1798

Referred Materials:

Gardiner

GHOW: (98-147) 1 skull with RM1, RM2, RM3, LM1, LM2, LM3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1; NISP=11; (98-148) 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=4; (98-154) 1 palatine with RM1, RM2, LM1, LM2, 1 R mandible with Rm1, Rm2, Rm3, MNI=1, NISP=9; (98-155) 1 skull with RM1, RM2, RM3, LM1, LM2, 2 LM3, 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=2, NISP=16; (98-156) 3 skulls with 3 RM1, 2 RM2, RM3, 3 LM1, 3 LM2, 3 R mandibles with 2 Rm1, 2 Rm2, Rm3, 3 L mandibles with 3 Lm1, 2 Lm2, Lm3, MNI=3, NISP=31; (98-157) 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=7; (98-158) 1 separated maxilla with 2 RM1, RM2, 2 LM1, LM2, LM3, 1 R mandible with 2 Rm1, Rm2, 1 L mandible with 2 Lm1, Lm2, 2 Lm3, MNI=2, NISP=19; (98-159) 1 R mandible with Rm1, Rm2, MNI=1, NISP=3; (98-161) 1 skull with RM1, RM2, RM3, LM1, LM2, LM3, MNI=1, NISP=7; (98-161) 2 separated maxilla with 2 RM1, 2 RM2, 2 RM3, 2 LM1, 2 LM2, 2 LM3, 2 R mandibles with Rm1, 2 L mandibles, MNI=2, NISP=19; (98-164) 1 palatine with RM1, 2 RM2, LM1, LM2, LM3, 2 R mandibles with 2 Rm1, 2 Rm2, 2 Rm3, 1 L mandible with Lm1,

Lm2, MNI=2, NISP=18; (98-166) 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=4;
 (98-167) 1 palatine with RM1, 2 RM2, RM3, LM1, LM2, 2 R mandibles with 2 Rm1, 2
 Rm2, 2 Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=2, NISP=19; (98-169) 1 skull
 with RM1, RM2, LM1, LM2, 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with
 Lm1, Lm2, MNI=1, NISP=12; (98-170) 1 L mandible with Lm1, Lm2, Lm3, MNI=1,
 NISP=4; (98-171) 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm2,
 Lm3, MNI=1, NISP=8; (98-177) 4 skulls with 4 RM1, 4 RM2, 3 RM3, 4 LM1, 3 LM2, 3
 LM3, 2 R mandibles with 2 Rm1, 2 Rm2, Rm3, 2 L mandibles with 2 Lm1, 2 Lm2, 2
 Lm3, MNI=4, NISP=40; (98-180) 1 skull with RM1, LM1, LM2, LM3, MNI=1, NISP=5;
 (98-181) 1 skull, 2 palatines with 3 RM1, 3 RM2, 2 RM3, 3 LM1, 3 LM2, 3 LM3,
 MNI=3, NISP=20; (98-184) 2 skulls with 2 RM1, RM2, 2 LM1, 2 LM2, 2 LM3, 4 R
 mandibles with 4 Rm1, 4 Rm2, 3 Rm3, 6 L mandibles with 6 Lm1, 6 Lm2, 2 Lm3,
 MNI=6, NISP=47; (98-185) 1 palatine with RM1, RM2, RM3, LM1, LM2, 2 R
 mandibles with 2 Rm1, 2 Rm2, Rm3, 1 L mandible with Lm1, MNI=2, NISP=14; (98-
 187) 1 skull, 1 palatine, 1 L maxilla with 4 RM1, 4 RM2, 3 RM3, 4 LM1, 4 LM2, 5 LM3,
 3 R mandibles with 4 Rm1, 4 Rm2, 3 Rm3, 3 L mandibles 4 Lm1, 4 Lm2, 2 Lm3,
 MNI=5, NISP=54; (98-188) 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with
 Lm1, Lm2, MNI=1, NISP=7; (98-189) 1 palatine with RM1, RM2, RM3, LM1, LM3, 1
 R mandible with Rm1, 1 L mandible with Lm1, Lm2, MNI=1, NISP=11; (98-190) 3
 palatines with 2 RM1, 3 RM2, 2 RM3, 3 LM1, 2 LM2, 1 LM3, 3 R mandibles with 3
 Rm1, 3 Rm2, Rm3, 3 Lm3, 3 Lm2, 3 Lm3, MNI=3, NISP=38; (98-190) 1 skull with
 RM1, RM2, RM3, LM1, LM2, 1 R mandible with Rm1, Rm2, 1 L mandible with Lm1,

Lm3, MNI=1, NISP=12; (98-192) 2 palatines with 2 RM1, RM2, RM3, LM1, LM3, 1 R mandible with Rm1, Rm2, Rm3, 2 L mandibles with 2 Lm1, 2 Lm2, 2 Lm3, MNI=2, NISP=20; (98-193) 1 palatine with RM1, RM2, RM3, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm2, 2 Lm3, MNI=2, NISP=16; (98-199) 1 skull with RM1, RM2, 2 RM3, LM1, LM2, 2 LM3, 1 R mandible with Rm1, Rm2, 2 Rm3, MNI=2, NISP=14; (98-201) 1 palatine with RM1, RM2, RM3, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=15; (98-203) 1 skull with RM1, RM2, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, Rm3, MNI=1, NISP=10; (98-205) 1 RM2, MNI=1, NISP=1; (98-209) 1 skull with RM1, RM2, RM3, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, Lm2, Lm3, MNI=1, NISP=12; (98-210) 2 palatines with 2 RM1, 2 RM2, 2 RM3, 2 LM1, 2 LM2, LM3, 2 R mandibles with 2 Rm1, 2 Rm2, Rm3, 2 L mandibles with 2 Lm1, 2 Lm2, 2 Lm3, MNI=2, NISP=28; (98-213) 1 skull with RM1, RM2, 2 RM3, LM1, LM2, LM3, 3 R mandibles with 3 Rm1, 3 Rm2, 2 Rm3, 5 L mandibles with 5 Lm1, 5 Lm2, 3 Lm3, MNI=5, NISP=37;

1999

Gardiner

GHOW: (99-3) 1 skull with RM1, RM2, RM3, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=14; (99-17) 1 RM1, RM2, RM3, LM1, LM2, LM3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=10; (99-20) 1 skull with RM1, RM2, LM1, LM2, 1 R mandible with Rm1, Rm2, Rm3, Lm3, MNI=1, NISP=10; (99-21) 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1,

Lm2, Lm3, MNI=1, NISP=8; (99-30) 1 RM3, 1 L maxilla with LM1, 2 LM3, 3 L mandibles with 3 Lm1, 3 Lm2, 2 Lm3, MNI=3, NISP=16; (99-33) 1 skull with RM1, RM2, RM3, LM1, 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=11; (99-35) 1 palatine with LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, Rm3, MNI=1, NISP=8; (99-51) 1 skull with RM1, RM2, RM3, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=14; (99-60) 1 skull with RM1, RM2, RM3, LM1, LM2, LM3, 2 R mandibles with 2 Rm1, 2 Rm2, 2 Rm3, 2 L mandibles with 2 Lm1, 2 Lm2, 2 Lm3, MNI=2, NISP=23; (99-192) 1 skull with RM1, RM2, RM3, LM1, LM2, 3 R mandibles with 3 Rm1, 3 Rm2, 2 Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=3, NISP=21; (99-196) 4 skulls with 4 RM1, 3 RM2, 2 RM3, 4 LM1, 4 LM2, 4 LM3, 5 R mandibles with 5 Rm1, 5 Rm2, 4 Rm3, 3 L mandibles with 3 Lm1, 3 Lm2, Lm3, MNI=5, NISP=54; (99-198) 1 skull with RM1, RM2, RM3, LM1, LM2, LM3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=11; (99-205) 1 skull, 1 palatine with 2 RM1, 2 RM2, 2 RM3, 2 LM1, 2 LM2, 1 L mandible with Lm1, Lm2, Lm3, MNI=2, NISP=16; (99-210) 1 palatine with RM1, LM1, LM2, 3 R mandibles with 3 Rm1, 3 Rm2, Rm3, 2 L mandibles with 3 Lm1, 3 Lm2, Lm3, MNI=3, NISP=23; (99-214) 1 skull with RM1, RM2, RM3, LM1, LM2, LM3, 2 R mandibles with 2 Rm1, 2 Rm2, Rm3, 2 L mandibles with 2 Lm1, 2 Lm2, MNI=2, NISP=20; (99-218) 3 palatines with 2 RM1, 2 RM2, 2 RM3, 3 LM1, 3 LM2, 2 LM3, 3 R mandibles with 3 Rm1, 3 Rm2, 3 Rm3, 2 L mandibles with 2 Lm1, 2 Lm2, Lm3, MNI=3, NISP=35; (99-231) 1 RM2, RM3, 1 R mandible with Rm1, Rm2, Rm3, 3 L mandibles with 3 Lm1, 3 Lm2, 2 Lm3, MNI=3, NISP=17; (99-697) 1 skull, 1 palatine with 2 RM1,

2 RM2, RM3, 2 LM1, LM2, LM3, 1 R mandible with 2 Rm1, 2 Rm2, Rm3, 2 L mandibles with 2 Lm1, Lm2, 2 Lm3, MNI=2, NISP=24;

Coyote: (99-5S) 1 palatine with RM1, RM2, RM3, LM1, LM3, 1 R mandible with Rm1, 2 Rm2, 2 Rm3, 1 L mandible with 2 Lm1, Lm2, MNI=2, NISP=16; (99-6S) 1 RM2, LM1, Rm1, Rm2, Rm3, 1 L mandible with 2 Lm1, Lm2, MNI=2, NISP=9; (99-15S) 1 RM1, RM3, LM1, LM2, MNI=1, NISP=4; (99-25S) 1 palatine with RM1, RM2, LM1, LM2, 1 R mandible with 2 Rm1, Rm2, 2 L mandibles with 2 Lm1, 2 Lm2, 2 Lm3, MNI=2, NISP=17; (99-30S) 1 RM1, Rm1, Rm2, Lm1, MNI=1, NISP=5; (99-39S) 2 palatines with RM2, RM3, 2 LM1, 3 LM2, LM3, 1 R mandible with 3 Rm1, 2 Rm2, Rm3, 2 Lm1, MNI=3, NISP=19;

Little Rattlesnake

CORA: (99-457) 1 R mandible with Rm1, Rm2, MNI=1, NISP=3; (99-682) 1 R mandible with Rm1, Rm2, MNI=1, NISP=3; (99-684) 1 L mandible with Lm1, MNI=1, NISP=2;

Town

CORA: 1 LM1, LM3, MNI=1, NISP=2; (99-241) 1 palatine with RM1, 3 LM1, LM2, 2 LM3, 1 R mandible with Rm1, Rm2, MNI=3, NISP=11;

Junction Butte

GHOW: (98-423) 2 skulls with 3 RM1, 2 RM2, 2 LM1, 2 LM2, 2 LM3, 1 R mandible with Rm1, Rm2, Rm3, 2 L mandibles with 2 Lm1, 2 Lm2, Lm3, MNI=3, NISP=24; (98-424) 1 palatine with RM1, RM2, RM3, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm2, MNI=1, NISP=14; (98-426) 1 R

mandible with Rm1, Rm2, Rm3, 2 L mandibles with 2 Lm1, 2 Lm2, 2 Lm3, MNI=2, NISP=12;

1999

GHOW: (99-64) 4 skulls with 4 RM1, 3 RM2, 3 RM3, 4 LM1, 2 LM2, 3 LM3, 2 R mandibles with 4 Rm1, 2 Rm2, 3 Rm3, 4 L mandibles with 4 Lm1, 4 Lm2, 3 Lm3, MNI=4; NISP=49; (99-65) 1 skull, 1 palatine with RM1, RM2, 2 RM3, LM1, LM2, LM3, MNI=2, NISP=9; (99-69) 2 R mandibles with 2 Rm1, 2 Rm2, Rm3, MNI=2, NISP=7; (99-71) 1 palatine with RM1, RM2, RM3, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=15; (99-74) 1 LM1, 3 R mandibles with 3 Rm1, 3 Rm2, 3 Rm3, MNI=3, NISP=13; (99-80) 1 skull with RM1, RM2, RM3, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=15;

RTHA: (98-244) 1 palatine with LM1, LM2, Rm1, MNI=1, NISP=4; (98-385) 1 Rm1, MNI=1, NISP=1, (98-386) 1 palatine with RM1, RM2, RM3, LM1, LM2, 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=14; (98-428) 2 skulls 2 RM1, 2 RM2, 2 RM3, 2 LM1, 2 LM2, 2 LM3, 2 R mandibles with 2 Rm1, 2 Rm2, 2 Rm3, 1 L mandible with 2 Lm1, Lm2, Lm3, MNI=2, NISP=27; (98-429) 2 skulls with 2 RM1, 2 RM2, 2 RM3, 2 LM1, 2 LM2, 2 LM3, 2 R mandibles with 2 Rm1, 2 Rm2, 2 Rm3, 2 L mandibles with 2 Lm1, 2 Lm2, 2 Lm3, MNI=2, NISP=30; (98-434) 2 skulls with 2 RM1, 2 RM2, 2 RM3, 2 LM1, 2 LM2, 2 LM3, 1 R mandible with Rm1, Rm2, Rm3, 2 L mandibles with 2 Lm1, 2 Lm2, 2 Lm3, MNI=2, NISP=26; (98-435) 1 skull with RM1, RM2, RM3, LM1, LM2, LM3, 1 L mandible with Lm1, Lm2,

Lm3, MNI=1, NISP=11; (98-436) 2 R mandibles with 2 Rm1, 3 Rm2, Rm3, 5 L mandibles with 5 Lm1, 5 Lm2, 4 Lm3, MNI=5, NISP=27; (98-437) 1 palatine with LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, Rm3, 2 L mandibles with 2 Lm1, 2 Lm2, 2 Lm3, MNI=2, NISP=16; (98-438) 2 skulls with 2 RM1, 2 RM2, 2 RM3, 2 LM1, 2 LM2, 2 LM3, 1 R mandible, 1 L mandible with 2 Lm1, 2 Lm2, 2 Lm3, MNI=2, NISP=22; (98-446) 1 skull with RM1, RM2, LM1, LM2; 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=9; (98-450) 1 RM1, RM2, LM1, LM2, 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=12;

1999

RTHA: (99-464) 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=4; (99-466) 1 L maxilla with LM1, LM2, 1 R mandible with Rm1, Rm2, Lm3, MNI=1, NISP=7;

Coyote: (99-38S) 1 Rm2, Lm1, Lm2, MNI=1, NISP=3; (99-42S) 1 Rm1, MNI=1, NISP=1;

1999

Tower

RTHA: (99-469) 1 separated maxilla with 2 RM1, RM2, RM3, LM1, LM2, Rm3, 3 L mandibles with 3 Lm1, Lm2, Lm3, MNI=3, NISP=16; (99-470) 1 separated maxilla, 1 L maxilla with 3 RM1, RM2, 2 LM1, LM2, LM3, Rm1, 2 L mandibles with 2 Lm1, 2 Lm2, Lm3, MNI=3, NISP=18; (99-471) 1 palatine with RM1, RM2, LM1, LM2, 1 L mandible with Lm1, Lm2, MNI=1, NISP=8; (99-473) 1 palatine with RM1, RM2, RM3, LM1, 1 R mandible with 2 Rm1, 2 Rm2, MNI=2, NISP=10; (99-669) 1 palatine with LM1, LM2, LM3, MNI=1, NISP=4;

South-side Lamar River

Coyote: (98-5S) 2 RM1, RM2, RM3, LM1, 2 Rm1, Rm2, Rm3, 1 L mandible with 2 Lm1, Lm2, Lm3, MNI=2, NISP=14; (98-8S) 1 palatine with 2 RM1, 2 RM2, 2 RM3, 1 LM1, 1 R mandible with Rm1, Rm2, Rm3, Lm1, Lm2, Lm3, MNI=2, NISP=15;

Lamar Bridge

CORA: (98-101) 1 RM1, RM3, LM3, MNI=1, NISP=3; (98-366) 1 L mandible with Lm1, MNI=1, NISP=2;

1999

Lamar Bridge

CORA: (99-129) 1 palatine with RM1, RM2, RM3, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, Rm3, 2 L mandibles with 2 Lm1, 2 Lm2, 2 Lm3, MNI=2, NISP=19; (99-132) 1 skull with RM1, RM2, LM1, 1 R mandible with Rm1, Rm2, 1 L mandible with Lm1, Lm2, MNI=1, NISP=10; (99-133) 2 palatines with 2 RM1, 2 RM2, RM3, 2 LM1, 2 LM2, LM3, 2 R mandibles with 2 Rm1, 2 Rm2, 2 Rm3, 2 L mandibles with 2 Lm1, 2 Lm2, 2 Lm3, MNI=2, NISP=26; (99-137) 1 RM1, RM3, Lm1, LM2, LM3, 1 R mandible with Rm1, Rm2, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=12; (99-139) 1 separated maxilla with RM1, RM3, LM2, LM3, 1 R mandible with Rm1, Rm2, 1 L mandible with Lm1, Lm2, MNI=1, NISP=11; (99-335) 1 skull with RM1, RM2, RM3, LM1, LM2, LM3, 1 R mandible with Rm1, Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=14; (99-337) 1 RM1, RM2, LM2, LM3, 1 R mandible with Rm1, MNI=1, NISP=6; (99-340) 1 RM3, 1 L mandible with Lm2, Lm3, MNI=1, NISP=4;

Lamar Cave

RTHA: (98-371) 1 RM1, RM2, 1 L maxilla with LM1, LM2, Rm1, Rm2, 1 L mandible with Lm1, MNI=1, NISP=9;

1999

Coyote: (98-1S) 1 RM1, MNI=1, NISP=1; (98-2S) 2 R mandibles with 2 Rm1, 2 Rm2, Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=2, NISP=11; (98-7S) 3 RM1, 2 RM2, 2 RM3, Rm1, Rm2, 1 L mandible with Lm1, Lm2, MNI=3, NISP=12; (98-9S) 1 RM1, 2 RM3, LM1, 2 LM3, 2 Rm1, 3 Rm2, Rm3, 2 L mandibles with 3 Lm1, 3 Lm2, Lm3, MNI=3, NISP=21;

Lamar Cave

Coyote: (99-17S) 1 separated maxilla with 2 RM1, 2 RM2, 3 RM3, 3 LM1, 3 LM2, 3 LM3, 5 R mandibles with 6 Rm1, 6 Rm2, 5 Rm3, 3 L mandibles with 4 Lm1, 4 Lm2, 3 Lm3, MNI=6, NISP=53; (99-18S) 2 RM1, RM2, 2 RM3, 2 LM1, LM2, 2 LM3, 2 R mandibles with 4 Rm1, 2 Rm2, 2 Rm3, 1 L mandible with 2 Lm1, Lm2, MNI=4, NISP=24; (99-29S) 1 RM1, Rm3, MNI=1, NISP=2;

Lower Owl Alley

GHOW: (98-277) 1 skull with RM1, RM2, RM3, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=15; (98-280) 1 RM1, RM2, 1 L maxilla, Rm2, Lm3, MNI=1, NISP=5; (98-283) 1 skull with RM1, RM2, LM1, LM2, 1 R mandible with Rm1, Rm2, 2 L mandibles with 2 Lm1, 2 Lm2, Lm3, MNI=2, NISP=15; (98-286) 2 R mandibles with 2 Rm1, Rm2, Rm3, MNI=2, NISP=6; (98-290) 1 Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=5;

1999

Lower Owl Alley

GHOW: (99-489) 5 skulls with 5 RM1, 5 RM2, 4 RM3, 5 LM1, 5 LM2, 4 LM3, 5 R mandibles with 6 Rm1, 6 Rm2, 3 Rm3, 4 L mandibles with 4 Lm1, 4 Lm2, 5 Lm3, MNI=6, NISP=70; (99-494) 1 LM1, MNI=1, NISP=1; (99-502) 2 skulls with 2 RM1, RM2, RM3, 2 LM1, 2 LM2, 2 LM3, Lm1, MNI=1, NISP=13; (99-504) 2 skulls with 2 RM1, 2 RM2, RM3, 2 LM1, 2 LM2, LM3, 3 R mandibles with 3 Rm1, 3 Rm2, 3 Rm3, MNI=3, NISP=24; (99-512) 1 LM1, MNI=1, NISP=1; (99-522) 1 skull with RM1, RM2, RM3, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, Rm3, MNI=1, NISP=11; (99-640) 1 skull, 1 L maxilla with 3 RM1, 2 RM2, 2 RM3, 2 LM1, 2 LM2, 2 LM3, 3 R mandibles with 3 Rm1, 3 Rm2, 3 Rm3, 3 L mandibles with 3 Lm1, 3 Lm2, 3 Lm3, MNI=3, NISP=39; (99-642) 1 skull with RM1, LM1, LM3, 1 R mandible with Rm1, Rm2, 2 Rm3, 2 L mandibles with 2 Lm1, 2 Lm2, 2 Lm3, MNI=2, NISP=17; (99-649) 1 RM3, 1 L mandible with Lm1, Lm2, MNI=1, NISP=4; (99-654) 1 RM1, RM3, MNI=1, NISP=2;

Coyote: (99-19S) 1 RM1, LM1, Rm1, Rm3, MNI=1, NISP=4; (99-20S) 2 palatines with 3 RM1, 5 RM2, 5 RM3, 3 LM1, 4 LM2, 3 LM3, 5 R mandibles with 3 Rm1, 6 Rm2, 5 Rm3, 3 L mandibles with 6 Lm1, 3 Lm2, 3 Lm3, MNI=6, NISP=59; (99-27S) 1 palatine with RM1, 2 RM2, RM3, LM1, LM2, LM3, Lm2, MNI=2, NISP=9; (99-28S) 2 palatines with 4 RM1, 4 RM2, 3 RM3, 4 LM1, 4 LM2, 2 LM3, 1 R mandible with 4 Rm1, 3 Rm2, 2 L mandibles with 6 Lm1, Lm2, Lm3, MNI=6, NISP=41;

South-side Slough Ck.

Coyote: (99-22S) 1 LM3, Rm1, 1 L mandible with 3 Lm1, 2 Lm2, Lm3, MNI=3, NISP=9; (99-26S) 1 RM1, RM3, 1 R mandible with Rm1, Rm2, Rm3, Lm2, MNI=1, NISP=7;

Slough

RTHA: (98-144) 1 Rm3, Lm1, MNI=1, NISP=2; (98-302) 1 Lm2, Lm3, MNI=1, NISP=2; (98-303) 1 skull with RM1, RM2, RM3, LM1, LM2, 2 R mandibles with 2 Rm1, 2 Rm2, Rm3, 2 L mandibles with 2 Lm1, 2 Lm2, 2 Lm3, MNI=2, NISP=21; (98-306) 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=8; (98-307) 1 skull with RM1, RM2, RM3, LM1, LM2, LM3, MNI=1, NISP=7; (98-390) 1 skull, 3 palatines with 4 RM1, 4 RM2, 3 RM3, 4 LM1, 4 LM2, 3 LM3, 4 R mandibles with 4 Rm1, 2 Rm1, 4 Rm3, 4 L mandibles with 4 Lm1, 4 Lm2, Lm3, MNI=4, NISP=56; (98-391) 5 skulls with 5 RM1, 4 RM2, 4 RM3, 5 LM1, 5 LM2, 4 LM3, 5 R mandibles with 5 Rm1, 5 Rm2, 5 Rm3, 6 L mandibles with 6 Lm1, 6 Lm2, 6 Lm3, MNI=6, NISP=77; (98-394) 1 skull with RM1, LM1, LM2, LM3, MNI=1, NISP=5; (98-395) 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=4,

E. Slough

RTHA: (98-352) 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=4; (98-353) 1 LM1, Lm3, MNI=1, NISP=2;

1999

E. Slough

RTHA: (99-475) 1 L mandible with Lm1, Lm2, MNI=1, NISP=3; (99-477) 1 skull with RM1, RM2, LM1, LM2, MNI=1, NISP=5; (99-666) 1 skull with RM1, RM2,

RM3, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=15; (99-667) 1 palatine with RM1, RM2, RM3, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm3, MNI=1, NISP=14;

Lamar

CORA: (99-177) 1 palatine with RM1, RM2, LM1, LM2, LM3, 2 R mandibles with 2 Rm1, 2 Rm2, Rm3, MNI=2, NISP=13; (99-178) 1 skull with RM1, RM2, RM3, LM1, LM2, LM3, 2 R mandibles with 2 Rm1, 2 Rm2, 2 Rm3, MNI=2, NISP=16; (99-179) 1 palatine with RM1, RM3, 1 R mandible with Rm1, Rm2, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=10; (99-181) 1 skull with RM1, RM2, RM3, LM1, LM2, 3 LM3, 1 R mandible with Rm1, Rm2, Rm3, MNI=3, NISP=13; (99-271) 1 RM2, 1 R mandible with Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=7;

Institute

RTHA: (99-664) 3 skulls with 3 RM1, 2 RM2, 2 RM3, 3 LM1, 2 LM2, LM3, 2 R mandibles with 2 Rm1, 2 Rm2, MNI=3, NISP=22;

Old Faithful

GHOW: (98-31) 1 R mandible with Rm1, Rm2, Rm3, MNI=1, NISP=4; (98-33) 3 partial skulls with 3 RM1, 3 RM2, 2 RM3, 3 LM1, 3 LM2, 2 LM3, 1 L mandible with 2 Lm1, Lm2, MNI=3, NISP=23; (98-34) 1 R mandible with Rm1, Rm2, Rm3, MNI=1, NISP=4; (98-35) 1 R mandible with Rm1, Rm2, Rm3, MNI=1, NISP=4; (98-36) 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=4; (98-37) RM1, RM2, LM1, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=7; (98-40) 1 skull with RM1, RM2,

RM3, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, Rm3, Lm3, MNI=1, NISP=12;
 (98-43) RM1, RM3, LM1, Rm3, 2 L mandibles with 2 Lm1, 2 Lm2, MNI=2, NISP=10;
 (98-44) 1 skull with RM1, RM2, RM3, 2 LM1, LM2, LM3, 2 L mandibles with 2 Lm1, 2 Lm2, 2 Lm3, MNI=2, NISP=16; (98-45) 1 skull with RM1, RM2, RM3, LM1, LM2, LM3, MNI=1, NISP=7; (98-48) 1 skull with RM1, RM2, LM1, 2 R mandibles with 2 Rm1, 2 Rm2, Rm3, MNI=2, NISP=11; (98-49) 1 R maxilla with RM1, RM2, RM3, MNI=1, NISP=4; (98-54) 1 skull with RM1, RM2, RM3, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=15; (98-58) 1 L mandible with Lm1, MNI=1, NISP=2; (98-59) 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=4; (98-70) 1 skull with RM1, RM2, RM3, LM1, LM2, 2 LM3; MNI=1, NISP=8; (98-74) LM3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=5; (98-89) 1 LM1, 1 R mandible with Rm1, MNI=1, NISP=3; (98-104) 1 Lm3, MNI=1, NISP=1; (98-106) 2 R mandibles with 2 Rm1, 2 Rm2, Rm3, MNI=2, NISP=7;

1999

Old Faithful

GHOW: (99-97) 1 L mandible with Lm2, Lm3, MNI=1, NISP=3; (99-102) 1 skull with RM1, RM2, RM3, 2 LM1, 2 LM2, LM3, 2 R mandibles with 2 Rm1, 2 Rm2, 2 L mandibles with 2 Lm1, 2 Lm2, 2 Lm3, MNI=2, NISP=24; (99-110) 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm2, MNI=1, NISP=7; (99-116) 1 skull with RM1, RM2, RM3, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=15; (99-119) 1 RM3, Rm3, MNI=1, NISP=2; (99-122) 1 skull with RM1, RM2, RM3, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2,

Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=15; (99-259) 1 Rm3, 1 L mandible with Lm1, Lm2, MNI=1, NISP=4; (99-261) 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=4; (99-306) 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=8; (99-431) 1 RM3, 1 L maxilla with LM1, LM2, 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=12; (99-445) 1 LM1, LM3, MNI=1, NISP=2; (99-451) 2 palatines with 2 RM1, 2 RM2, RM3, LM1, LM2, 3 R mandibles with 3 Rm1, 3 Rm2, Rm3, 3 L mandibles with 3 Lm1, 3 Lm2, 2 Lm3, MNI=3, NISP=29; (99-551) 1 LM1, 2 L mandibles with 2 Lm1, 2 Lm2, Lm3, MNI=2, NISP=8; (99-552) 2 palatines with 2 RM1, 2 RM2, RM3, 2 LM1, 2 LM2, LM3, 2 R mandibles with 2 Rm1, 2 Rm2, Rm3, 2 L mandibles with 2 Lm1, 2 Lm2, Lm3, MNI=2, NISP=26;

CORA: (99-249) 1 palatine with RM1, RM2, RM3, LM1, LM2, LM3, MNI=1, NISP=7; (99-296) 1 LM1, 1 R mandible with Rm1, Rm2, Lm1, Lm2, MNI=1, NISP=6;

Coyote: (99-33S) 1 RM3, MNI=1, NISP=1; (99-34S) 1 R maxilla with 2 RM1, 2 RM2, 2 RM3, LM1, 2 LM2, LM3, 2 R mandibles with 3 Rm1, 3 Rm2, 2 Rm3, MNI=3, NISP=22; (99-36S) 1 RM3, LM1, LM2, MNI=1, NISP=3;

Porcupine

RTHA: (99-531) 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=4; (99-532) 1 LM1, Rm1, MNI=1, NISP=2; (99-533) 1 LM1, LM2, MNI=1, NISP=2; (99-534) 1 Rm1, MNI=1, NISP=1; (99-561) 1 LM1, LM3, Rm2, MNI=1, NISP=3;

Alum Ck.

SEOW: (98-293) 1 skull with RM1, RM2, RM3, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, Rm3, MNI=1, NISP=11; (98-294) 1 skull with RM1, RM2, RM3, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=15; (98-296) 1 palatine, 1 separated maxilla with 3 RM1, 3 RM2, 2 LM1, 2 LM2, 2 LM3, 1 R mandible with Rm1, Rm2, Rm3, 2 L mandibles with 3 Lm1, Lm2, 2 Lm3, MNI=3, NISP=26; (98-297) 1 skull with RM1, RM2, RM3, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=15; (98-298) 1 skull, 1 L maxilla with 3 RM1, RM2, RM3, 2 LM1, 2 LM2, LM3, 2 R mandibles with 2 Rm1, 2 Rm2, Rm3, 3 L mandibles with 3 Lm1, 2 Lm2, 3 Lm3, MNI=3, NISP=30; (98-313) 1 skull with RM1, RM2, RM3, LM1, LM2, LM3, MNI=1, NISP=7; (98-314) 2 separated maxilla with 2 RM1, 2 RM2, RM3, 2 LM1, 2 LM2, LM3, 1 R mandible with 2 Rm1, Rm2, 2 L mandibles with 2 Lm1, 2 Lm2, 2 Lm3, MNI=2, NISP=26; (98-316) 1 palatine with RM1, RM2, RM3, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=15; (98-317) 2 palatines with 2 RM1, 2 RM2, RM3, LM1, 2 LM2, 2 LM3, 1 R mandible with Rm1, Rm2, 2 Rm3, 2 Lm1, 2 Lm3, MNI=2, NISP=21; (98-319) 1 RM1, RM2, LM1, LM3, 3 R mandibles with 3 Rm1, 3 Rm2, 3 Rm3, 4 L mandibles 4 Lm1, 4 Lm2, 3 Lm3, MNI=4, NISP=31; (98-503) 1 LM1, MNI=1, NISP=1; (98-504) 1 R maxilla with 2 RM1, 2 RM2, LM1, LM2, LM3, 2 R mandibles with 2 Rm1, 2 Rm2, 2 Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=2, NISP=20; (98-506) 1 skull with RM1, RM2, RM3, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=15; (98-507) 1 skull with RM1, RM2, RM3, LM1, LM2, LM3, 1 R mandible with

Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=15;

1999

Alum Ck.

SEOW: (99-342) 1 skull with RM1, RM2, RM3, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=15; (99-343) 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=8;

SWHA: (99-156) 1 RM1, 2 RM3, 2 L maxilla with 2 LM1, 2 LM2, LM3, Rm1, Rm2, 2 Lm1, Lm2, Lm3, MNI=2, NISP=16; (99-157) 1 R maxilla with RM1, RM2, RM3, 1 R mandible with Rm1, Rm2, MNI=1, NISP=7; (99-158) 1 skull with 2 RM1, RM2, RM3, 2 LM1, 2 LM2, 2 LM3, 2 Rm1, 1 L mandible with 2 Lm1, Lm2, Lm3, MNI=2, NISP=18; (99-159) 1 RM1, Rm1, MNI=1, NISP=2; (99-160) 1 skull with RM1, RM2, RM3, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=14; (99-161) 1 separated maxilla with RM1, RM3, LM1, LM2, LM3, 1 R mandible with Rm1, 1 L mandible with Lm1, Lm2, MNI=1, NISP=11; (99-163) 1 separated maxilla with RM1, RM2, RM3, LM1, LM2, LM3, 1 R mandible with RM1, 1 L mandible with Lm1, Lm2, MNI=1, NISP=12; (99-164) 1 Lm2, MNI=1, NISP=1; (99-165) 1 RM2, RM3, LM3, 1 R mandible with Rm1, Rm2, 2 Rm3, MNI=2, NISP=8; (99-166) 1 RM1, RM2, RM3, LM1, LM2, LM3, Lm1, MNI=1, NISP=7; (99-167) 1 separated maxilla with RM1, RM3, LM1, LM2, 2 R mandibles with 2 Rm1, 2 Rm2, Rm3, 1 L mandible with Lm1, Lm2, MNI=1, NISP=14; (99-346) 1 skull with RM1, 2 RM2, 2 RM3, LM1, 2 LM2, 2 LM3, 1 R mandible with Rm1, Rm2, Rm3, 1 L

mandible with Lm1, Lm3, MNI=2, NISP=18; (99-347) 1 skull, 1 palatine with RM1, 2 RM2, RM3, 2 LM1, 2 LM2, 2 LM3, 1 R mandible with 2 Rm1, 1 L mandible with Lm1, Lm2, MNI=2, NISP=18; (99-348) 1 R maxilla with 2 RM1, RM2, RM3, 2 LM1, LM2, 2 R mandibles with 3 Rm1, Rm2, 2 Rm3, 1 L mandible with 2 Lm1, Lm2, Lm3, MNI=3, NISP=21; (99-349) 1 R maxilla with 2 RM1, RM2, 2 RM3, 2 LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=2, NISP=18; (99-350) 1 palatine, 1 L maxilla with 4 RM1, 2 RM2, 2 RM3, 5 LM1, 2 LM2, 3 LM3, 1 R mandible with 2 Rm1, 2 Rm2, 1 L mandible with 3 Lm1, 2 Lm2, Lm3, MNI=5, NISP=32; (99-351) 1 palatine, 1 R maxilla with 3 RM1, 2 RM2, RM3, LM1, LM2, 2 LM3, 1 R mandible with 2 Rm1, 2 Rm2, Rm3, Lm1, Lm2, MNI=3, NISP=20; (99-352) 1 skull, 1 L maxilla with RM1, RM2, RM3, 3 LM1, LM2, LM3, 1 L mandible with 2 Lm1, Lm2, MNI=3, NISP=14; (99-356) 1 RM2, Rm1, MNI=1, NISP=2; (99-357) 1 RM1, RM2, RM3, 1 L maxilla with LM1, LM2, LM3, 1 R mandible with 2 Rm1, 2 Rm2, Rm3, 1 L mandible with 2 Lm1, Lm2, MNI=2, NISP=17; (99-358) 1 LM2, LM3, 1 R mandible with Rm1, Rm2, MNI=1, NISP=5; (99-361) 1 RM2, LM3, 1 R mandible with 2 Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=2, NISP=11; (99-362) 1 palatine with RM1, RM2, RM3, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=15; (99-363) 1 RM1, RM2, RM3, 1 L maxilla with LM1, LM2, 2 LM3, 1 R mandible with Rm1, Rm2, Lm1, MNI=2, NISP=12; (99-364) 1 separated maxilla with RM1, RM2, 2 LM1, 3 R mandibles with 3 Rm1, 2 Rm2, Rm3, 1 L mandible with 2 Lm1, 2 Lm2, Lm3, MNI=3, NISP=21; (99-365) 1 skull, 1 L maxilla with RM1, RM2, RM3, 3 LM1, 2 LM2, 2 LM3, 1 R mandible with 3 Rm1, 2

Rm2, Rm3, 2 L mandibles with 3 Lm1, 2 Lm2, 2 Lm3, MNI=3, NISP=28; (99-366) 1 Lm2, MNI=1, NISP=1; (99-369) 1 Rm1, MNI=1, NISP=1; (99-370) 1 RM1, RM2, RM3, Lm1, MNI=1, NISP=4; (99-589) 1 R maxilla with RM1, RM2, RM3, 2 LM1, 2 R mandibles with 2 Rm1, Rm2, 2 L mandibles with 2 Lm1, 2 Lm2, 2 Lm3, MNI=2, NISP=19; (99-591) 1 skull with 3 RM1, RM2, RM3, 2 LM1, 2 LM2, 3 LM3, 4 Rm1, 2 Rm2, Rm3, 1 L mandible with 4 Lm1, Lm2, MNI=4, NISP=26; (99-592) 1 R maxilla with 2 RM1, RM2, RM3, 1 R mandible with Rm1, Rm2, MNI=1, NISP=8; (99-593) 1 L maxilla with LM1, 1 R mandible with Rm1, Rm2, Rm3, MNI=1, NISP=6; (99-597) 1 skull, 1 L maxilla with 3 RM1, 3 RM2, 3 RM3, 2 LM1, 2 LM2, 2 LM3, 3 R mandibles with 3 Rm1, 3 Rm2, 3 Rm3, 2 L mandibles with 2 Lm1, 2 Lm2, 2 Lm3, MNI=3, NISP=37;

Coyote: (99-3S) 1 skull, 1 separated maxilla with 2 RM1, 2 RM2, 3 RM3, 4 LM1, 2 LM2, LM3, 4 R mandibles with 5 Rm1, 4 Rm2, 3 Rm3, 2 L mandibles with 5 Lm1, Lm2, Lm3, MNI=5, NISP=41; (99-4S) 1 skull, 1 R maxilla with 4 RM1, 4 RM2, 2 RM3, 4 LM1, 4 LM2, 3 LM3, 4 R mandibles with 8 Rm1, 4 Rm2, Rm3, 4 L mandibles with 7 Lm1, 4 Lm2, Lm3, MNI=8, NISP=56; (99-8S) 1 LM1, LM2, Rm3, MNI=1, NISP=3; (99-9S) 1 palatine with 2 RM1, 3 RM2, 2 RM3, 3 LM1, LM2, LM3, 2 R mandibles with 3 Rm1, 5 Rm2, 2 Rm3, 2 L mandibles with 3 Lm1, 3 Lm2, 2 Lm3, MNI=5, NISP=35; (99-10S) 6 RM1, 3 RM2, 5 RM3, 3 LM1, LM2, 4 LM3, 5 R mandibles with 8 Rm1, 6 Rm2, 5 Rm3, 1 L mandible with 2 Lm1, 3 Lm2, 5 Lm3, MNI=8, NISP=58; (99-11S) 2 RM1, 2 RM2, RM3, LM1, 2 LM2, 2 LM3, 1 R mandible with 3 Rm1, 2 Rm2, Rm3, 4 Lm1, Lm2, Lm3, MNI=4, NISP=23; (99-14S) 1 palatine with 2 RM1, 2 RM2, 2 RM3, 4

LM1, 4 LM2, 2 LM3, 2 R mandibles with 2 Rm1, 2 Rm2, 4 Rm3, 2 L mandibles with 4 Lm1, 2 Lm2, 2 Lm3, MNI=4, NISP=38; (99-23S) 4 palatines with 4 RM1, 4 RM2, 3 RM3, 5 LM1, 4 LM2, 3 LM3, 4 R mandibles with 4 Rm1, 4 Rm2, 3 Rm3, 4 L mandibles with 4 Lm1, 3 Lm2, Lm3, MNI=5, NISP=54;

Trout Ck.

LEOW: (99-168) 1 skull with RM1, RM2, RM3, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, Rm3, MNI=1, NISP=11; (99-169) 1 skull, 1 separated maxilla with 2 RM1, 2 RM2, RM3, 2 LM1, 2 LM2, 2 LM3, 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=2, NISP=21; (99-170) 1 L mandible with Lm1, Lm2, MNI=1, NISP=3; (99-171) 1 separated maxilla with RM1, RM2, LM1, 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=12; (99-172) 1 skull with RM1, RM2, RM3, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=15; (99-173) 1 skull with RM1, RM2, RM3, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=15; (99-174) 1 palatine with RM2, RM3, LM1, LM2, 2 LM3, 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=2, NISP=15; (99-175) 1 skull, 1 palatine with Rm1, 2 RM2, 2 LM1, 2 LM2, LM3, 2 L mandibles with 2 Lm1, 2 Lm2, Lm3, MNI=2, NISP=17; (99-176) 1 skull with RM1, RM2, RM3, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=15; (99-372) 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=4; (99-374) 1 skull with RM1, RM2, RM3, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, Rm3, 2 L mandibles with 2 Lm1, 2 Lm2, 2 Lm3, MNI=2,

NISP=19; (99-376) 1 skull with RM1, RM2, RM3, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=15; (99-381) 1 skull with RM1, RM2, RM3, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=15; (99-383) 1 skull with RM1, RM2, RM3, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=15; (99-386) 1 R mandible with Rm1, Rm2, Rm3, MNI=1, NISP=4; (99-387) 1 palatine with RM1, RM2, RM3, LM1, LM2, LM3, 1 R mandible with Rm1, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=13; (99-399) 1 RM1, RM2, RM3, LM1, LM2, 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm2, MNI=1, NISP=12; (99-401) 1 skull with RM1, RM2, RM3, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=15; (99-407) 1 palatine with RM1, RM2, RM3, LM1, LM2, 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=14; (99-409) 1 skull with RM1, RM2, RM3, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=15; (99-602) 1 palatine, 1 separated maxilla with 2 RM1, 2 RM2, 2 RM3, 2 LM1, 2 LM2, 2 R mandible with 2 Rm1, 2 Rm2, 2 L mandibles with 2 Lm1, 2 Lm2, 2 Lm3, MNI=2, NISP=26; (99-610) 1 skull with RM1, RM2, RM3, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=14; (99-613) 2 skulls with 2 RM1, 2 RM2, 2 RM3, 2 LM1, 2 LM2, 2 LM3, 2 R mandibles with 2 Rm1, 2 Rm2, 2 Rm3, 2 L mandibles with 2 Lm1, 2 Lm2, 2 Lm3, MNI=2, NISP=30; (99-616) 1 skull with RM1, RM2, RM3, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=15;

(99-621) 1 skull with RM1, RM2, RM3, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, Rm3, MNI=1, NISP=11;

Lake

CORA: (99-422) 1 palatine, 1 L maxilla with RM1, RM2, 2 LM1, 1 L mandible with Lm1, Lm2, MNI=2, NISP=9; (99-423) 1 R mandible with Rm1, Mni=1, NISP=2; (99-424) 1 Lm2, MNI=1, NISP=1; (99-427) 1 RM1, LM1, Lm1, MNI=1, NISP=3; (99-569) 1 Rm1, MNI=1, NISP=1; (99-570) 1 LM1, Lm2, MNI=1, NISP=2; (99-575) 1 RM2, 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=9; (99-583) 1 palatine with RM1, RM2, RM3, LM2, 1 R mandible with Rm1, Rm2, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=10; (99-586) 1 RM2, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm2, MNI=1, NISP=11; (99-587) 2 skulls with 2 RM1, 2 RM2, 2 RM3, 2 LM1, 2 LM2, 2 LM3, 1 L mandible with Lm1, Lm2, Lm3, MNI=2, NISP=18;

Identification: Vole teeth are rootless, with the outer and inner re-entrant angles being approximately equivalent. M2 has at least four closed triangles and M3 has three closed triangles. In mandibular teeth, m1 has five closed triangles, m3 has three transverse loops with no triangles (Chomko 1980).

Ondatra zibethicus (Linnaeus, 1766) (muskrat)

Comparative Materials: Denver Museum of Natural History # 8489, Montana State University Vertebrate Collection # 6549, # 6550.

Referred Materials:

1999

Junction Butte

GHOW: (99-65) 1 skull with RM1, RM2, RM3, LM1, LM2, LM3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=11;

Tower

RTHA: (99-468) 1 skull with RM1, RM2, RM3, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=15;

Old Faithful

GHOW: (98-103) 1 Lm1, MNI=1, NISP=1; (98-109) 1 R maxilla with RM1, LM1, Rm1, Rm2, partial L mandible, MNI=1, NISP=6;

Identification: The cheek teeth are rooted in adults. The first mandibular molar (m1) has six triangles between the terminal loops, m3 has three outer salient angles (Chomko 1980). Muskrat teeth are similar to vole teeth having long angular prismatic elements. They were the largest teeth identified in this study.

Present Distribution: Muskrats have a wide distribution including most of the United States and Canada. They are excluded from portions of southern Texas and southern Florida (Pattie and Hoffmann 1990).

Ecology: Muskrats inhabit aquatic areas including streams, seeps, lakes, marshes and ponds. They are semi-aquatic like beaver but they do not build dams. They build houses of mud and vegetation that are conical in shape or they burrow into stream banks (Clark and Stromberg 1987).

Muskrats are primarily herbivores eating a variety of aquatic vegetation and

emergent vegetation such as cattails, water lilies and sedges. They will also eat crayfish, molluscs and fish (Clark and Stromberg 1987, Streubel 1989).

Phenacomys intermedius Merriam, 1889 (heather vole)

Comparative Materials: Denver Museum of Natural History # 5992, # 7235, # 7236, Montana State University Vertebrate Collection # 5219, # 5220.

Referred Materials:

Gardiner

GHOW: (98-188) 1 L mandible with Lm3, MNI=1, NISP=3;

Old Faithful

GHOW: (98-42) 1 skull with RM1, RM2, RM3, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm3, MNI=1, NISP=14; (98-88) 1 skull with RM1, RM2, RM3, LM1, LM2, 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=14;

1999

Old Faithful

GHOW: (99-256) 1 skull, 1 R maxilla with 2 RM1, 2 RM2, 2 RM3, LM1, LM2, 2 LM3, 2 R mandibles with 2 Rm1, 2 Rm2, 2 Rm3, 2 L mandibles with Lm1, 2 Lm2, Lm3, MNI=2, NISP=26;

Identification: Similar to other Microtinae, *Phenacomys* have long, angular teeth that consist of prismatic elements (Hillson 1986). The cheek teeth are rooted in adults and lack cementum in the re-entrant angles. In the mandibular molars, the inner re-entrant angle is deeper than the outer re-entrant angle (Chomko 1980). In the Yellowstone

samples, *Phenacomys* teeth are similar in size to *Microtus* species but larger than *Clethrionomys*.

Present Distribution: The heather vole ranges across Canada from the Yukon eastward to Labrador and south along the extent of the Cascade Mountains and Rocky Mountains to northern New Mexico (Pattie and Hoffmann 1990).

Ecology: Heather voles are associated with coniferous forests but can also be found in sagebrush and alpine tundra (Clark and Stromberg 1987, Pattie and Hoffmann 1990).

They are active year round and feed on grasses, herbaceous vegetation, berries, lichens and willow (Pattie and Hoffmann 1990).

Neotoma cinerea (Ord, 1815) (bushy-tailed woodrat)

Comparative Materials: Denver Museum of Natural History # 7530, #7531, Montana State University Vertebrate Collection # 6541, # 6424.

Referred Materials:

Gardiner

GHOW: (98-161) 1 L maxilla with LM1, LM2, LM3, MNI=1, NISP=4; (98-171) 1 R mandible with Rm1, Rm2, MNI=1, NISP=3; (98-196) 1 R maxilla with RM1, RM2, RM3, 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=12; (98-207) 1 L mandible with Lm2, MNI=1, NISP=2;

1999

Gardiner

GHOW: (99-33) 1 separated maxilla with RM1, RM2, RM3, LM1, LM2, LM3, 1 R mandible, 1 L mandible with Lm3, MNI=1, NISP=10; (99-45) 1 skull with RM1, RM2,

RM3, LM1, LM2, LM3, 1 L mandible with Lm1, Lm2, MNI=1, NISP=10; (99-58) 2 L mandibles with 2 Lm1, 2 Lm2, Lm3, MNI=2, NISP=7; (99-198) 1 L maxilla with LM1, LM2, MNI=1, NISP=3; (99-691) 1 separated maxilla with RM1, RM2, RM3, LM1, LM2, LM3, Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=12; (99-694) 1 R mandible with Rm1, Rm2, Rm3, MNI=1, NISP=4;

Junction Butte

GHOW: (98-432) 1 skull with RM1, RM2, RM3, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, Rm3, MNI=1, NISP=11;

1999

Lower Owl Alley

GHOW: (99-493) 1 R mandible with Rm1, Rm2, MNI=1, NISP=3; (99-520) 1 separated maxilla with RM1, RM2, RM3, LM1, LM2, LM3, Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=12;

Identification: *Neotoma* teeth are large, rooted, prismatic and hypsodont. They are superficially similar in structure to Microtinae, but are less complex and larger in length and width. M1 has a deep anteriointernal re-entrant angle; M3 has a closed anterior triangle and two confluent posterior loops (Hall 1981). M1 has two outer and inner folds; M2 has two outer and one inner fold. Mandibular molars, m1 and m2 have two outer folds and m3 has one outer fold (Chomko 1980).

Present Distribution: Bushy-tailed woodrats range along the west coast of North America from the Yukon to California, east to the Dakotas and south to New Mexico (Clark and Stromberg 1987).

Ecology: The bushy-tailed woodrat or packrat can be found in a variety of habitats but has specific nest-building requirements that include caves, talus slopes, rocky crevices and cliffs. Woodrats collect a variety of materials for their nests including wood, vegetation, bone and scats (Streubel 1989). They are active year-round, solitary, and mainly crepuscular in their activities. They eat green vegetation in the spring and summer such as leaves, conifer needles, mushrooms and forbs. In the fall, they collect and store corms and roots that they pile near their nests (Pattie and Hoffmann 1990).

Peromyscus maniculatus (Wagner, 1845) (deer mouse)

Comparative Materials: Denver Museum of Natural History # 7633, #7634, Montana State University Vertebrate Collection #7329, #7397.

Referred Materials:

Gardiner

GHOW: (98-147) 1 R maxilla with RM1, RM2, MNI=1, NISP=3; (98-149) 2 separated maxilla with RM1, RM2, 2 LM1, 2 LM2, LM3, 2 R mandibles with 2 Rm1, Rm2, 1 L mandible with Lm1, MNI=2, NISP=17; (98-150) 2 separated maxilla with RM1, RM2, RM2, 2 LM1, LM2, LM2, 2 R mandibles with Rm1, Rm2, 2 L mandibles with Lm1, 2 Lm2, Lm3, MNI=2, NISP=19; (98-151) 1 L maxilla, 1 L mandible with Lm1, MNI=1, NISP=3; (98-152) 1 separated maxilla with RM3, 1 R mandible with Rm3, 1 L mandible with Lm1, MNI=1, NISP=6; (98-153) 2 R maxilla with RM1, 2 RM2, RM3, 1 L maxilla with LM1, 2 LM2, LM3, 3 R mandibles with Rm1, Rm2, Rm3, 3 L mandibles with Lm1, Lm2, Lm3, MNI=3, NISP=22; (98-154) 1 L maxilla with LM1, LM2, 2 R mandibles with Rm1, Rm2, 3 L mandibles with Lm1, Lm2, MNI=3, NISP=12;

(98-155) 3 R maxilla with 2 RM1, 2 RM2, RM1, 1 L maxilla with LM1, LM2, 2 LM3, 3 R mandibles with 2 Rm1, 2 Rm2, 2 Rm3, 2 L mandibles with Lm1, 2 Lm2, MNI=3, NISP=26; (98-156) 1 L palatine with LM1, LM2, LM3, 1 R mandible with Rm1, 2 L mandible with 2 Lm1, Lm2, Lm3, MNI=2, NISP=12; (98-157) 3 separated maxilla with 3 RM1, 2 RM2, 2 RM3, 4 LM1, 3 LM2, LM3, 4 R mandibles with 3 Rm1, 3 Rm2, 2 Rm3, 5 L mandibles with 4 Lm1, 4 Lm2, 4 Lm3, MNI=5, NISP=47; (98-158) 2 L maxilla with 2 LM1, 2 LM2, LM3, 3 R mandibles with 2 Rm1, Rm2, Rm3, 2 L mandibles with Lm1, Lm2, 2 Lm3, MNI=3, NISP=20; (98-159) 3 separated maxilla with 3 RM1, 3 RM2, 2 RM3, 4 L maxilla with 4 LM1, 2 LM2, 2 LM3, 4 R mandibles with 3 Rm1, 3 Rm2, 2 Rm3, 2 L mandibles with Lm1, MNI=4, NISP=35; (98-162) 1 separated maxilla with RM1, 2 L maxilla with 3 LM1, 2 R mandibles with 4 Rm1, Rm2, Rm3, 1 Lm2, MNI=4, NISP= 15; (98-163) 2 separated maxilla with 2 RM1, RM2, 2 LM1, 2 LM2, LM1, 5 R mandibles with 4 Rm1, 6 Rm2, 4 Rm3, 6 L mandibles with 5 Lm1, 3 Lm2, 3 Lm3, MNI=6, NISP=56; (98-164) 1 R maxilla with RM1, 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm2, MNI=1, NISP=9; (98-165) 2 L maxilla with LM1, LM2, LM3, 2 R mandibles with Rm1, Rm2, 2 Rm3, 2 L mandibles with Lm1, Lm2, Lm3, MNI=2, NISP=16; (98-166) 1 R maxilla with RM1, RM2, RM3, MNI=1, NISP=4; (98-167) 1 R mandible with Rm1, Rm2, Rm3, MNI=1, NISP=4; (98-169) 1 separated maxilla with RM1, RM2, RM3, LM1, 2 R mandibles with 2 Rm1, 2 Rm2, Rm3, 1 L mandible, MNI=2, NISP=13; (98-171) 3 separated maxilla with 3 RM1, 2 RM2, 2 RM3, 3 LM1, 2 LM2, 2 LM3, 2 R mandibles with Rm1, 4 L mandibles with 2 Lm1, Lm2, MNI=4, NISP=27; (98-173) 1 separated maxilla with RM1, RM2, LM1, 1 R mandible with Rm1,

Rm2, Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=12; (98-174) 2 R maxilla with RM1, 3 L maxilla with 2 LM1, 2 LM2, LM3, 2 R mandibles with Rm1, 2 Rm2, Rm3, 4 L mandibles with 4 Lm1, 2 Lm2, Lm3, MNI=4, NISP=26; (98-176) 1 L maxilla, 1 Rm1, Lm1, MNI=1, NISP=3; (98-177) 1 R maxilla with RM2, RM3, 1 R mandible with Rm1, MNI=1, NISP=5; (98-181) 2 R maxilla with 2 RM1, RM2, RM3, 1 R mandible with Rm1, Rm2, MNI=2, NISP=9; (98-182) 1 separated maxilla with LM1, 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible, MNI=1, NISP=7; (98-184) 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=4; (98-185) 2 R maxilla with RM1, RM2, RM3, 1 R mandibles with 2 Rm1, 2 Rm2, 2 Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=2, NISP=18; (98-187) 1 R maxilla with 2 RM1, 3 RM2, 2 L maxilla with 2 LM1, 5 R mandibles with 2 Rm1, Rm2, 5 L mandibles with 3 Lm1, 2 Lm2, MNI=5, NISP=27; (98-189) 1 separated maxilla with RM1, RM2, LM1, LM2, 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1, MNI=1, NISP=11; (98-190) 1 separated maxilla with RM1, RM2, LM1, 1 R mandible with Rm1, 1 L mandible with Lm1, MNI=1, NISP=8; (98-191) 1 separated maxilla with RM1, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=11; (98-193) 1 R maxilla with RM1, 1 Rm3, MNI=1, NISP=3, (98-196) 1 R maxilla with RM1, RM2, 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm2, MNI=1, NISP=10; (98-199) 2 R maxilla with 2 RM1, RM2, 1 L maxilla with LM1, 2 R mandibles with Rm2, 2 L mandibles with 2 Lm1, MNI=2, NISP=13; (98-200) 1 R maxilla with RM1, RM2, RM3, 1 R mandible with Rm1, Rm2, 1 L mandible with Lm1, Lm2, MNI=1, NISP=10; (98-201) 2 separated maxilla with 2 RM1, 2 RM2, 2 RM3, 2 LM1, 2 LM2, 2 LM3, 2 R mandibles

with 2 Rm1, 2 Rm2, Rm3, 2 L mandibles with 2 Lm1, 2 Lm2, Lm3, MNI=2, NISP=28; (98-202) 1 L maxilla, 1 L mandible with Lm2, MNI=1, NISP=3; (98-203) 2 separated maxilla with 2 RM1, LM1, LM2, 2 R mandibles with 2 Rm1, Rm2, 2 L mandibles with 2 Lm1, 2 Lm2, Lm3, MNI=2, NISP=16; (98-204) 1 R maxilla with RM1, 1 R mandible, MNI=1, NISP=3; (98-205) 3 R maxilla with 3 RM1, 4 RM2, 2 RM3, 1 L maxilla with LM1, LM2, 2 R mandibles with 2 Rm1, 2 Rm2, Rm3, 3 L mandibles with 3 Lm1, 3 Lm2, 2 Lm3, MNI=4, NISP=32; (98-206) 3 R maxilla with 3 RM1, 2 RM2, RM3, 4 L maxilla with 4 LM1, 2 LM2, LM3, 4 R mandibles with 3 Rm1, Rm2, Rm3, 4 L mandibles with 3 Lm1, 2 Lm2, 2 Lm3, MNI=4, NISP=37; (98-207) 2 separated maxilla with 2 RM1, RM2, 2 RM3, 2 LM1, 2 LM2, 3 R mandibles with 3 Rm1, 3 Rm2, 2 Rm3, 2 L mandibles with 2 Lm1, 2 Lm2, Lm3, MNI=3, NISP=29; (98-208) 3 separated maxilla with 2 RM1, RM2, RM3, 3 LM1, LM2, LM3, 3 R mandibles with Rm1, 3 L mandibles with 3 Lm1, 2 Lm2, 2 Lm3, MNI=3, NISP=26; (98-209) 3 separated maxilla with 3 RM1, 4 RM2, 2 RM3, 3 LM1, 3 LM2, 2 LM3, 3 R mandibles with 3 Rm1, 4 Rm2, Rm3, 3 L mandibles with 4 Lm1, 2 Lm2, 2 Lm3, MNI=4, NISP=42; (98-210) 4 R maxilla with 5 RM1, 4 RM2, 2 RM3, 5 L maxilla with 4 LM1, 2 LM2, 2 LM3, 5 R mandibles with 5 Rm1, 3 Rm2, 2 Rm3, 3 L mandibles with 3 Lm1, 3 Lm2, 2 Lm3, MNI=5, NISP=50; (98-212) 1 skull, 3 R maxilla with 3 RM1, 3 RM2, RM3, 2 L maxilla with 3 LM1, 3 LM2, 3 LM3, 4 R mandibles with 3 Rm1, 2 Rm2, 2 Rm3, 4 L mandibles with 3 Lm1, 4 Lm2, 4 Lm3, MNI=4, NISP=46; (98-213) 1 L maxilla with LM1, LM2, LM3, 3 R mandibles with 2 Rm1, Rm2, 2 Rm3, 1 L mandible with Lm1, Lm2, MNI=3, NISP=15;

1999

Gardiner

GHOW: (99-3) 5 separated maxilla with 5 RM1, 2 RM2, RM3, 4 LM1, 4 LM2, LM3, 4 R mandibles with 3 Rm1, 2 Rm2, Rm3, 5 L mandibles with 5 Lm1, 4 Lm2, 4 Lm3, MNI=5, NISP=50; (99-13) 1 LM1, LM2, 1 R mandible with Rm1, 1 L mandible with Lm1, Lm2, MNI=1, NISP=7; (99-21) 2 R maxilla with 2 RM1, 2 RM2, RM3, 3 L maxilla with 3 LM1, LM2, 2 LM3, 2 R mandibles with Rm1, Rm3, 3 L mandibles with 2 Lm1, 2 Lm2, 2 Lm3, MNI=3, NISP=29; (99-33) 1 separated maxilla with RM1, RM2, RM3, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=15; (99-45) 1 L maxilla with LM1, MNI=1, NISP=2; (99-191) 2 separated maxilla with 2 RM1, RM2, RM3, 2 LM1, 2 LM2, 2 LM3, 2 R mandibles with 2 Rm1, Rm2, 2 Rm3, 2 L mandibles with Lm1, 2 Lm2, 2 Lm3, MNI=2, NISP=26; (99-192) 1 separated maxilla with RM1, RM2, RM3, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=15, NISP=15; (99-198) 1 separated maxilla with RM1, LM1, 1 R mandible with Rm1, Rm2, MNI=1, NISP=6; (99-203) 3 separated maxilla with RM1, RM2, 2 LM1, LM2, LM3, 3 R mandibles with 2 Rm1, Rm2, 3 L mandibles with Lm1, Lm2, MNI=3, NISP=20; (99-210) 1 R maxilla with RM2, MNI=1, NISP=2; (99-214) 1 separated maxilla with RM1, RM2, RM3, LM1, LM2, LM3, MNI=1, NISP=7; (99-218) 1 R maxilla with RM1, RM2, MNI=1, NISP=3; (99-685) 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=8; (99-689) 1 R maxilla with RM1, MNI=1, NISP=2; (99-694) 1 L maxilla with LM1, LM2, 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm2, MNI=1, NISP=10; (99-697) 3 separated maxilla with 3 RM1, 2 RM2, RM3, 3

LM1, LM2, LM3, 1 R mandible with 2 Rm1, 2 L mandibles with 3 Lm1, Lm2, Lm3, MNI=3, NISP=24;

Coyote: (99-24S) 2 R maxilla, 1 L maxilla with 2 RM1, 2 LM1, 3 R mandibles with 3 Rm1, Rm2, 3 L mandibles with 3 Lm1, 2 Lm2, Lm3, MNI=3, NISP=22; (99-25S) 1 R maxilla with RM1, RM2, LM1, 2 LM2, 2 R mandibles with Rm1, 2 Rm2, Rm3, 1 L mandible with Lm1, 3 Lm2, Lm3, MNI=3, NISP=18;

Little Rattlesnake

CORA: (98-325) 1 R maxilla, Rm1, Rm2, Rm3, MNI=1, NISP=4;

1999

Town

CORA: (99-237) 1 L maxilla with LM1, LM2, 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm2, MNI=1, NISP=10; (99-628) 1 R maxilla, Rm1, Rm2, MNI=1, NISP=3;

Junction Butte

GHOW: (98-423) 1 separated maxilla with RM1, RM2, RM3, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, 1 L mandible with Lm1, Lm2, MNI=1, NISP=13; (98-424) 1 separate maxilla with RM1, LM1, 1 R mandible with Rm1, Rm2, 1 L mandible with Lm2, MNI=1, NISP=8; (98-426) 2 R maxilla with 2 RM1, 2 RM2, RM3, 1 L maxilla with LM1, LM2, 2 R mandibles with 2 Rm1, 2 Rm2, 2 Rm3, 2 L mandibles with 2 Lm1, 2 Lm2, Lm3, MNI=2, NISP=24; (98-431) 1 R maxilla with RM1, RM2, RM3, 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=12; (98-433) 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1,

MNI=1, NISP=6; (98-435) 1 L maxilla with LM1, LM2, LM3, MNI=1, NISP=4; (98-437) 1 R maxilla with RM1, RM2, RM3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=8; (98-438) 1 R maxilla with RM1, RM2, LM2, MNI=1, NISP=4; (98-440) 1 L maxilla with LM1, LM2, 1 R mandible with Rm2, MNI=1, NISP=5; (98-441) 1 R maxilla with RM1, 1 L mandible with Lm1, MNI=1, NISP=4; (98-444) 1 R maxilla with RM2, RM3, 2 L maxilla with 2 LM1, LM2, 2 LM3, 1 R mandible with 2 Rm1, Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=17; (98-446) 2 R maxilla with 2 RM1, RM2, RM3, 2 R mandibles with 2 Rm1, Rm2, 2 Rm3, 1 L mandible with Lm1, Lm2, MNI=2, NISP=16; (98-450) 1 skull with RM1, RM2, RM3, 1 L maxilla with 2 LM1, 2 LM2, LM3, 2 R mandibles with 2 Rm1, 2 Rm2, 2 Rm3, 3 L mandibles with 3 Lm1, 2 Lm2, 3 Lm3, MNI=3, NISP=30; (98-452) 1 L mandible with Lm2, Lm3, MNI=1, NISP=3;

1999

Junction Butte

GHOW: (99-69) 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=4; (99-74) 1 skull with RM1, RM2, RM3, LM1, LM2, LM3, 2 R mandibles with 2 Rm1, 2 Rm2, 2 Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=20;

Lamar Bridge

CORA: (98-15) 1 R maxilla with RM1, RM2, MNI=1, NISP=3; (98-25) 1 L maxilla with LM1, 1 L mandible with Lm1, MNI=1, NISP=4; (98-232) 1 L maxilla with 2 LM2, LM3, 1 L mandible with Lm1, MNI=2, NISP=6; (98-240) 1 L maxilla, 1 R mandible with Rm1, 1 L mandible, MNI=1, NISP=4; (98-495) 1 L maxilla, 1 R

mandible, 1 L mandible, MNI=1, NISP=3; (98-496) 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=8;

1999

Lamar Bridge

CORA: (99-136) 1 R maxilla with RM1, RM2, RM3, 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1, MNI=1, NISP=10; (99-140) 1 R mandible with Rm1, 1 L mandible with Lm1, MNI=1, NISP=4; (99-327) 1 separated maxilla with RM1, RM2, LM1, LM2, LM3, 1 L mandible with Lm1, Lm2, Lm3, MNI=10; (99-329) 2 separated maxilla with 2 RM1, RM2, 2 LM1, 2 R mandibles with 2 Rm1, Rm2, Rm3, 2 L mandibles with Lm1, Lm2, MNI=2, NISP=17; (99-330) 1 separated maxilla with RM1, RM2, RM3, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1, MNI=1, NISP=13; (99-332) 1 separated maxilla with RM1, RM2, RM3, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=15; (99-338) 1 R mandible, MNI=1, NISP=1;

Tower

RTHA: (99-671) 1 L maxilla with LM1, LM2, LM3, 1 L mandible with Lm1, Lm3, MNI=1, NISP=7;

Lower Owl Alley

GHOW: (98-276) 1 L maxilla, 1 R mandible, 2 L mandible with Lm1, Lm2, 2 Lm3, MNI=2, NISP=8; (98-280) 1 RM1, 2 L maxilla with 2 LM1, 2 LM2, 2 LM3, Rm2, 3 L mandibles with 3 Lm1, 2 Lm2, 2 Lm3, MNI=3, NISP=20; (98-283) 1 R maxilla with RM1, RM2, MNI=1, NISP=3; (98-286) 1 R maxilla with RM1, 1 R mandible with Rm1,

MNI=1, NISP=4; (98-290) 1 separated maxilla with RM1, RM2, RM3, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, Rm3, MNI=1, NISP=11; (98-299) 2 L maxilla with LM1, LM2, 2 R mandibles with Rm1, 2 Rm2, 2 Rm3, 2 L mandibles with Lm1, Lm2, Lm3, MNI=2, NISP=16; (98-301) 4 R maxilla with 4 RM1, 4 RM2, 3 RM3, 5 L maxilla with 5 LM1, LM2, LM3, 4 R mandibles with 4 Rm1, 3 Rm2, 3 Rm3, 4 L mandibles with 4 Lm1, 3 Lm2, 3 Lm3, MNI=5, NISP=51; (98-302) 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=4; (98-376) 1 separated maxilla with RM1, 1 R mandible with Rm1, 1 L mandible, MNI=1, NISP=5; (98-390) 1 L maxilla with LM1, LM2, LM3, 1 R mandible with Rm2, Rm3, 1 L mandible with Lm1, MNI=1, NISP=9; (98-392) 1 separated maxilla, 2 R mandibles with 2 Rm1, Rm2, Rm3, MNI=2, NISP=7; (98-393) 1 R maxilla with RM1, RM2, 2 L maxilla with LM1, LM2, LM3, 2 R mandibles with 3 Rm1, 2 L mandibles with 2 Lm1, Lm2, Lm3, MNI=3, NISP=18; (98-394) 3 R maxillas with 3 RM1, 3 RM2, 2 RM3, 2 R mandibles with 2 Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm2, MNI=3, NISP=20;

1999

Lower Owl Alley

GHOW: (99-489) 1 R maxilla with RM1, MNI=1, NISP=2; (99-504) 1 L maxilla with LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, Rm3, 2 L mandibles with 2 Lm1, 2 Lm2, 2 Lm3, MNI=2, NISP=16; (99-638) 3 separated maxilla with 3 RM1, 4 RM2, 3 RM3, 4 LM1, 2 LM2, 4 R mandibles with 2 Rm1, 4 Rm2, 5 L mandibles with 2 Lm1, 2 Lm2, Lm3, MNI=5, NISP=39; (99-640) 1 L maxilla with LM1, LM2, 1 R mandible with Rm1, Rm2, 2 L mandibles with 2 Lm1, 2 Lm2, Lm3, MNI=2, NISP=13; (99-642) 1 R

maxilla with RM1, 1 L mandible with Lm1, MNI=1, NISP=4; (99-654) 1 separated maxilla with RM1, RM2, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, Rm3, MNI=1, NISP=10;

Coyote: (99-27S) 1 Rm1, Rm2, MNI=1, NISP=2;

E. Slough

RTHA: (99-182) 1 separated maxilla with RM1, RM2, RM3, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, Lm2, MNI=1, NISP=11; (99-184) 1 R mandible with Rm1, Rm2, MNI=1, NISP=3; (99-474) 2 L maxilla with 2 LM1, 2 LM2, 2 LM3, MNI=2, NISP=8; (99-478) 1 separated maxilla with RM1, RM2, RM3, LM1, LM2, LM3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=11; (99-667) 1 separated maxilla with RM1, LM1, LM2, 1 R mandible with Rm1, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=10;

Lamar

CORA: (99-179) 1 RM1, 1 R mandible, MNI=1, NISP=2;

Old Faithful

GHOW: (98-33) 1 R maxilla with RM1, MNI=1, NISP=2; (98-36) 1 L mandible with Lm1, MNI=1, NISP=2; (98-40) 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1, MNI=1, NISP=6; (98-43) 1 L maxilla with LM1, MNI=1, NISP=2; (98-73) 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=4; (98-78) 1 L maxilla with LM1, LM2, LM3, MNI=1, NISP=4; (98-87) 1 L maxilla with LM1, LM2, LM3, MNI=1, NISP=4; (98-103) 1 separated maxilla with RM1, RM2, RM3, LM1, LM2, 1 R mandible with Rm1, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=12; (98-109) 1 R

mandible with Rm2, 1 L mandible Lm1, Lm2, MNI=1, NISP=5;

1999

Old Faithful

GHOW: (99-256) 1 separated maxilla with RM1, RM2, LM1, LM2, 1 R mandible with Rm1, MNI=1, NISP=7; (99-259) 1 L maxilla, Rm1, MNI=1, NISP=2; (99-291) 1 separated maxilla, 1 L maxilla with RM1, RM2, 2 LM1, 2 LM2, LM3, 1 R mandible with Rm1, Rm2, Rm3, 2 L mandibles with Lm1, Lm3, MNI=2, NISP=17; (99-552) 1 separated maxilla with RM1, RM2, RM3, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=15;

CORA: (99-301) 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=4;

Porcupine

RTHA: (99-567) 1 R maxilla with RM1, RM2, RM3, MNI=1, NISP=4;

Trout Ck.

LEOW: (99-169) 1 skull with RM1, RM2, RM3, LM1, LM2, LM3, 1 R mandible with Rm1, Rm2, Rm3, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=15; (99-383) 2 separated maxilla with 2 RM1, RM2, RM3, 2 LM1, 2 LM2, LM3, 2 R mandibles with 2 Rm1, 2 Rm2, Rm3, 1 L mandible with Lm1, Lm3, MNI=2, NISP=21;

Lake

CORA: (99-569) 1 R mandible with Rm3, MNI=1, NISP=2;

Identification: Mandibular molars have two roots and maxillary molars have three roots. Molars are small, bracyodont and tuberculate with the major cusps arranged in two longitudinal rows (Chomko 1980). Deer mice teeth are similar in size to *Zapus*

princeps but slightly smaller than *Tamias* spp.

Present Distribution: The deer mouse is found throughout North America and ranges from the Yukon to the southern regions of Mexico. It is absent in the southeastern portions of the United States (Clark and Stromberg 1987, Pattie and Hoffmann 1990).

Ecology: Deer mice are active year-round and mainly nocturnal. They are very adaptable and can be found in a variety of habitats including tundra, meadows, forests and arid regions (Pattie and Hoffmann 1990). In Yellowstone they seem to prefer drier open areas over moist forests and meadows although they are found in both (Streubel 1989, R. Douglass personal comm. 1998). Deer mice eat a variety of seeds, fruits, nuts, fungus and insects (Clark and Stromberg 1987).

Lagomorpha

Three different species of Leporidae were used for comparisons as possible species present in and around the Gardiner area. Species used in the comparison were *Lepus* (snowshoe hare), *L. townsendii* (white-tailed jackrabbit) and *Sylvilagus nuttallii* (mountain cottontail).

Rabbits and hares are very difficult to identify to species based on fragmented dental and skeletal remains that are typically found in pellet and scat remains. The distinction between *Lepus* and *Sylvilagus* is based on overall size and the following cranial characteristics. The interparietal is fused with parietal bone in *Lepus* and is not fused and indistinct in *Sylvilagus* and juvenile *Lepus* (Hoffmann and Pattie 1968). The palatine bar width is wider in *Lepus* than in *Sylvilagus*.

Leporidae Linnaeus 1758 (rabbits and hares)

Referred Materials:**Gardiner**

GHOW: (98-149) 1 LI1, LI2, LM2, MNI=1, NISP=3; (98-155) 1 L maxilla with LP2, LP3, LP4, LM1, LM2, Ri1, MNI=1, NISP=7; (98-156) 1 L maxilla with LI1, LI2, LP3, LP4 1 R mandible with Ri1, MNI=1, NISP=9; (98-159) 2 R mandibles with 2 Rp3, 2 Rp4, 2 Rm1, 2 Rm2, 2 Rm3, MNI=2, NISP=12; (98-161) 1 palatine with RP2, RP3, RP4, RM1, LM1, 1 L mandible with Li1, Lp3, Lm1, Lm2, MNI=1, NISP=11; (98-163) 1 palatine with RP3, RP4, RM1, RM2, MNI=1, NISP=5; (98-166) 1 R maxilla with RI1, RI2, RP3, RP4, 1 R mandible with Rp3, Rp4, Rm1, Rm2, Rm3, MNI=1, NISP=10; (98-167) 1 Li1, MNI=1, NISP=1; (98-169) 1 partial R zygomatic arch, 1 radius, MNI=1, NISP=2; (98-174) 1 R maxilla with RP2, RP3, RP4, RM1, RM2, RM3, MNI=1, NISP=7; (98-175) 1 palatine with RP2, RP3, RP4, RM1, RM2, 1 R mandible with Ri1, Rp3, 1 L mandible with Li1, MNI=1, NISP=11; (98-176) 1 separated maxilla with RI1, RI2, RP2, RP3, RP4, RM2, LI1, LI2, 1 R mandible with Ri1, Rp3, Rp4, Li1, MNI=1, NISP=14; (98-177) 1 R maxilla with RI1, RI2, RP2, RP3, RP4, RM1, RM2, LI1, LI2, 1 R mandible Rp3, Rp4, Rm1, Rm2, Rm3, Li1, dLp3, MNI=1, NISP=18; (98-178) 1 LM1, LM2, 1 L mandible with Lm1, Lm2, Lm3, MNI=1, NISP=6; (98-183) 1 R mandible with Rp4, Rm1, Rm2, 1 L mandible with Li1, dLp3, Lp4, MNI=1, NISP=9; (98-184) 1 L maxilla with LP2, LP3, LP4, LM1, LM2, 1 L mandible with Lp3, Lp4, Lm1, Lm2, MNI=1, NISP=13; (98-186) 1 partial femur, 1 lumbar vertebrae, 1 partial tibia, MNI=1, NISP=3; (98-193) 1 R maxilla with RP2, RP3, RP4, RM2, 1 L mandible with Lp3, Lp4, Lm1, Lm2, Lm3, MNI=1, NISP=11; (98-197) 1 L femur, 1 R tibia, 1 L tibia, MNI=1, NISP=3;

(98-198) 1 R femur, 1 sacrum, 1 R calcaneus, 1 L calcaneus, 1 R innominate, 1 L innominate, MNI=1, NISP=6; (98-202) 1 partial L humerus, MNI=1, NISP=1; (98-204) 1 R femur, 1 L femur, 1 R tibia, 1 L tibia, 1 R calcaneus, 1 L calcaneus, MNI=1, NISP=6; (98-211) 1 radius, MNI=1, NISP=1; (98-330) 1 L mandible with Lp3, Lp4, Lm1, Lm2, MNI=1, NISP=5;

1999

GHOW: (99-20) 1 L maxilla with LP2, LP3, LP4, LM1, LM2, LM3, Ri1, 1 L mandible with Li1, Lp3, Lp4, MNI=1, NISP=12; (99-198) 1 R maxilla with RP2, RP3, RM1, RM2, RM3, LP3, LM2, Li1, Lm1, Lm2, MNI=1, NISP=11; (99-203) 1 R innominate, R innominate, R femur, L femur, MNI=1, NISP=4; (99-214) 2 cervical vertebrae, 2 ribs, calcaneum, metatarsal, MNI=1, NISP=6; (99-222) 1 separated maxilla with RI1, RI2, RP3, RP4, RM1, RM2, RM3, LI1, LI2, LP3, LP4, LM1, LM2, 1 R mandible with Ri1, Rp4, Rm1, Rm2, Rm3, 1 L mandible with Li1, Lp4, Lm1, Lm2, Lm3, MNI=1, NISP=26; (99-225) 1 sacrum, R femur, L femur, 3 lumbar vertebrae, 3 vertebrae, R innominate, L innominate, MNI=1, NISP=11; (99-685) 1 partial L tibia, 3 vertebrae, MNI=1, NISP=4; (99-689) 1 R maxilla with RP2, RP3, RP4, RM1, RM2, RM3, MNI=1, NISP=7;

Coyote: (99-15S) 1 RI1, RM1, 1 R mandible with Ri1, Rp4, Rm1, Li1, Lp3, Lm1, Lm2, Lm3, MNI=1, NISP=11;

Little Rattlesnake

CORA: (98-273) 1 R mandible with Rp4, Rm1, Rm2, Rm3, MNI=1, NISP=5; (98-274) 1 atlas, 1 lumbar vertebrae, MNI=1, NISP=2;

1999

Little Rattlesnake

CORA: (99-186) 1 RI1, dRP2, RP3, dLp3, MNI=1, NISP=4; (99-188) 3 thoracic vertebrae, MNI=1, NISP=3, (99-190) 2 vertebrae, 2 ribs, MNI=1, NISP=4; (99-682) 1 partial R femur, MNI=1, NISP=1;

Town

CORA: (99-235) 1 vertebrae, 2 ribs, MNI=1, NISP=3; (99-237) 1 LI1, Lp3, MNI=1, NISP=2; (99-631) 1 RI1, RI2, LI1, LI2, MNI=1, NISP=4;

Identification: Leporidae (rabbits and hares) teeth are distinct in that they are hypsodont and rootless. The first incisor (I1) is deeply grooved and there is a second peg-like incisor tucked posterior to I1. Ochotonidae (pikas) also contain double incisors. The cheek teeth are prismatic and divided into two elements by a deep infolding (Hillson 1986). The re-entrant enamel ridges of the upper cheek are crenulated (Vaughan 1986).

Leporidae have a unique bone structure. Skeletal elements, such as, the femur, pelvis, tibia, humerus, radius and vertebrae can be used to assign specimens to the family Leporidae. Size is used to discriminate within the family to genera. (Gilbert 1980). In cases where teeth were not available, skeletal elements were used to identify to genera.

Lepus americanus Erxleben 1777 (snowshoe hare)

Comparative Materials: Denver Museum of Natural History # 3424, # 3706, Montana State University Vertebrate Collection # 6108, #310.

Present Distribution: The snowshoe hare ranges through the boreal regions of Newfoundland throughout Canada into Alaska. It ranges south to northern California,

along the Rocky Mountains to New Mexico (Pattie and Hoffmann 1990).

Ecology: Snowshoe hares are associated with coniferous forests with dense understory.

They are mainly nocturnal and can be found resting in dense thickets during the day.

Snowshoe hares are well camouflaged in both winter and summer as their pelage turns from a grayish brown in summer to pure white in the winter. Snowshoe hares eat a variety of plant matter depending on the season, during the summer they forage on herbs, grasses and willows. In winter, they feed on bark and twigs of deciduous trees (Clark and Stromberg 1987).

Lepus townsendii Bachman 1839 (white-tailed jackrabbit)

Comparative Materials: Montana State University Vertebrate Collection # 312, # 314.

Present Distribution: The white-tailed jackrabbit is distributed throughout the northern Great Plains from the eastern Cascade Mountains and Sierra Nevada east to the Mississippi River, north into Alberta and Saskatchewan. It ranges as far south as northern Arizona and northern New Mexico (Pattie and Hoffmann 1990).

Ecology: White-tailed jackrabbits are nocturnal and are especially active at dusk and dawn. Similar to the snowshoe hare, their pelage changes color from gray-brown in the summer to pure white in the winter (Clark and Stromberg 1987, Streubel 1989). In summer they feed on a variety of green succulent vegetation. In the winter, they eat bark and buds that are above the current snow level (Clark and Stromberg 1987). The white-tailed jackrabbit can be found in a variety of habitats but it is mainly associated with open shrub-grass communities or in large openings in montane forests (Banfield 1974, Steubel 1989).

Sylvilagus nuttallii (Bachman, 1837) (mountain cottontail)

Comparative Materials: Denver Museum of Natural History #7455, #7546, #5734, Montana State University Vertebrate Collection # 321, # 6030.

Identification: *S. nuttallii* can be determined from others in this genus by the presence or absence of two anterior inflections on the third lower premolar. *S. idahoensis* has no enamel inflections and is smaller and *S. audubonii* has one anterior enamel inflection (Hadly 1990).

Present Distribution: Mountain cottontails are found within the intermountain regions of the western United States. They range from Montana south through the Rocky Mountains to New Mexico and Arizona, and west through Nevada and north into eastern Washington (Pattie and Hoffmann 1990).

Ecology: The mountain cottontail is usually found in rocky, brushy areas including sagebrush. It eats primarily grasses, but in the winter it will eat sagebrush, juniper and other woody shrubs. (Clark and Stromberg 1987). In Yellowstone, mountain cottontails can be seen near Mammoth and along the Gardiner River (Streubel 1989).

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