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EFFECTS OF CLIMATE CHANGE ON MAMMALIAN FAUNA COMPOSITION AND STRUCTURE DURING THE ADVENT OF NORTH AMERICAN CONTINENTAL GLACIATION IN THE PLIOCENE

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EFFECTS OF CLIMATE CHANGE ON MAMMALIAN FAUNA COMPOSITION AND STRUCTURE DURING THE ADVENT OF NORTH AMERICAN CONTINENTAL GLACIATION IN THE PLIOCENE

by

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EFFECTS OF CLIMATE CHANGE ON MAMMALIAN FAUNA COMPOSITION AND STRUCTURE DURING THE ADVENT OF NORTH AMERICAN CONTINENTAL GLACIATION IN THE PLIOCENE

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The cooling preceding the beginning of North American continental glaciation is beautifully represented by the thick fluvial and lacustrine sequences of the Pliocene Glenns Ferry Formation at the Hagerman Fossil Beds National Monument (HAFO), Idaho. This time interval is commonly studied because it contains the elevated global temperatures predicted to result from continued anthropogenic warming. The fossil mammals at HAFO were examined to see the effects of climate change on past mammalian assemblages.

The nature of the fossiliferous localities at HAFO was documented to establish which localities could be considered in situ. Additionally, the structural architecture of the beds was mapped to establish an idealized stratigraphic datum to which localities were tied. This facilitated temporal comparison of the widespread localities at HAFO. Second, a high-resolution record of climate change was created using global climate models to predict which oceanic areas varied in temperature in concert with HAFO during the middle Pliocene. Data from deep-sea cores from those oceanic areas were combined to create a proxy temperature pattern; such a detailed record from terrestrial data in the Glenns Ferry Formation is not currently possible.

Selected mammalian groups, carnivorans, insectivorans, and leporids, were examined in light of the established climatic patterns. The cooling through the lower portion of the Glenns Ferry Formation corresponds to variation in the morphology of individual species, the relative abundance of species, and the species-level diversity of mammalian groups. There is a return to warm temperatures near the top of the section at HAFO, and the mammals returned to the conditions exhibited before the cool-temperature extreme. This faunal resilience, however, occurred over hundreds of thousands of years.

The final paleoecologic approach established correlations between the species diversity of groups of modern mammals and modern climatic values. Many modern groups were found to be highly-significantly correlated to climate, but when the established predictive equations were applied to HAFO, the results were variable. Estimates of annual precipitation varied widely, depending on the taxonomic group, and also deviated from precipitation estimates from sedimentology. Temperature patterns were more consistent with each other and with the pattern of the deep-sea core proxy.

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CHAPTER 1. INTRODUCTION TO THE DISSERTATION

Study of entire or significant portions of fossil mammalian assemblages may provide insights into paleoecology and paleoclimates that are not always apparent from inspection of a single taxon. Recently developed methodologies attempt paleoenvironmental reconstruction in an objective manner, rather than on the more traditional method of taxonomic analogues (Dodd and Stanton, 1990). With these techniques the entire assemblage, or a significant subset, is used to estimate the paleoclimate rather than using only one or a few species. In this dissertation, I examine the reverse; during a time interval of known climatic changes, how is the fauna affected? More specifically, did the climatic changes during the advent of North American continental glaciation in the middle Pliocene affect the paleomammalian assemblage at different ecologic scales?

STUDY AREA

The middle Pliocene, coinciding with the beginning of North American glaciation, is beautifully represented by the thick fluvial and lacustrine sequences at the Hagerman Fossil Beds National Monument (HAFO), southern Idaho (Figure 1.1;

McDonald et al., 1996). The Pliocene fossiliferous beds at HAFO lie within the Glenns Ferry Formation, which stretches through southwestern Idaho and easternmost Oregon (Malde and Powers, 1962). This formation, consisting of lacustrine, fluvial, and floodplain deposits, is as much as 600 m thick in outcrops, but less than half of that sum is exposed within the park (Malde and Powers, 1962). Although the Glenns Ferry Formation spans the Pliocene epoch, the mammalian fossils from HAFO are concentrated in the portion from 4.2 to 3.1 Ma. The best known locality within HAFO is the Hagerman Horse Quarry, which has produced hundreds of skeletons of *Equus shoshonensis.* This locality is one of the youngest exposures of the Glenns Ferry Formation at HAFO and is estimated as about 3.2 Ma (Hart and Brueseke, 1999).

ECOLOGICAL SCALES

Examination of change at HAFO is done at different ecological scales. Three neoecological scales fit together in a perfect hierarchy (sensu Beckner, 1974; and implicitly Andrewartha, 1961); in this sense, individuals, populations, and communities are nested so that each component is assigned to exactly one higher level and is composed entirely of lower levels. The name of each level describes its components. The individual scale examines discrete organisms. The population scale focuses on single groups consisting of individuals of a single species. Finally,

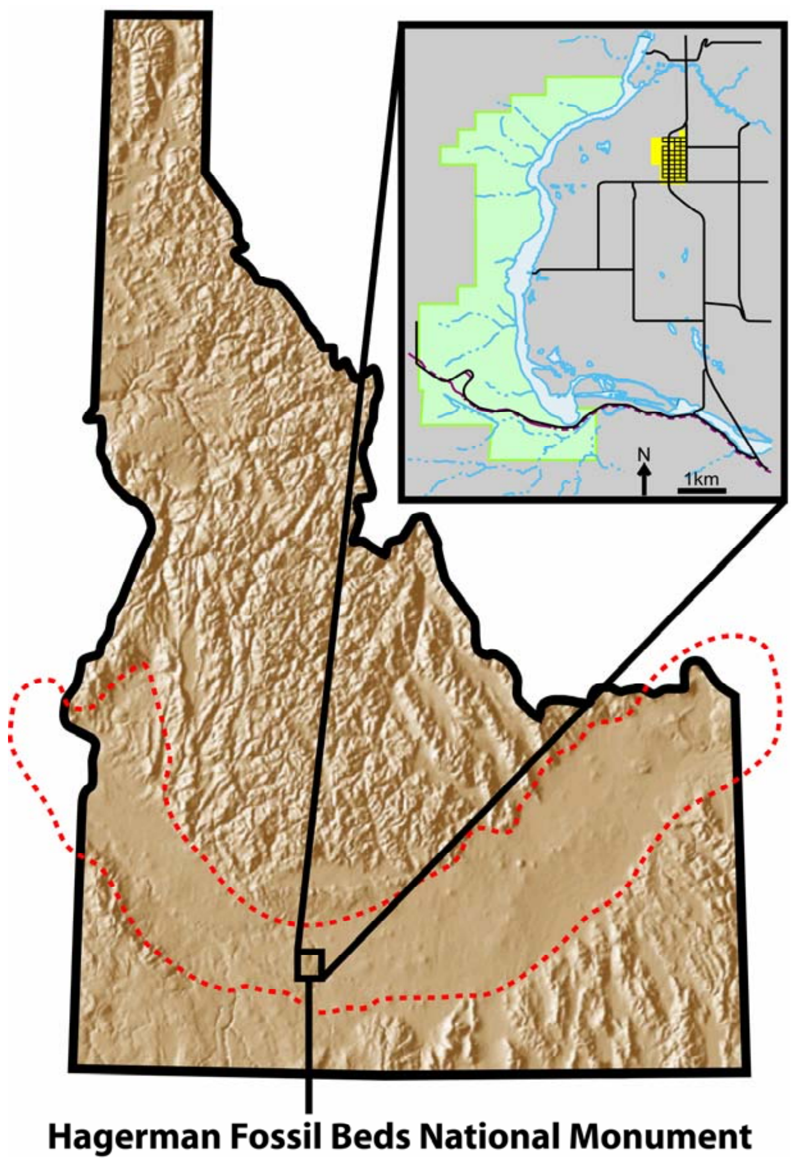


Figure 1.1. Location of study area. The dotted red line outlines the Snake River Plain-Yellowstone Plateau (sensu Leeman, 1982), but excludes the Owyhee Plateau in southwestern Idaho. The inset map shows the boundaries of HAFO (in green) to the west of the Snake River, yellow representing the city of Hagerman, paved roads as black lines, and purple lines for the Oregon Trail. The topographic map is adapted from Link et al. (undated) in accordance with their usage policy.

the community scale expands to include the collection of populations of different species from a single locality. Each level yields different factors from its components (Table 1; Schoener, 1986), which may in turn be used to evaluate higher levels. For example, the data produced from individual scale analyses may be combined to give the information listed under population scale.

Although the term community is applied almost exclusively in both neo- and paleoecology in reference to only a portion of the total biota in any area, that use is inappropriate. Instead, assemblages accurately refer to a phylogenetically delimited sample of a community, and a local guild is the more appropriate term for groups restricted by other factors such as functional morphology or behavior (Figure 1.2). Groups of the local biota distinguished by both phylogeny and guild position are ensembles. For the remainder of the dissertation I will use these less-common terms when appropriate. Because my dissertation only discusses only the fossil mammals, at no point do I examine the entire community at HAFO. The generic term community, however, will be retained to encompass any combination of more than one assemblage, local guild, and/or ensemble.

Ecologists of modern ecosystems may argue that the paleoecological analyses in this dissertation do not examine the individual, population, and community scales, but uses them to study other levels that do not fit perfectly into the ecological hierarchy (Schoener, 1986). By including a physical setting and the effects of climate, my analyses may be termed ecosystem ecology (Whittaker, 1975). Further, by extending my study across geologic time, I will be looking at yet another

Table 1.1. Ecologic scales and the information they provide. Modified from Schoener (1986).

Organismal Scale	Population Scale	Community Scale
physiology	age structure	abundance distributions
behavior	sex ratios	species diversity
ecomorphology	growth rates/ontogeny	species turn-over rates
territory size	reproductive schedules	habitat distribution
	migration	trophic distribution
	succession	

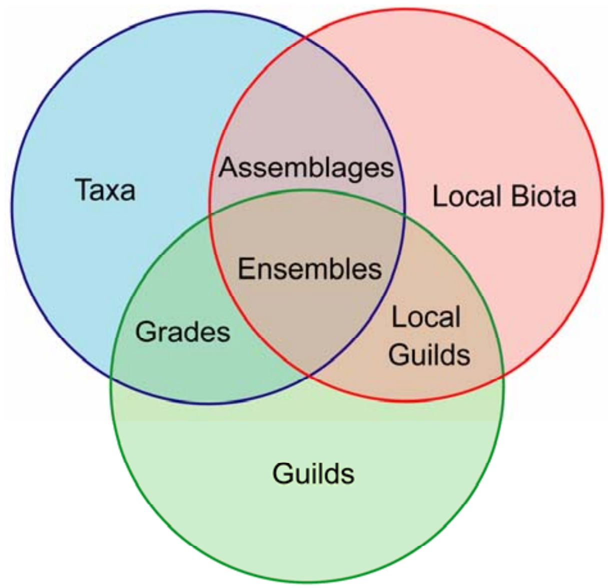


Figure 1.2. Interaction of the major components in community ecology (systematics, geography, and resources) and the appropriate terminology for subsets of the community. Modified from Fauth et al. (1996).

dimension, evolutionary ecology (Winsatt, 1976). Rather than this being a criticism of my work, this integration of climate and deep time will ultimately clarify the interrelationships of the hierarchical levels in ecology.

FAUNAL COHESION

Most methods of paleoecological reconstructions can only give repeatable and potentially accurate interpretations if there is an ecological reason for similarities between assemblages that may be separated by space and time. Such similarities between disparate assemblages have been noted since antiquity. Theophrastus, a student of Aristotle, studied the groupings of flora and fauna that consistently co-occurred (Allee et al., 1949). This repetition of community composition is typically explained as the result of biotic interactions, excluding significant effects of the physical environment (i.e., Elton, 1927; MacArthur, 1972; Ricklefs and Schuter, 1993). Regardless of the cause, faunal similarities are known to occur within a wide range of organisms: communities of corals, seagrasses, and mangroves (McCoy and Heck, 1976); bat faunas (Hill and Smith, 1984); assemblages of reef fish (Ross, 1986); and marine invertebrate paleofaunas (summarized in Boucot, 1983).

My definition of faunal cohesion is a determinate community structure and composition resulting from the interaction of environmental and biological processes, that may be reproduced regardless of taxonomic similarities and that may (in theory) be used as a predictor. This definition combines the biological factors held as dominant by the authors discussed earlier, and the environmental agents of Gleason (1926) and Andrewartha and Birch (1954), which set the range of possibilities for colonization, reproduction, growth, and survival. I use the term faunal, rather than community, cohesion to distinguish this from the community cohesion of Martin and Fairbanks (1999) and the community scale dynamics of neoecologists.

Faunal cohesion must have limits. Speciation and extinction events change the taxa that may occur in a specific location, and the physical nature of the environment can impede or facilitate the dispersal of populations. The limits of faunal cohesion in the fossil record, and therefore of most paleoecological interpretations, are poorly understood, and my dissertation admittedly does not adequately investigate this important aspect. However, examining the reliability of paleoecological reconstructions at HAFO does present a 'best case' scenario. Fossils are extremely abundant at HAFO and although the species represented are extinct, they are closely related to modern taxa. If paleoecological methods do not work at HAFO, they are unlikely to work at any other pre-Holocene fossil locality.

FORMAT OF THE DISSERTATION

Chapters 2-8 are written as discrete units to facilitate subsequent publication. If the chapters are read sequentially, there will therefore be some redundancy noted.

Chapter 2 describes the geology of the Glenns Ferry Formation and the nature of the fossiliferous localities at HAFO. Additionally, marker beds and the structural architecture of the Glenns Ferry Formation are integrated to create a single standardized datum to allow localities to be compared vertically.

Chapter 3 reviews the paleoclimatic data for the Glenns Ferry Formation at HAFO and introduces a new method of generating high-resolution estimates of paleotemperatures for terrestrial sites. Global climate models (GCMs) were examined in order to see which oceanic places on Earth experienced Pliocene temperature changes in the same pattern as HAFO. Sea surface temperatures were taken from oceanic cores drilled in places indicated as similar to HAFO by the GCMs.

Chapter 4 synthesizes the diverse studies on the fossil mammals from HAFO. It also updates the taxonomy, reviews the distribution of the species outside of HAFO, and critically evaluates published and unpublished suggested occurrences of species at HAFO.

Chapters 5, 6, and 7 evaluate the changes in the carnivoran, leporid, and insectivoran assemblages with regard to stratigraphy. These changes are tied to the paleoclimatic data generated in Chapter 3. In this way, changes in fossil mammals are examined with regard to established climate variations.

Chapter 8 evaluates the correlation between taxonomic diversity and climate in modern ecosystems and uses the modern correlations to calculate estimates of paleoclimatic values for the Glenns Ferry Formation at HAFO. These estimates are then compared to those generated in Chapter 3. The correlations established in this chapter may be applied to other paleofaunas in North America to produce quantitative estimates of temperature and precipitation. The modern dataset can also be used in the evaluation of other quantitative methods of paleoecological reconstruction.

CHAPTER 2. FRAMEWORK FOR STRATIGRAPHIC ANALYSIS OF THE MIDDLE PLIOCENE FOSSILIFEROUS DEPOSITS AT HAGERMAN FOSSIL BEDS NATIONAL MONUMENT, IDAHO

ABSTRACT

Hagerman Fossil Beds National Monument (HAFO), Idaho, is internationally significant because it encompasses hundreds of fossil localities representing many of the most important terrestrial Pliocene sites known. This study establishes the background for comparisons between localities in the Glenns Ferry Formation within HAFO by describing the nature of the fossiliferous deposits, using published data to provide revised age estimates for HAFO localities, and better marking the relative difference in elevation for particular time horizons. Fossils from the Hagerman Horse Quarry, anthills, and blowout localities are considered to be essentially at the original stratigraphic level of deposition. Species of modern ants belonging to *Pogonomyrmex* do gather fossils from more than the immediate area, but the estimated maximum vertical movement is within the resolution of elevation possible at most HAFO localities. The microstratigraphy of blowout localities is described here for the first time, with vertebrate fossils derived exclusively from layers of

about 12 cm thickness. Fossils recovered as surface float generally should be excluded from stratigraphic comparisons.

Based on a combination of paleomagnetic and radiometric studies, the maximum age for the top of the Glenns Ferry Formation exposed at HAFO is 3.11 Ma, and the minimum age for the lowermost exposures is 4.18 Ma. It is unlikely that there is any Glenns Ferry Formation sediment younger than 3.04 Ma or older than 4.29 Ma at HAFO. Finally, using marker beds and published stratigraphic sections, the necessary change in elevation to compare all Glenns Ferry Formation fossil localities at HAFO against an idealized composite section is established. Within this framework fossil sites can be placed in their proper stratigraphic context and faunal change can be identified more precisely.

INTRODUCTION

For more than seven decades, Hagerman Fossil Beds National Monument (HAFO), Idaho (Figure 2.1), has served as one of the world's most important sources of middle Pliocene paleontological data, particularly for mammalian fossils (McDonald et al., 1996). There is a long history of paleontological field work at HAFO, with large-scale efforts beginning with the U. S. National Museum excavations from 1929 to 1934, and subsequently revived by the University of Michigan Museum of Paleontology and the Idaho Museum of Natural History. The paleontological resources of HAFO are stewarded today by the National Park

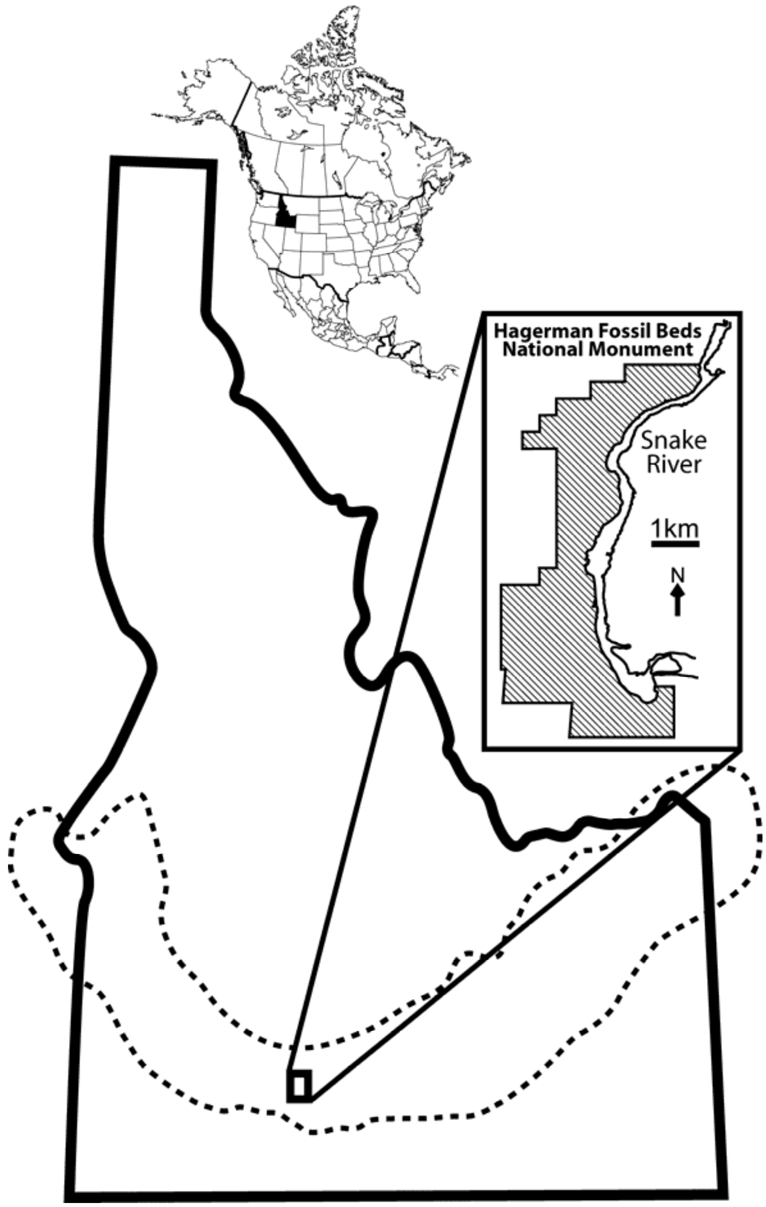


Figure 2.1. Location of Hagerman Fossil Beds National Monument, Idaho. The dotted line outlines the Snake River-Yellowstone Plateau (sensu Leeman, 1982), but excludes the Owyhee Plateau in southwestern Idaho. The inset map shows the boundaries of HAFO to the west of the Snake River. The modern Snake River flows to the west.

Service. Other smaller-scale field efforts, including those by the University of Utah, Natural History Museum of Los Angeles County, and Pacific Union College, emphasized work at the Hagerman Horse Quarry (Macdonald, 1966; Akersten and Thompson, 1992).

This paper brings together the disparate studies on the geology of the Glenns Ferry Formation and the chronology of the fossil deposits. It also adds new empirical observations on the nature of the deposits and presents data that allow more accurate stratigraphic placement of localities at HAFO. In a companion work to this study, the climatic patterns during the Pliocene interval represented at Hagerman will be synthesized (Chapter 3). At that point, faunal changes can more accurately be assessed in light of environmental change.

STRATIGRAPHIC NOMENCLATURE

Detailed discussion of the nomenclatural issues associated with the Glenns Ferry Formation is available elsewhere (Repenning et al., 1995), so only a brief treatment is included here to introduce the various names. Sediments of the Glenns Ferry Formation were first recognized from deposits of Lake Idaho and associated fossil fish (Cope, 1883b). These sediments were named the Idaho Formation, but it is unclear if this was meant also to include deposits other than those currently recognized as the Glenns Ferry Formation. Nomenclatural refinement of the Idaho

Formation later restricted the name to Pliocene deposits and explicitly excluded the older Payette Formation as a distinct formation (Lindgren, 1898, 1900).

The Idaho Formation was redefined as all deposits above the Columbia River Basalt Group by Kirkham (1931), who intended to exclude the Payette Formation from the Idaho Formation. Kirkham (1931) stated that the Payette Formation was overlain by at least 300 m of Columbia River Basalt, but the two units actually intertongue (Malde and Powers, 1962). Neither the Payette Formation nor the Columbia River Basalt occurs in the Hagerman area, and neither is coeval with any part of the Idaho Group (Malde and Powers, 1962).

In the 1960s the nomenclature of nearly every sedimentary unit within the Idaho Formation was changed or redefined. Malde and Powers (1962) erected the Idaho Group and included within it seven formations: Poison Creek Formation, Banbury Basalt, Chalk Hills Formation, Glenns Ferry Formation, Tuana Gravel, Bruneau Formation, and Black Mesa Gravel (Figure 2.2). The Idaho Group overlies the Idavada Volcanics and is capped by the Snake River Group; both upper and lower boundaries of the Idaho Group are unconformable surfaces.

The Banbury Basalt in this chapter refers only to the early Pliocene olivine tholeiite between the Glenns Ferry and Chalk Hills formations. The Banbury Basalt was originally named for exposures at Banbury Hot Springs, Idaho (Stearns, 1936), but some authors recognized a second unit also called the Banbury Basalt that is correlative with the Poison Creek Formation (e.g., Malde and Powers, 1962; McKee and Mark, 1971; Mark et al., 1975; Stewart and Carlson, 1976). This lower basalt is

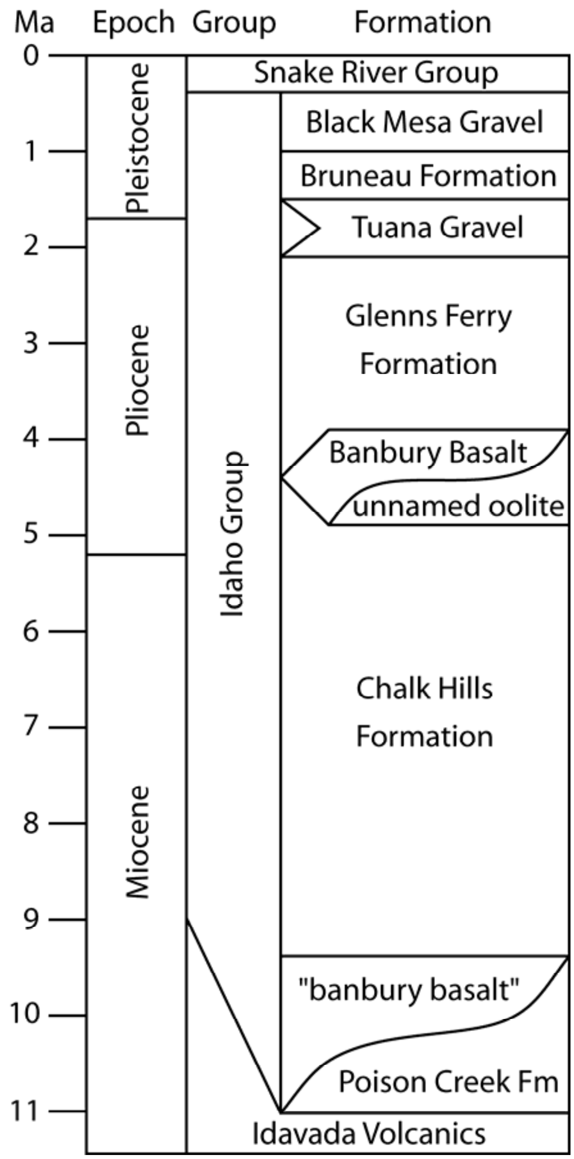


Figure 2.2. Stratigraphic summary of the Idaho Group adapted from Lee et al. (1995). Comments on the placement of the Banbury Basalt and the Tuana Gravel are in the text. The Sand Spring Basalt, Yahoo Clay, McKinney Basalt, Crowsnest Gravel, and Melon Gravel are within the Snake River Group. An erosional unconformity exists at the top of each sedimentary unit.

approximately twice the age of the tholeiite from the Banbury Hot Springs (Armstrong et al., 1975) and differs genetically from the majority of Snake River Plain basalts (Hart et al., 1984). Even when this diachronous use of the term Banbury Basalt is recognized, the name is often retained for lack of a formal name for the lower basalt (e.g., Lee et al., 1995), sometimes erroneously to the exclusion of the type locality (Swirydczuk et al., 1982).

Placement of the contact between the Chalk Hills Formation and the overlying Glenns Ferry Formation varies widely, but the original proposal was a widespread orange oolite (and the presumed chronologic equivalent algal limestone at Horse Hill, Idaho) as the basal member of the Glenns Ferry Formation (Malde and Powers, 1962). In contrast, this oolite was also considered as the topmost bed of the Chalk Hills Formation (Warner, 1976) or excluded from both the Glenns Ferry and Chalk Hills Formation (Repenning et al., 1995) because of the different paleoenvironment (following Swirydczuk et al., 1979), relative thinness, and different areal extent. The limestone at Horse Hill was determined to be significantly older and within the Chalk Hills Formation (Swirydczuk, 1977). The contact between the Chalk Hills Formation and Glenns Ferry Formation at Horse Hill was later set at the base of a quartzite-cobble bed (Swirydczuk et al., 1981). A more complete study concluded that the oolite was as a temporal equivalent of the quartzite-cobble bed and either could be used to mark the base of the Glenns Ferry Formation (Swirydczuk et al., 1982). Neither the oolite nor the cobble bed occur in the Hagerman area. Instead the Glenns Ferry Formation at HAFO directly overlies the Banbury Basalt.

LATE CENOZOIC HISTORY OF THE HAGERMAN AREA

Active and extensive volcanism related to the Yellowstone-Snake River Plain hotspot dominated south-central Idaho during the middle Miocene (Pierce and Morgan, 1992). Normal faulting (Malde, 1991) and cooling after the eastward movement of the hotspot caused subsidence in the western Snake River Plain and resulted in the graben now filled with the Idaho and Snake River Groups (Othberg, 1994). Deposition began with the diversion of the Snake River into the graben and continued until Hell's Canyon opened sufficiently to keep the area drained (Othberg et al., 1996). Most of the Glenns Ferry Formation at HAFO (Figure 2.3) was deposited in a meandering stream and flood plain setting east of the Glenns Ferry Lake (Malde and Powers, 1962; Malde, 1972).

The Tuana and Tenmile gravels unconformably overlie the Glenns Ferry Formation and consist of coarse deposits transported by the increased competency of the Snake River once captured by the Columbia River (Malde, 1991). The Tenmile Gravel only appears in the Boise area (Othberg, 1994), whereas the Tuana Gravel is common in HAFO as the capping sedimentary unit (Malde, 1991). The Tuana Gravel consists of gravels, sands, and silts mainly derived from the Twin Falls Volcanic Field, but it also contains sediments likely from parent material in northern

Figure 2.3. West-looking photo of Glenns Ferry Formation at Hagerman Fossil Beds National Monument taken from east of the Snake River, in the Hagerman Valley.

Nevada and central and eastern Idaho (Sadler et al., 1997). Although the Tuana Gravel reaches a thickness of more than 60 m in the type locality (Malde and Powers, 1962), the unit at HAFO is only 5-20 m (Sadler et al., 1997).

Distribution of the lake and stream sediments of the Bruneau Formation is partially controlled by coeval basalt flows (Malde et al., 1963). Exposures of the Bruneau Formation previously mapped at HAFO (Malde, 1971, 1972; Malde and Powers, 1972) were later reinterpreted as deposits of Yahoo Clay (Malde, 1982). The nearest deposits of Bruneau Formation are approximately 15 km northwest of HAFO (Malde, 1982). The uppermost unit of the Idaho Group, the Black Mesa Gravel, is composed of sand and gravel eroded from the Bruneau and Glenns Ferry formations (Malde and Powers, 1962). The closest exposures of Black Mesa Gravel are south of the town of Glenns Ferry, about 30 km west of HAFO.

The middle to late Pleistocene Snake River Group consists of complex arrangements of basalts, lacustrine clastics, and gravels, resulting from local volcanism, lava damming of the river to form lakes, and flooding events following dam breakage (Malde and Powers, 1962). Several of these formations are very localized and not expressed in the Hagerman area. The Sand Spring Basalt occurs in the Hagerman Valley only across the Snake River from HAFO. Outcrops of the Sand Spring Basalt 3 km north of Hagerman are the westernmost exposures of the formation (Malde and Powers, 1962). The Yahoo Clay does occur within HAFO. It was deposited within the Pleistocene McKinney Lake, which was formed by the damming of the Snake River by pillow lava of the McKinney Basalt near Bliss, Idaho (Malde, 1982). The McKinney Basalt is the youngest volcanic unit in the western Snake River Plain (Malde, 1965). This basalt has normal magnetic polarity (Malde, 1991), and its age was estimated at 70 to 50 ka based on the lack of buried soils (Pierce et al., 1982). Crowsnest Gravel is found in the southern part of HAFO and rests on eroded surfaces of Yahoo Clay (Malde, 1991).

The youngest sedimentary formation in the Snake River Group is the Melon Gravel (Figure 2.4), which occurs throughout the Hagerman Valley as a result of the Bonneville Flood (Jarrett and Malde, 1987). The largest of the Pleistocene lakes in the Basin and Range region of the western United States, Lake Bonneville, broke through its dam at Red Rock Pass (southeastern Idaho) about 15 kya, scouring the course of the Snake River (Gilbert, 1878; Malde, 1991). The water surface within the Snake River Canyon elevated more than 130 m above the present level (Jarrett and Malde, 1987). Discharge along the Snake River south of Boise during this flood is estimated at 935,000 m^3/s (Jarrett and Malde, 1987); the average historical discharge along the Snake River before damming and draining for agriculture was 1260 m^3/s (Chow, 1964). For comparison, the highest known discharge for the Mississippi River at St. Louis, Missouri was 36,800 m^3/s in 1844 (Parrett et al., 1993), and the greatest modern discharge ever measured in the United States was 70,000 m^3/s at Arkansas City, Arkansas, for the 1927 flood of the Mississippi River (Dalrymple, 1964). The water level in Lake Bonneville dropped 108 m as a result of the flood, which corresponds to 4,700 km^3 of water lost from the lake (Currey and Oviatt, 1985). If the discharge remained constant at the estimated rate of 935,000

Figure 2.4. Melon Gravel in a field in the southern portion of Hagerman Valley.

m^3/s, the flood would have lasted 8 weeks (Jarrett and Malde, 1987). The Bonneville Flood eroded much of the sediments of the Snake River Group and Idaho Group, leaving only isolated deposits in the Snake River Plain. The undisturbed sediment of the Glenns Ferry Formation at HAFO may have been sheltered by the resistant caliche in the overlying Tuana Gravel (Sadler et al., 1997).

MAMMAL-PRODUCING FOSSIL LOCALITIES

Glenns Ferry Formation

HAFO contains 183 m of lacustrine, fluvial, and floodplain deposits of the Glenns Ferry Formation (Malde and Powers, 1962; Lee et al., 1995) exposed along the west bank of the Snake River (Figure 2.3). HAFO is situated at the eastern edge of the western Snake River Plain, the geology of which is dominated by siliciclastic sediments, but also includes volcanic units (Othberg, 1994). Basalts and ashes of the area are discussed in the chronology section. West of HAFO the Glenns Ferry Formation reaches 900 m in thickness (Malde, 1991; Williams, 1994).

Extensive sequences within the Glenns Ferry Formation suggest uniform sedimentary environments with little lateral migration of lithofacies (Malde, 1972). Given the low topographic gradient indicated by the meandering stream deposits, subsidence is suggested as having proceeded at approximately the same rate as sedimentation (Lee et al., 1995). Indications of paleocurrent directions vary widely. Interpretation of the Hagerman Horse Quarry deposits suggests flow was from west to east (Akersten and Thompson, 1992), whereas measurements from multiple localities indicated flow from north to south (Riedel, 1992 not seen, cited in Lee et al., 1995). Data presented by Lee et al. (1995) exhibited wide variation, but generally showed flow from the south to the north. Such discordance strongly supports the interpretation of deposition by low-gradient, widely-meandering streams.

Sands in the Glenns Ferry Formation were deposited primarily by lateral accretion at point bars; muddy lithofacies represent flood events (Lee et al., 1995). Approximately half of the sands in the Glenns Ferry Formation at HAFO are from rhyolitic rocks. Basaltic sands are the second most abundant and account for another 11% of the total (Lee et al., 1995). Clay beds at HAFO contain smectite and illite (Gautier, 1979).

Hagerman Horse Quarry

Although hundreds of documented localities lie within the Hagerman Fossil Beds National Monument boundaries, many paleontologists are familiar only with a single site – the Hagerman Horse Quarry (HHQ). Several universities and museums, and many amateurs, have collected fossils from HHQ, near the top of Smithsonian Institution Hill in the northern part of HAFO (Figure 2.5). These collections are from excavations at slightly different locations, but were made predominantly along the western and southern exposures of the hill, confined vertically to a thickness of about 12 m (Akersten and Thompson, 1992). Most sands in the Glenns Ferry

Figure 2.5. East-looking view into Fossil Gulch, in the northern portion of Hagerman Fossil Beds National Monument. In the upper left part of the photo, Smithisonian Institution Hill can be seen with a road leading to the Hagerman Horse Quarry. The Snake River is visible in the distance separating HAFO from the Hagerman Valley to the east.

Formation are uncemented and friable, but the HHQ consists of carbonate-cemented, cross-bedded sands. It is unclear how laterally extensive the cemented area was originally because the cemented sands cannot be traced to other hillsides.

The earliest published interpretation of the HHQ suggested slow accumulation of remains in a boggy setting such as a water hole (Gidley, 1930b). Based on the identification of channel sands at HHQ this idea was revised and the deposit was said to be the gradual accumulation of fossils in an east-west trending river aided by bog trapping (Gazin, 1935b, 1936).

Fossils from the HHQ, however, lack significant wear which commonly results from water transport (Akersten and Thompson, 1992). Further, the lack of weathering and of carnivoran modification, together with the presence of associated skeletal elements, suggests carcasses were exposed for only a short time and, if transported, were not carried far (Akersten and Thompson, 1992). Akersten and Thompson (1992) used this evidence to suggest the HHQ is the result of a single flood event that killed a herd of horses and a few other animals. Their alternative scenario involved carcass accumulation by a flood event, a short period of exposure, and a second flood to bury everything. Analysis of the population structure of the HHQ horses supported the idea of a herd killed during a single flooding event or trying to cross a deep river (McDonald, 1995). Recently, however, the water-hole idea was revisited; quantitative evaluation of sediments and trough cross-sets indicates low flow velocity and water depth of less than about 0.5 m (Richmond and

McDonald, 1998). In this new scenario, a drought brought animals to a water hole where they died. After a short period of exposure, a minor flood buried the remains. The HHQ is not the only locality within HAFO that contains fossils *in situ* and, in some cases, partially articulated. Such localities are, however, rare at HAFO; only 19 are known to have at least some fossils from undisturbed sediment.

Anthills

Anthills can be great caches of paleontological wealth anywhere the fossils are about the size of the ants (Galbreath, 1959). Several species of the harvester ant, *Pogonomyrmex*, are most commonly the fossil-collecting formicids in North America (Scott, 1951), because they armor their mounds with 1-2 cm of coarse particles (Headlee and Dean, 1908). Not only can fossils be collected from ant mounds, but localities known to have fossils can be farmed by seeding an area with ants (Hatcher, 1896). Mounds of harvester ants occur within a cleared collection radius of about 2 m, and have tunnels reach as much as 2 m in depth (Scott, 1951). An experiment to determine if sediment was actually displaced stratigraphically (Matthias and Carpenter, 2004:tab. 1) exhibited a high degree of disturbance, but the maximum vertical movement measured in the study was less than 10 cm. Gaglio and Julian (1999) demonstrated that most fossils collected from ant mounds originated from nearby surface exposures and were not the result of excavation.

At HAFO, collecting fossils from anthills quickly accumulates small fossils. Although much of this material is undiagnostic, abundant recognizable rodent and insectivoran material is gathered by these harvester ants. Over an 11 day period in June 1980, the Idaho Museum of Natural History made a collection of approximately 1500 arvicoline rodent molars, most of them complete, from a single anthill within a blowout (personal observation).

Anthills at HAFO are typically limited to horizontal areas, such as blowouts and along ridge crests. Because of their location and the lack of data to support significant vertical movement of fossils by ants, fossils recovered from ant mounds can be considered to be derived from the stratigraphic horizon of the ant mound. Given the 2 m radius of collection and the maximum angle of the hill slopes of about 35°, collecting by ants exclusively on the surface could sample a stratigraphic interval of 1.1 m. This is within the stratigraphic resolution possible at most sites at HAFO, and is therefore not considered significant.

Surface Float

Surface float specimens are typically isolated finds and show evidence of recent weathering and transport. The only stratigraphic data possible for these fossils is that they are derived from the level where collected or upslope. In order to confirm that surface specimens were not derived from the horizon upon which they were collected, I sampled in situ material from the southwest part of the monument. This area has abundant surface fossils, but far fewer blowouts and anthills than other parts of HAFO. I collected one square meter of sediment in 10 cm increments to a depth of 1 m. The sediment was dry screened in the field with a 1-mm mesh sieve and washed through a 0.25-mm screen upon return to the HAFO research facility. The concentrate was examined with a binocular microscope for any fossils. No fossils were found in the *in situ* sediments, although fossils were recovered from the loose surficial sediment immediately overlying and adjacent to the *in situ* excavation. Surface float specimens at HAFO should not be considered in place, but merely at a lowest possible elevation.

Blowouts

Blowouts within HAFO are conspicuous as flat, level areas devoid of vegetation that are filled with loose sand and abundant fossils (Figure 2.6). Other flat areas are at the western edge of HAFO where the section is capped by Tuana Gravel. Blowouts were described as producing a concentration of fossils from the winnowing of finer sediments (Shotwell, 1958; Bjork, 1970). In situ material stratigraphically above two of the most productive blowouts at HAFO was sampled to assess the original fossil density. At each a 1 m by 0.5 m block of sediment was removed beginning approximately one meter stratigraphically above the level of the blowout to a depth of 1 m. In both cases, the sediment was entirely trough crossbedded sands. Sampling methodology followed that outlined above for *in situ* sediments. No fossils were recovered in the *in situ* channel sands.

Excavating through the blowout surface revealed the source of the fossils (Figure 2.7). The loose surface sediments in the blowouts range from 1 to 10 cm in thickness, and generally thicken toward the northeast. The loose sediments are

Figure 2.6. Blowout in Hagerman Fossil Beds National Monument.

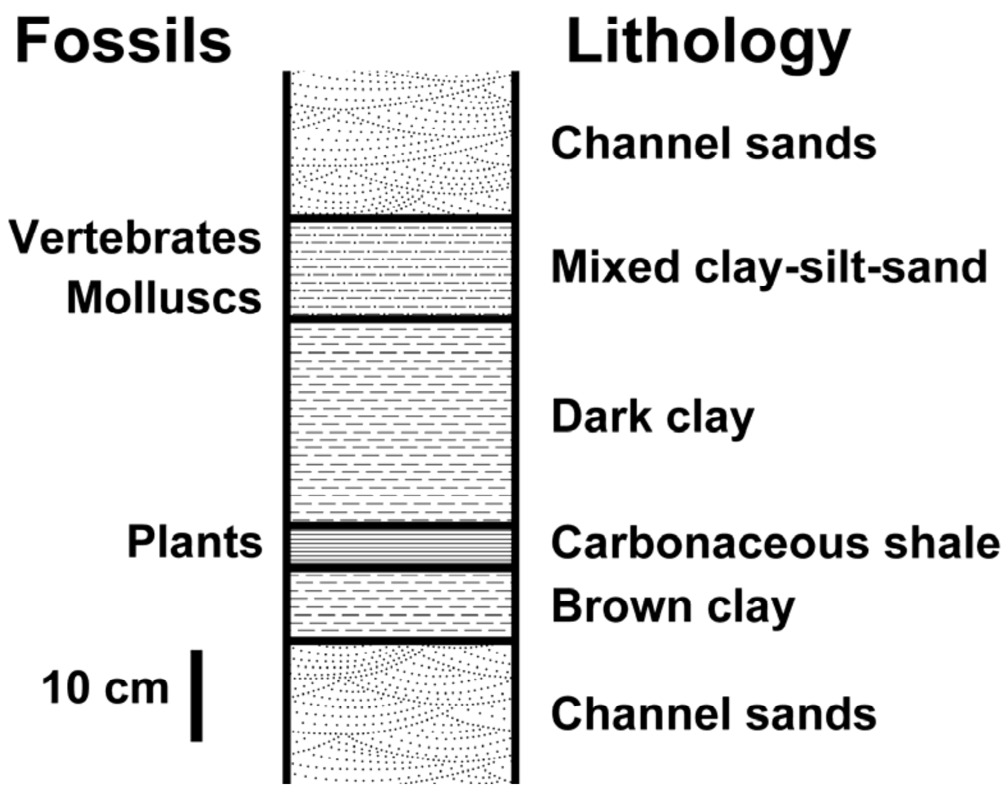


Figure 2.7. Typical microstratigraphy of blowout localities at Hagerman Fossil Beds National Monument.

derived from a mixed clay-silt-sand layer under the channel sands; most likely the channel sands also contribute to this loose material. Underlying the mixed layer in the blowout is a massive dark clay layer, gray in places, but greenish black in others. Stratigraphically lower is a carbonaceous shale and brown clay; below these is another large package of channel sands. The dark clay, brown clay, and channel sands did not contain visible fossils. The carbonaceous shale does contain abundant plant fragments, but no animal remains were identified.

The mixed layer consists of poorly-sorted clay, silts, and sands and averages about 12 cm in thickness (Figure 2.7). This layer is easily eroded and only found lateral to the blowout where it is still overlain by other layers. Pelecypods occur throughout this layer, but are extremely fragile and difficult to excavate intact. Sediment samples weighing approximately 1 kg were taken from the top, middle, and bottom third of this mixed layer. The top third yielded 270 vertebrate fossils, the middle third produced 1334 vertebrate fossils, and the bottom third contained only a single specimen. Rather than being the winnowed concentrate of some large volume of sediments of unknown stratigraphic provenance, the fossils in the blowouts are derived from a discrete layer only a few centimeters thick.

The microstratigraphy of the blowout localities can be explained with a sequence stratigraphic approach (sensu Van Wagoner et al., 1988). Although sequence stratigraphy is most commonly applied to marine and coastal depositional systems controlled by sea level, it is increasingly used with nonmarine closed basins because of the hydrocarbon potential in lacustrine sediments (Keighley et al., 2003).

Depositional environments for the lithologies at HAFO are fluvial channel deposits for the trough crossbedded sands, shallow lacustrine for the massive clay layers, lacustrine delta for the mixed clay-silt-sand layer, and deep lacustrine for the carbonaceous shale (Milligan and Lemons, 1998). A local transgression raised the water level of the lake, corresponding to the vertical change from sands to clay to carbonaceous shale. A regression followed, lowering the water level until the lake no longer existed in this locality. This decrease in water level was likely the result of a drought, in which case streams would be the primary source of drinking water. Fluvial transport of vertebrate remains could then bring the fossils to the lacustrine delta.

Other Fossiliferous Formations at HAFO

The majority of sediments at HAFO are exposures of the Glenns Ferry Formation sands, silts, and clays. Because other sedimentary formations do occur within the boundaries of the monument, their ages, and the potential for vertebrate fossils to be recovered from them, warrant discussion.

A few vertebrate fossils are known from the Tuana Gravel, but these are only of large mammals. Mammalian fossils from the Tuana Gravel include proboscidean fragments reported by Schultz, Tanner, and Lewis (in Malde and Powers, 1962) and a *Camelops* skull, femur, and humerus currently in the HAFO collections (Thompson and White, 2004; personal observation). These fossils were recovered from gravelly sand units and exhibited signs of extensive erosion because of transport (Sadler et al., 1997). No small vertebrate fossils are known from the Tuana Gravel.

There are no reliable dates on the Tuana Gravel itself; geochronology of the unit is dependent on radiometric dates and biochronologic age estimates of overlying and underlying deposits. Stratigraphically constraining the age of the Tuana Gravel is the overlying Bruneau Formation and the older Glenns Ferry Formation. The Bruneau Formation, contains basal basalts at Jackass Butte with K-Ar dates of 1.92 +/- 0.16 and 2.06 +/- 0.24 Ma (Amini, 1983; Amini et al., 1984a, b, 1985). These dates support a Pliocene age for the Tuana Gravel.

The Froman Ferry sequence, at the top of the Glenns Ferry Formation, was estimated to date between 1.5 and 1.67 Ma (Repenning et al., 1995) based upon magnetic stratigraphy of the section (Van Domelen and Rieck, 1992) and an Ar-Ar date for the overlying basalt from Pickles Butte of 1.58 +/- 0.085 Ma (Othberg in Repenning et al., 1995). Between the basalt from Pickles Butte and the Froman Ferry beds is an unconformity of unknown duration. However, the paleomagnetic survey found only reversely polarized sediments, so "on the basis of vertebrate fossil assemblages and the large apparent thickness of reversed polarity sediments…the Froman Ferry section was deposited sometime during the long reversed period after the end of the Olduvai Subchron, probably between 1.67 Ma and about 1.4 Ma" (Van Domelen and Rieck, 1992:6). Actually, the only fossil vertebrate used to determine this time frame was the presence of *Phenacomys gryci*: "Aside from *P. gryci*, all fossil material from the Froman Ferry localities, including diatoms…is typical of the well-studied Blancan V-age [sensu Repenning, 1987] Grand View fauna" (Van Domelen and Rieck, 1992:5). Repenning (1987) suggested the duration of his Blancan V land mammal age as 2.6 to 1.9 Ma and his Irvingtonian I as 1.9 to 0.9 Ma. Therefore the dates for the magnetic stratigraphy (Van Domelen and Rieck, 1992) were based on the presence of *Phenacomys gryci* in the Irvingtonian I (sensu Repenning 1987) and specifically excluded all other taxa at Froman Ferry which suggested an older age (Blancan V; sensu Repenning, 1987). The dates from the magnetic stratigraphy were then used to date the Froman Ferry sequence and the dispersal of *Phenacomys gryci* into the conterminus United States (Repenning et al., 1995).

If the Froman Ferry beds were actually deposited during the reversed interval above the Olduvai, which with refinement of the geomagnetic polarity time scale (Berggren et al., 1995) increases the older age boundary to 1.77 Ma, it represents the youngest 'dated' occurrence of several biochronologically-useful taxa (Bell et al., 2004). However, the possibility that the reversed polarity of the Froman Ferry sequence could represent an earlier time in the Matuyama (which is indicated by the fossil mammal assemblage except for *P. gryci*) has not been discussed. Below the Olduvai is another long interval of mostly reversed polarity (2.58 to 1.95 Ma) interrupted only by a brief (2.14 to 2.15 Ma) normal polarity event (Berggren et al., 1995). This reversed polarity interval closely matches the span of the Blancan V. If the Froman Ferry sequence were deposited during this earlier part of the Matuyama, the temporal range of *P. gryci* within the contiguous United States would be extended, however, this species is known in Alaska at about 2.3 Ma (Repenning et al., 1987). Additionally, the last occurrences of *Hypolagus*, *Borophagus*, and *Ophiomys* during the earlier part of the Matuyama would reduce the ranges of those taxa and be more concordant with records elsewhere. I consider it most likely that the sequence from Froman's Ferry is older than previously understood and future work on Blancan biostratigraphy should take this older age into account.

The basalt from Pickles Butte was said to interbed with the Glenns Ferry Formation to the east of the Froman Ferry sequence (Weasma in Repenning et al., 1995). If true, this would be the only evidence supporting a Pleistocene age for any portion of the Glenns Ferry Formation. This observation, however, may actually be the result of a misidentification of units. The Glenns Ferry Formation in the Boise Valley was overlain by Tenmile Gravel prior to eruption of the basalt at Pickles Butte (Othberg, 1994; personal observation). Sedimentary units interbedded with early to middle Pleistocene basalts in the area are likely strata of the Bruneau Formation.

The Yahoo Clay contains molluscs and pollen (Malde, 1982), but there are no published records of fossil vertebrates. The collections at HAFO contain five vertebrate fossils said to be from the Yahoo Clay on the monument, but locality data are incomplete and the fragmentary nature of the fossils precludes identification more specific than 'mammal.' The Crowsnest Gravel rests on surfaces formed during the dissection of the Yahoo Clay (Bliss and Moyle, 2001), but no fossils are known from the Crowsnest Gravel.

CHRONOLOGY OF THE GLENNS FERRY FORMATION

Vertebrate Biochronology

The study of fossil fish from the Idaho Group has a long history, beginning in the 19th century (Cope, 1870a, b, 1883a, b; Newberry, 1870a, b, 1871a, b; Leidy, 1873). Following a long hiatus, study of the fish from the Glenns Ferry Formation was revived at the University of Michigan (e.g., Uyeno, 1960, 1961; Miller and Smith, 1967) and Idaho State University (e.g., Linder, 1970; Linder and Koslucher, 1974). The Idaho Group contains the most diverse late Cenozoic fish fauna in western North America (Smith, 1981) and is about twice as diverse as extant fish faunas in western North America (Miller and Smith, 1967).

Fossil fish faunas reflect the depositional environment and can be used for biochronologic interpretation within much of the western Snake River Plain (Smith et al., 1982). The fish fauna is significantly different taxonomically between the Chalk Hills and Glenns Ferry formations, and variation in the number of pharyngeal teeth of *Mylocheilus* distinguishes the upper, middle, and lower Glenns Ferry Formation (Smith et al., 1982). The fish faunas from Lake Idaho are regarded as lacustrine, except for the fossils from Hagerman (Smith, 1975). Fossil fish from HAFO are indicative of more fluvial settings than likely for the Glenns Ferry Formation elsewhere.

The numerous publications on mammalian biostratigraphy in the Pliocene and Pleistocene of North America were recently reviewed and extensively revised

(Bell et al., 2004). Characteristic taxa restricted to the Blancan and known from the Glenns Ferry Formation at HAFO include *Megalonyx leptostomus*, *Procastoroides*, *Mictomys vetus*, *Ophiomys*, *Ondatra minor*, *Canis lepophagus*, *Ursus abstrusus*, and *Platygonus pearcei*. Taxa at HAFO first appearing earlier, but characteristic of the Blancan include, *Hypolagus*, *Paenemarmota*, *Satherium*, *Trigonictis*, and *Megantereon*. Of the characteristic Blancan species first appearing in the Blancan and persisting into the Irvingtonian, only *Mammut americanum* occurs at HAFO. Based on the characteristic taxa, all of the Glenns Ferry Formation at HAFO is referable to the Blancan exclusive of the late Blancan (sensu Bell et al., 2004).

Repenning (1987) put HAFO localities below the 2950 foot contour in his Blancan II and those above in Blancan III. *Ondatra minor* and *Ophiomys taylori* were used as characteristic of Blancan III faunas. The lowest occurrence of *Ondatra* at HAFO is 27 m above the Cochiti subchron of the Gilbert Chron (McDonald et al., 1996); the top of the Cochiti is dated at 4.18 Ma (Berggren et al., 1995). Until recently, this scenario of the Hagerman faunas spanning from the Blancan II to the Blancan III persisted. A subsequent revision of the arvicoline biochronology of North American included all of the Hagerman beds within the Blancan III, which was suggested as extending from 3.7 to 3.0 Ma (Repenning et al., 1990). The Blancan III as currently recognized extends from approximately 4.1 to approximately 2.5 Ma (Bell et al., 2004) and includes the Blancan IV (sensu Repenning, 1987; Repenning et al., 1990). The deposits at HAFO allow not only for detailed examination of the chronological range of these divisions of the Blancan land mammal age, but also for study of faunal changes that may occur in addition to the occurrences of the characteristic taxa of these divisions (e.g., Chapters 5-7).

Magnetostratigraphy

The pattern of magnetic polarity reversals within the Glenns Ferry Formation in the Hagerman area is rather simple. The longest section at HAFO, Peters Gulch, contains two intervals of deposition during reversed magnetic polarity and two intervals of normal polarity (Neville et al., 1979; Neville, 1981). Two sections elsewhere at HAFO contain one normal and one reversed interval each, and another section consists of only reversed polarity sediments (Neville et al., 1979; Neville, 1981). The geomagnetic polarity determinations for the four sections studied at HAFO were correlated in part with prominent volcanic stratigraphic markers. Based on radiometric dates by Evernden et al. (1964), the geomagnetic polarity pattern observed at HAFO was interpreted to span the Gilbert-Gauss boundary (Neville et al., 1979; Neville, 1981). The upper- and lower-most intervals were included within the Mammoth reversed and Cochiti normal subchrons, respectively. Recent calibration of the global magnetic polarity time scale has refined some of the associated dates. The base of the Mammoth is currently at 3.33 Ma and the top of the Cochiti is at 4.18 Ma (Berggren et al., 1995).

Radiometric Dates

The basalts and ashes in HAFO provide potential material for radiometric dating. Unfortunately some of the results from discrete horizons have yielded discordant ages, and some others are too imprecise to be useful (Lee et al., 1995).

Samples of Banbury Basalt from near Hagerman gave K-Ar dates of 4.4 +/- 0.6 and 4.9 +/- 0.6 Ma (Armstrong et al., 1975). The Notch Butte fauna was derived from sediments within flows of the Banbury Basalt and includes mammals described as late Hemphillian and dating to between 4 and 5 Ma (Akersten et al., 1999). The presence of *Pliotaxidea* and *Teleoceras* does suggest a Hemphillian age (Tedford et al., 2004), but if the cf. *Mimomys* represents a species of *Mimomys*, the fauna is actually very early Blancan in age (Bell et al., 2004). Based on faunas from Nevada, the Blancan-Hemphillian boundary was constrained at between 4.89 and 4.98 Ma (Lindsay et al., 2002). In this case, a biochronologic date actually serves to refine a radiometric date, instead of the other way around; the actual age of the Banbury Basalt is about 4.9 Ma.

Fission-track dates of 7.4 and 8.55 Ma on the Peters Gulch Ash (Kimmel, 1979, 1982), which occurs in the Glenns Ferry Formation within HAFO, exceed the K-Ar age of the underlying Banbury Basalt (Armstrong et al., 1975). A later fission-track study on the Peters Gulch Ash produced a much more concordant result of 3.75 +/- 0.36 Ma (Izett, 1981). The discrepancy between these dates and more recent Ar-Ar analyses (4.19-10.74 Ma; Peters in Sadler et al., 1997) may be the result of the Peters Gulch Ash containing reworked components (Sadler et al., 1997).

Stratigraphically higher is the Fossil Gulch Ash, which was K-Ar dated at 3.3 Ma (Evernden et al., 1964). Recent Ar-Ar analyses on a basaltic glass (Bed G) above both of the above-mentioned ashes established a date of 3.79 +/- 0.03 Ma (Hart and Brueseke, 1999).

Basalts from HAFO show a scatter of K-Ar results (Everden et al., 1964; Armstrong et al., 1975, 1980) similar to the ash dates. More precise Ar-Ar analyses yielded dates of 3.40 +/- 0.02 and 3.68 +/- 0.02 Ma for the Deer Gulch Basalt and Shoestring Basalt, respectively (Hart and Brueseke, 1999). This results in an extrapolated age for the Peters Gulch Ash within the range proposed by Izett (1981). A dacitic ash described as synchronous or slightly older than the Hagerman Horse Quarry was dated at 3.2 Ma, but the age was considered too young based on the hydrated nature of the glass shards (Evernden et al., 1964). It is unclear if this ash is chronologically equivalent to the silicic tephra that was sampled above the Hagerman Horse Quarry and yielded a poorly constrained Ar-Ar date of 3.7 +/- 0.7 Ma (Hart and Brueseke, 1999). This silicic tephra was estimated to date at approximately 3.19 Ma based on uniform sediment accumulation rates between higher and lower levels anchored with paleomagnetic and more precise radiometric dates (Hart and Brueseke, 1999).

The recent radiometric dates produced by Hart and Brueseke (1999) allow further revision of the magnetic stratigraphy interpretations for HAFO. Dates for the Shoestring Basalt and a basaltic ash (Bed G) above Fossil Gulch Ash and the predicted magnetic character from the geomagnetic polarity time scale (Berggren et al., 1995) match the paleomagnetic observations at HAFO (Neville et al., 1979). Likewise, the date estimated for the Hagerman Horse Quarry is consistent with the normal polarity observed. This placement, however, is younger than the Mammoth subchron. The reversed polarity sediments stratigraphically above the HHQ must therefore have been deposited during the Kaena. The Kaena subchron extended from 3.11 to 3.04 Ma (Berggren et al., 1995) and encompasses the youngest Glenns Ferry Formation sediments at HAFO (Figure 2.8).

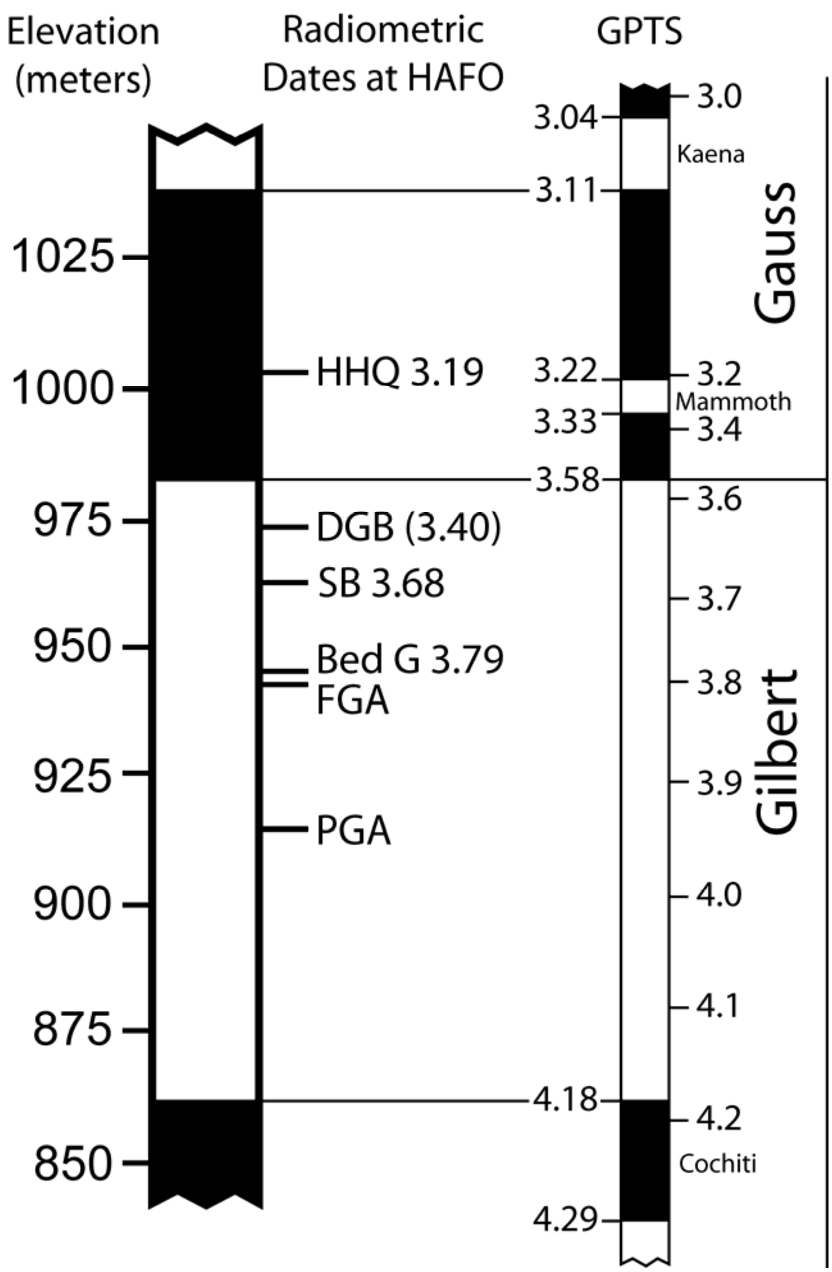
The Ar-Ar date on the Deer Gulch Basalt of 3.40 Ma (Hart and Brueseke, 1999) falls within a global interval of normal polarity (Berggren et al., 1995), but the samples taken from the Deer Gulch Basalt (and 35 m of sediments above it outside of HAFO) are reversely polarized (Neville et al., 1979; Neville, 1981). In support of their date for the Deer Gulch Basalt, Hart and Brueseke hypothesized a "Deer Gulch – Shoestring Unconformity" (1999:19) which resulted in the absence of sediments from 3.68 to 3.4 Ma. About 12 km north of HAFO, the Deer Gulch Basalt does directly overly the Shoestring Basalt, but as much as 11 m of sediment lies between the basalts closer to HAFO. Additionally, this sediment is entirely of reversed polarity (Neville et al., 1979; Neville, 1981), whereas most of the duration of the proposed "Deer Gulch – Shoestring Unconformity" falls within a normally polarized portion of the Gauss. Finally, this scenario requires lowering the globally determined older boundary of the Mammoth subchron by at least 70 ka to 3.4 Ma. A subsequently published stratigraphic column for the Glenns Ferry at HAFO (Link et al., 2002) incorporated radiometric dates from Hart and Brueseke (1999), but did not accept their proposed unconformity. I also consider the "Deer Gulch – Shoestring Unconformity" to be unlikely. My placement of the Deer Gulch Basalt is interpolated in Figure 2.8 based on the radiometric date for the Shoestring Basalt and the paleomagnetic date for the Gilbert-Gauss boundary.

Development of Hagerman Horse Quarry Datum

To properly place the HAFO faunas in their correct relative and absolute stratigraphic position, correlations must be made between localities within HAFO. Previously published stratigraphic sections (Bjork, 1970; Lee et al., 1995), established chronostratigraphic marker beds (Powers and Malde, 1961), and geologic maps of HAFO (Figure 2.9) were used to produce an isopleth map (Figure 2.10) showing the elevation adjustment necessary to bring localities into their proper chronologic position. Connecting fossil localities within HAFO in this manner to other Glenns Ferry Formation faunas west of Hagerman would be more difficult. Although several time-stratigraphic ash beds connect much of the Glenns Ferry Formation, the most widespread beds could not be traced to ashes in HAFO (Swirydczuk et al., 1981, 1982).

Although the stratigraphy of the Glenns Ferry Formation is relatively simple, a few factors complicate attempts to compare faunas from HAFO in a stratigraphic context. First, although the beds are nearly horizontal, there is a slight dip. Second, significant faulting occurs in the southern part of the monument. Finally, the

Figure 2.8. Composite stratigraphic section of the Glenns Ferry Formation at HAFO with radiometric dates and geomagnetic correlations. Only dates and correlations accepted in this study are depicted here, with the exception of the Deer Gulch Basalt date shown in parentheses. Abbreviations: DGB, Deer Gulch Basalt; FGA, Fossil Gulch Ash; GPTS, geomagnetic polarity time scale; HAFO, Hagerman Fossil Beds National Monument; HHQ, Hagerman Horse Quarry; PGA, Peters Gulch Ash; SB Shoestring Basalt. GPTS dates follow Berggren et al. (1995) and are given in Ma. Paleomagnetic stratigraphy for the Glenns Ferry Formation follows Neville et al. (1979). Dates for Bed G, SB, and DGB are Ar-Ar analyses from Hart and Brueseke (1999). The HHQ date from Hart and Brueseke (1999) is based on a combination of evidence.



Elevation (meters)
Radiometric Dates at HAFO
GPTS
1025
1000
975
950
925
900
875
850
HHQ 3.19
DGB (3.40)
SB 3.68
Bed G 3.79
FGA
PGA
3.04
3.11
3.22
3.33
3.58
4.18
4.29
3.0
Kaena
3.2
Mammoth
3.4
3.6
3.7
3.8
3.9
4.0
4.1
4.2
Cochiti
Gauss
Gilbert

Figure 2.9. Geology of Hagerman Fossil Beds National Monument. Geology follows Malde and Powers (1972), updated according to Malde (1991); eastern edge of HAFO along Snake River follows the Hagerman Quadrangle topographic map published by the United States Geological Survey (1992); faults are mapped as in Bjork (1970) and Malde and Powers (1972).

Figure 2.10. Isopleth map of Hagerman Fossil Beds National Monument showing the change in elevation necessary to adjust localities in the Glenns Ferry Formation to the HHQ datum. SS1, SS2, and SS3 indicate the positions of measured sections reported by Lee et al. (1995); A, B, C, D, E, F, and H show the positions of measured sections by Bjork (1970) used here. Shaded area represents the faulted area where no estimates are made as to the elevation changes needed to adjust to the HHQ datum. Isopleths are dashed when placed with less certainty. Isopleths as drawn continue under the thin deposits of colluvium, Yahoo Clay, Crowsnest Gravel, and small isolated pockets of Tuana Gravel, but not under the much more substantial Tuana Gravel exposures capping the plateau to the west of HAFO.

localized lateral accumulation of channel sands results in variable thicknesses during known intervals of deposition.

The average dip in the northern part of HAFO does not exceed 3°; the directions of dip vary from about N45W to N45E (personal observation). In the southern part of the monument, faulting resulted in the tilting of a wedge that dips at about 5°NE at the tip of the wedge to the northwest, and increases to a dip of over 10°NE south of HAFO (Bjork, 1970). Maps of faults in or near the southern part of HAFO by Bjork (1970) and Malde and Powers (1972) are inconsistent with each other (Figure 2.9). In the south-central and southeastern portions of HAFO (sections 4 and 3, T8S, R13E, Boise Meridian) the placements of inferred faults differ by more than 0.5 km. Also, contrasting with the suggestion of two faults that merge into each other within HAFO (Bjork, 1970), Malde and Powers (1972) only depicted a single fault within HAFO (and a second south of the monument. The fault placements are mainly tentative, and although several small faults are known in the area, none has the offset necessary to account for the presence of the Deer Gulch and Peters Gulch Ash as much as 50 m higher south of the faulted area than north of it. The problematic area in Figure 2.10 is shaded to indicate the inability to confidently place Glenns Ferry Formation localities in this area into a stratigraphic framework. Much of this difficulty is from the abundance of Yahoo Clay and Crowsnest Gravel in the area (Figure 2.9), obscuring the Glenns Ferry Formation. However, because the Glenns Ferry Formation is covered, there are few fossil localities in this area.

Because the HHQ is the best known locality within HAFO, this site is the anchor for an idealized stratigraphic section to allow comparisons between localities. More accurately, because the multiple excavations of the HHQ have actually encompassed slightly different stratigraphic thicknesses and levels (Akersten and Thompson, 1992), the anchor point to the modern elevation is at the current top of Smithsonian Institution Hill. In the area of HHQ, the measured section 'A' of Bjork (1970) represents the idealized section. Deeper sediments are not well exposed in Fossil Gulch and the stratigraphic levels must be interpreted from other measured sections. Figure 2.8 shows the complete HHQ datum section with adjusted thicknesses and dates. The time scale in Figure 2.8 varies because the estimated rates of deposition at HAFO vary. Deposition rates are held constant within intervals bracketed by either radiometric or paleomagnetic dates. Although fluvial systems are unlikely to maintain a constant rate of deposition, by breaking the HAFO section into such intervals, the results are more accurate than any estimates based on an overall average value.

The isopleth map in Figure 2.10 indicates the amount of shift in elevation necessary to place faunas within the HHQ datum. These shifts are based primarily on correlations between previously-published measured sections (Bjork, 1970; Malde, 1972; Lee et al., 1995). Stratigraphic changes between measured sections were calculated with arithmetic averages unless other evidence was present. Isopleth lines placed with less certainty are drawn as a dashed line. These instances include areas far from measured sections, elevations significantly above or below the observed intervals in nearby measured sections, areas near faults, and areas where the reason for the change in elevation observed in measured sections is unclear.

Appendix A contains a list of HAFO localities, their equivalents at other institutions with significant collections, and the revised elevations. Fossil localities are not indicated on Figure 2.10 because of concerns associated with protecting the fossil resources of HAFO and because of the difficulty in illustrating hundreds of localities on a small map. Detailed locality data are on file, and available to qualified researchers, with HAFO. The list of revised elevations for each site permits proper placement of fossils from published locality numbers.

Along with the HHQ datum-adjusted elevations, estimates were made of the stratigraphic resolution possible for each locality. These values should be considered a 'worst case scenario' and only useful in a general sense to compare reliability of stratigraphic placement. Estimates are based on personal observation of data from topographic maps, GPS data, photos, and any other methods of locating the sites. Older GPS data were sometimes discarded when they contrasted sharply with simple field observations such as presence on ridgelines. The elevation of the HHQ is the current value of the recent National Park Service excavations; adjustment for other collections from the HHQ can be made using the data provided by Akersten and Thompson (1992). The minimum stratigraphic resolution possible was considered to be 1 m.

CONCLUSIONS

Much background work is synthesized here so that published records of Hagerman fossils and unpublished materials currently in collections can be used without revisiting and reevaluating each of the hundreds of localities from the Glenns Ferry Formation in HAFO. The list showing the equivalent locality numbers between the three largest collections from HAFO (Appendix A) facilitates combining data from these institutions. The nature of fossil deposits was previously published for only a few of the hundreds of localities at HAFO. Although it was not possible to do so for all localities, the nature of more than 350 fossil deposits is presented here.

The most significant discovery presented here is the nature of the blowout localities at HAFO. Fossils in blowouts are derived from discrete, thin layers, rather than being the winnowed concentrate of an unknown amount of overlying sediment. This means that the fossils from these localities can be accurately placed into a stratigraphic context and included in studies of faunal changes through time. Blowout deposits outside of HAFO should also be closely examined to determine if they are also the product of a discrete layer.

I anticipate that this study will need ongoing updates for two reasons. First, locality data for some sites listed here as 'unknown' may exist. Second, fossil collecting is ongoing at HAFO and new localities will certainly be discovered. As they are found, the National Park Service is carefully documenting the nature and precise location of each locality.

CHAPTER 3. MIDDLE PLIOCENE PALEOCLIMATE IN THE GLENNS FERRY FORMATION OF HAGERMAN FOSSIL BEDS NATIONAL MONUMENT, IDAHO: A BASELINE FOR EVALUATING FAUNAL CHANGE

ABSTRACT

The densely fossiliferous Glenns Ferry Formation (Pliocene) at Hagerman Fossil Beds National Monument (HAFO), Idaho, is well suited for study of the effects of climate change on mammalian paleofaunas. Current understanding of the paleoenvironment in the Glenns Ferry Formation at HAFO, however, does not discriminate among more than two climate regimes. In order to produce a much more refined pattern of climate change, I synthesized data for the time interval represented at HAFO and connected the resulting patterns to established chronological markers in the Glenns Ferry Formation. Data were gathered from deep-sea records in areas estimated by global climate models to change in concert with the HAFO area. Temperature records indicate a slight cooling during deposition of the lower portion of the Glenns Ferry Formation at HAFO. This was followed by a rapid cooling event centered at about 3.45 Ma and rapid warming until about 3.2 Ma. The uppermost portion of Glenns Ferry Formation at HAFO is

progressively cooler. Records of precipitation are more difficult to quantify, but based on sedimentological data, an interval of abundant surface water at HAFO is suggested from 3.94 to 3.65 Ma.

INTRODUCTION

Recent publications have emphasized the importance of the Pliocene in paleoclimate studies because this relatively recent interval had warmer global temperatures than at present (e.g., Zubakov and Borzenkova, 1988; Cronin and Dowsett, 1991; Poore and Sloan, 1996a). The warmer climates are similar to those that are hypothesized to result from continued anthropogenic emissions of greenhouse gases; the Pliocene can therefore be used to estimate the potential impact of both global warmth and global warming (Poore and Sloan, 1996b). Additionally, Pliocene deposits are abundant and widespread, most fossil taxa have close phylogenetic relationships to modern forms, and stratigraphic relationships are typically better resolved, when compared to earlier warm intervals (Crowley, 1996; Poore and Sloan, 1996b). Moreover, the climate during the Pliocene includes intervals of both warming and cooling (Poore and Sloan, 1996a), which more specifically allow for examination of faunal change during periods of changing temperatures.

The rapid rate of climate change and the abundance of studies make the Pliocene an excellent time span in which to examine the effects of environmental change and to evaluate paleoclimate models, but in North America, few areas contain the long stratigraphic sections of Pliocene terrestrial deposits necessary to evaluate the impact of climate change on land mammals. Three regions are best suited for such evaluations: southern California, southwestern Kansas, and southern Idaho (Bell et al., 2004). Here I synthesize the climate data for the Pliocene interval of southern Idaho represented by the Glenns Ferry Formation at Hagerman Fossil Beds National Monument (HAFO).

For more than seven decades, HAFO has been one of the world's most important sources of Pliocene mammalian fossils (McDonald et al., 1996). The significance of that paleontological resource will be greatly expanded when it can be examined in light of the environmental changes presented here. Existing local paleoecological data from HAFO, however, do not provide adequate temporal resolution necessary to examine detailed stratigraphic changes in the mammalian assemblage in a refined climatic and temporal context. Ocean sediment records from cores collected by the Integrated Ocean Drilling Program (a continuation of Ocean Drilling Program and Deep Sea Drilling Program) provide fine-scale patterns of climate change in the Pliocene, but HAFO is about 800 km from the nearest of these cores. General circulation models (GCMs) provide paleoclimate estimates of the entire globe, but lack the desired temporal resolution. Instead, GCMs are used here to evaluate which areas on the globe likely experienced temperature patterns in the Pliocene similar to that seen in the Glenns Ferry Formation at HAFO. Temperature patterns from deep-sea cores in the areas suggested by the GCMs were averaged, to minimize the effects of local variations, producing a marine-data proxy for the terrestrial temperature pattern of southern Idaho.

PREVIOUS CLIMATE DATA FROM THE GLENNS FERRY FORMATION

Most prior paleoclimate studies (discussed below) either lumped together the entire section at HAFO, or divided the Glenns Ferry Formation into only three portions. These methods are insufficient for detailed examination of faunal response to climate change. Additionally, HAFO contains the oldest exposures of the Glenns Ferry Formation and most outcrops of Glenns Ferry Formation elsewhere are younger; therefore, studies of this formation sometimes excluded the time interval represented at HAFO. This section summarizes previous paleoecological work on the Glenns Ferry Formation, both within HAFO and elsewhere, in order to illustrate the limitations in existing data for southern Idaho in the Pliocene.

Seasonality

Miocene to Pliocene seasonality of the Glenns Ferry Formation and the older Chalk Hills Formation was estimated previously by a combination of the composition of the fossil fish assemblage and stable oxygen isotopic analyses of growth rings in an aragonitic otolith of a sunfish (Smith and Patterson, 1994). The climate of the Snake River Plain in the Pliocene was suggested as more moderate than today, with warmer mean temperatures of the coldest month (Smith and

Patterson, 1994). The estimated seasonal range in temperature during the Pliocene (21°C) is significantly less than the historical seasonal range (28°C) for southern Idaho; likewise, the mean annual temperature for the Pliocene (11°C) and today (8°C) also differ (United States Department of Commerce, 1968; Smith and Patterson, 1994). These paleoclimatic values for the Pliocene Glenns Ferry Formation are intermediate between modern temperatures and estimates for the Miocene Chalk Hills Formation (seasonal range in temperature of 11°C and mean annual temperature of 14°C; Smith and Patterson, 1994). Taken together, these data suggest a trend of overall cooling and increasing seasonality from the late Miocene to today; unfortunately, data were given for only three points during this span of more than 5 my.

The seasonal range in temperatures derived from oxygen isotopic analysis of a horse tooth from the HAFO (mistakenly referred to as *Pliohippus;* Kohn et al., 2002:155) was estimated at 12°C (Kohn et al., 2002), a 9°C difference from the estimate based on the fish otolith by Smith and Patterson (1994). Also, the seasonal range (25°C) estimated for the late Miocene based on the isotopic values of *Neohipparion* from the Rattlesnake Formation at John Day Fossil Beds National Monument, Oregon (~400 km NW; Kohn et al., 2002), differ dramatically from the value derived from the fish fauna (8°C; Smith and Patterson, 1994).

Both of the studies mentioned above included fossil material from HAFO in their determinations of paleoclimate, but because the temporal lengths of the intervals between data points are longer than the entire Pliocene interval at HAFO, they lack the resolution to examine fauna change within the Glenns Ferry Formation. Additionally, they vary widely not only in the absolute values of temperature estimates, but also in the overall trends. Based on fossil fish, the seasonal range of temperature in the Pliocene was twice that of the Miocene; based on fossil horse teeth, the range in the Miocene was twice that of the Pliocene.

Precipitation/Surface Moisture

Based on the fossil fish fauna, Smith and Patterson (1994) argued for higher precipitation rates in the Miocene and Pliocene relative to today and even presented an estimate of 300 mm/yr (~11.8 in/yr), although no data were provided in support of that value. Ostracodes also suggest wetter-than-today conditions throughout the portion of the Glenns Ferry Formation at HAFO (Forester, 1991).

Pollen data from HAFO suggest pine woodland or open forest vegetation with steppe taxa (Leopold and Wright, 1985). The lower portion of the Glenns Ferry Formation at HAFO contained pollen suggesting a conifer forest with small amounts of hardwoods. The middle and upper portions suggest an open landscape with xeric components. Additionally, the middle portion had a much higher abundance of aquatic taxa. Subsequently, a core taken near Bruneau, Idaho, yielded pollen samples at fine-scale stratigraphic intervals, but the deposits probably represent sediments younger than the Glenns Ferry Formation exposed at HAFO (Thompson, 1992, 1996).

Terrestrial isotopic records can potentially give direct paleoecologic information (Flenley, 1984). Shells of land snails record the oxygen isotopic values of the atmospheric water vapor, which in most areas is controlled by rain water (Goodfriend et al., 1989). However, humidity can alter these values when a large body of water is nearby (Goodfriend, 1992). Therefore isotopic changes in snail shells from HAFO may reflect the growth and shrinkage of Pliocene Lake Idaho. Even during intervals when Lake Idaho was relatively distant from HAFO, the abundant gastropod and mammal fossils do not readily lend themselves to isotopic analysis for the interpretation of precipitation. Ingested water would likely be associated with streams flowing through the area to Lake Idaho, but the isotopic composition of that water could be unrelated to local temperature patterns. Today the Snake River contains water that fell on parts of Idaho, Nevada, Utah, and Wyoming. This includes high and low elevation localities as well as ones with low and high precipitation rates, and high and low relative humidities. Each of these variables introduces a unique fractionation effect. Therefore, stratigraphic changes in oxygen isotopic composition in fossils from Hagerman may represent changes in the Snake River drainage or changes in precipitation patterns across unspecified distances in any of the regions within that drainage basin.

Sedimentology

The Glenns Ferry Formation at HAFO is divided into three informal units described as representing upper and lower floodplain environments and an intermediate marshy interval (Zakrzewski, 1969b; Bjork, 1970; “members” sensu Lee et al., 1995). The middle unit is bounded by the Fossil Gulch Ash above and the Peters Gulch Ash below. Based on the chronology suggested in Chapter 2, the middle member of the Glenns Ferry Formation was deposited between about 3.78 and 3.94 Ma. It is unclear whether the lowest stratigraphic exposures of Glenns Ferry Formation at HAFO identified as lacustrine deposits by Repenning et al. (1995) represent an additional extensive unit of the Glenns Ferry Formation.

The middle unit of the Glenns Ferry Formation contains abundant carbonaceous shales, which in large part led to the interpretation of deposition in a marsh flood plain environment with a relatively high water table (Malde and Powers, 1962; Zakrzewski, 1969b; Bjork, 1970; Malde, 1972). An alternate explanation based on the sequence of stratigraphic stacking suggests the carbonaceous shales are the result, at least in part, of deposition in anoxic lake waters (Chapter 2). Such lakes could result from local subsidence caused by the cooling of basalts in the Snake River Plain, or from damming by extrusive volcanism (Othberg, 1994; Malde, 1991). Regardless, both the lake and marsh hypotheses require the presence of abundant, low-energy surface water.

Significant thicknesses of carbonaceous shales at HAFO occur for about 25 m stratigraphically above the middle member, and the same environmental interpretation can be made for those beds. Therefore the wet interval at HAFO is here treated as deposits between the Peters Gulch Ash and the Deer Gulch Basalt; it includes more than the middle unit of the Glenns Ferry Formation.

OTHER TERRESTRIAL PALEOCLIMATIC RECORDS IN WESTERN U.S.

Although terrestrial climate records only provide a localized perspective of temperature trends, the availability of data from another fossiliferous Blancan locality in the western United States is mentioned here for comparison. Oxygen isotopic compositions of pedogenic carbonates from the St. David Formation of southeastern Arizona indicate slight cooling until 3.6 Ma, rapid cooling from 3.6 to 3.3 Ma, and a slight warm peak at 3.2 Ma (Wang et al., 1993). This terrestrial record matches the global pattern derived from the deep-sea cores (see below).

Analysis of pollen from Pliocene cores in seven states indicates that the western United States in general was both wetter and warmer prior to 2.5 Ma than today (Thompson, 1991). Likewise, a study of reworked pollen in sediments of southern California suggests the region west of the Rocky Mountains was significantly wetter in the Pliocene (Fleming, 1994).

GLOBAL PALEOCLIMATE IN THE PLIOCENE

The terrestrial paleoclimatic data reviewed above lack the detailed resolution needed to examine the effect of climate change on the mammalian assemblage at HAFO. In order to compare stratigraphic changes in faunas at HAFO, climate patterns are needed at much more tightly constrained temporal intervals. Global climate patterns in the Pliocene are here examined, and these patterns are then refined in light of regional data. Finally, the climate estimates will be paired with the chronology for HAFO developed in Chapter 2.

Global Circulation Models

The mean annual temperatures in the middle Pliocene were higher than today, but the differences were not distributed evenly across the Earth. Multiple global circulation models (GCMs) have estimated the mean annual temperature for the HAFO area in the Pliocene at about 3.5°C warmer than today (Raymo et al., 1990; Covey et al., 1991; Crowley et al., 1994; Sloan et al., 1996; Haywood et al., 2000, 2001; Jiang et al., 2005), although Crowley (1991) suggested no difference in temperature as compared to today. Estimates for precipitation are more variable: numerical estimates of as much as 365 mm/yr (14.4 in/yr) of additional rainfall (Sloan et al., 1996) or as much as 730 mm/yr (28.4 in/yr; Jiang et al., 2005), conflict with an earlier suggestion that the Idaho of 3 Ma experienced the same amount of precipitation as today (Crowley, 1991). Unfortunately, all of these GCMs provide estimates of paleoclimate for only a single instance in the Pliocene, usually at 3 Ma.

Although GCMs do not provide the resolution necessary to examine the faunal shifts at HAFO in light of environmental changes, they can be used to determine which other areas on Earth had similar changes in temperature, both in direction and magnitude, as HAFO. Differences in temperature between the Pliocene and today in southern Idaho are mirrored by changes in sea surface temperatures of most areas between 30° and 60° north latitude (especially the northwest Pacific and north Atlantic) and between 40° and 60° south latitude (Dowsett et al., 1996; Sloan et al., 1996; Haywood et al., 2000, 2001; Jiang et al., 2005). Deep-sea cores from these areas can therefore be used as a proxy for the pattern of temperature change in the Pliocene at HAFO. The estimated pattern of terrestrial climate change east of the Rocky Mountains differs dramatically from the area to the west, including HAFO (Haywood et al., 2002). Therefore, the pattern determined in this paper may not be applicable to other Pliocene deposits in North America.

Pliocene Climate from Deep-Sea Cores

I gathered and evaluated Pliocene temperature patterns derived from microfossil abundances and isotopic data (Table 3.1). Results were adjusted to match the Berggren et al. (1995) geologic time-scale for consistency. For the interval from 3.0 to 4.2 Ma, which encompasses the time of deposition of the Glenns Ferry Formation at HAFO, the temperature magnitudes were rescaled so that the total variation was the same in each dataset. Rescaling is appropriate because the patterns, not actual temperature estimates, are the focus of this examination. Additionally, in the case of several studies incorporated here, only relative changes were reported. Only microfossil abundance studies with temporal resolutions of 50 ky and less were

Table 3.1. References used to construct the temperature profiles. References marked with an asterisk indicate the study included only a portion of the interval being examined or did not have the preferred temporal resolution.

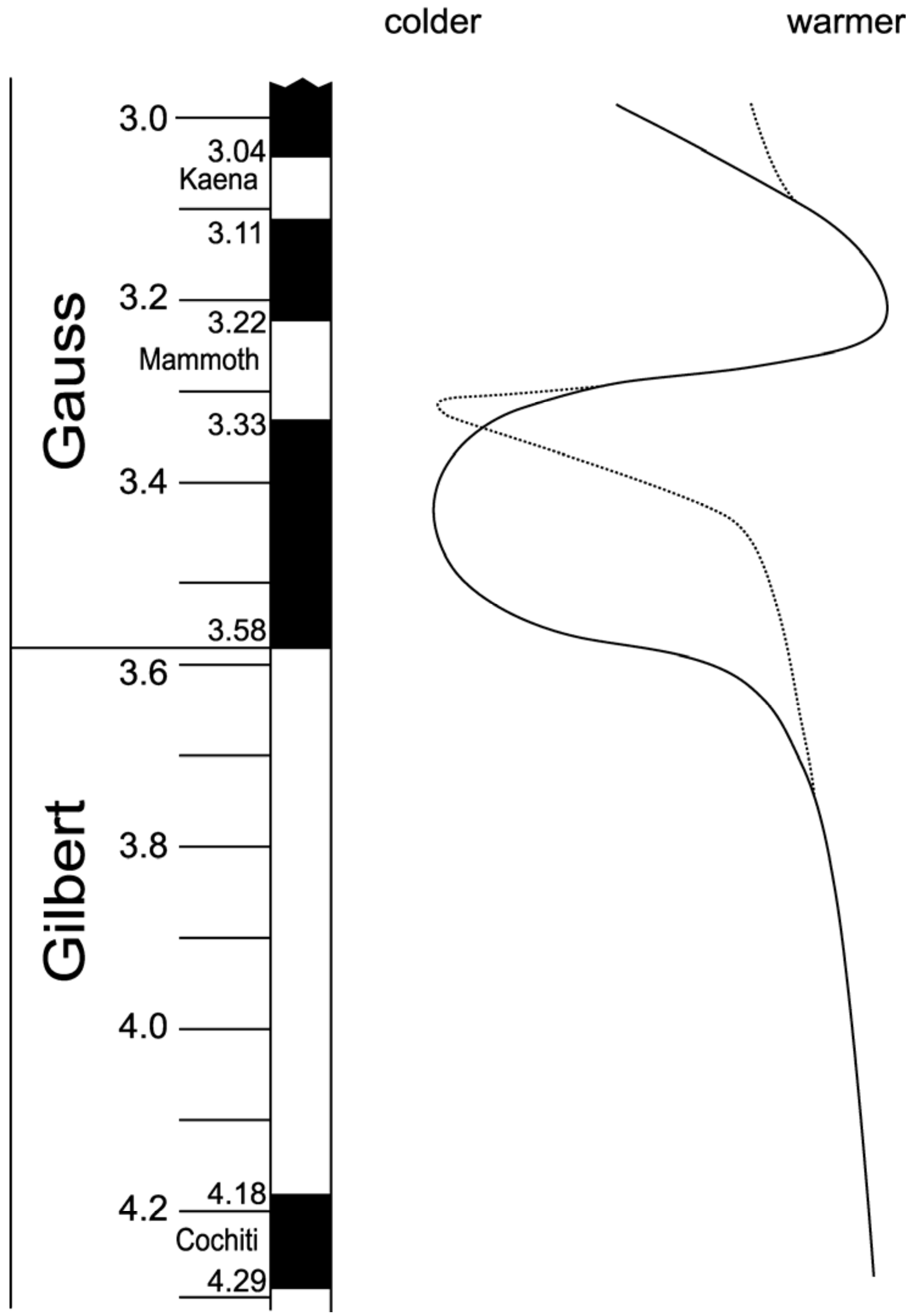
Microfossil abundance	Oxygen isotopes
Keigwin, 1976	Ciesielski and Weaver, 1974
Poore, 1981	Shackleton and Hall, 1984
Dowsett and Poore, 1990	Ciesielski and Grimstead, 1986
Hagelberg and Pisias, 1990	Hodell and Kennett, 1986
Barron, 1992*	Kennett, 1986
Cronin et al., 1993*	Keigwin, 1987
Le and Shackleton, 1994	Joyce et al., 1990
Heusser and Morley, 1996	Hodell and Warnke, 1991
Andersson, 1997	Gallagher et al., 2003*
Kameo, 2002*	Wang et al., 1993
	Tiedemann et al., 1994
	Shackleton and Hall, 1995
	Shackleton et al., 1995
	King, 1996
	Clemens and Tiedemann, 1997
	Andersson et al., 2002
	Billups, 2002

included; studies on temperatures derived from oxygen isotopes were only included when sampling increments were less than 20 ky.

Multivariate analysis of microfossil abundance was first shown to be useful for reconstruction of paleoclimate by using transfer functions for planktic foraminifers (Imbrie and Kipp, 1971). These transfer functions are sets of equations which relate environmental data to faunal diversity. This method was subsequently extended to diatoms (e.g., Sancetta, 1979), radiolarians (e.g., Hays et al., 1989), calcareous nannoplankton (Hiramatsu and De Deckker, 1997), ostracodes (Mourguiart and Correge, 1998), terrestrial mollusks (Rousseau, 1991; Moine and Rousseau, 2002; Sümegi and Krolopp, 2002), and pollen (Bryson and Kutzbach, 1974; Andrews et al., 1979; Norton et al., 1986; Pienitz et al., 1999; Fauquette et al., 1999; Andreev et al., 2001, 2002, 2003, 2004). Although originally used only for late Pleistocene sediments, extending the ecological interpretations of modern taxa to closely-related extinct forms permitted the use of transfer functions on assemblages dating back to the late Miocene (Keigwin, 1976; Poore, 1981).

In the following discussion of temperature patterns (Figure 3.1), only the studies that deviate from the norm are cited. The lower half of the interval at HAFO is marked by slight cooling (Figure 3.1), although a slight warming or no change was suggested for the northwest Pacific (Heusser and Morley, 1996). Beginning at 3.6 Ma, or perhaps as late as 3.5 Ma (Heusser and Morley, 1996), the rate of cooling was greatly accelerated. This continued until 3.35 Ma, and was followed by rapid warming for 50 to 100 ky, and a subsequent renewal of cooling. The peak that

Figure 3.1. Middle Pliocene temperature trends. The solid line indicates the temperature pattern exhibited by data generated from microfossil abundance. The dashed line illustrates where the isotopic data deviate. The data for the time scale are from Berggren et al. (1995). All dates indicated are in millions of years.

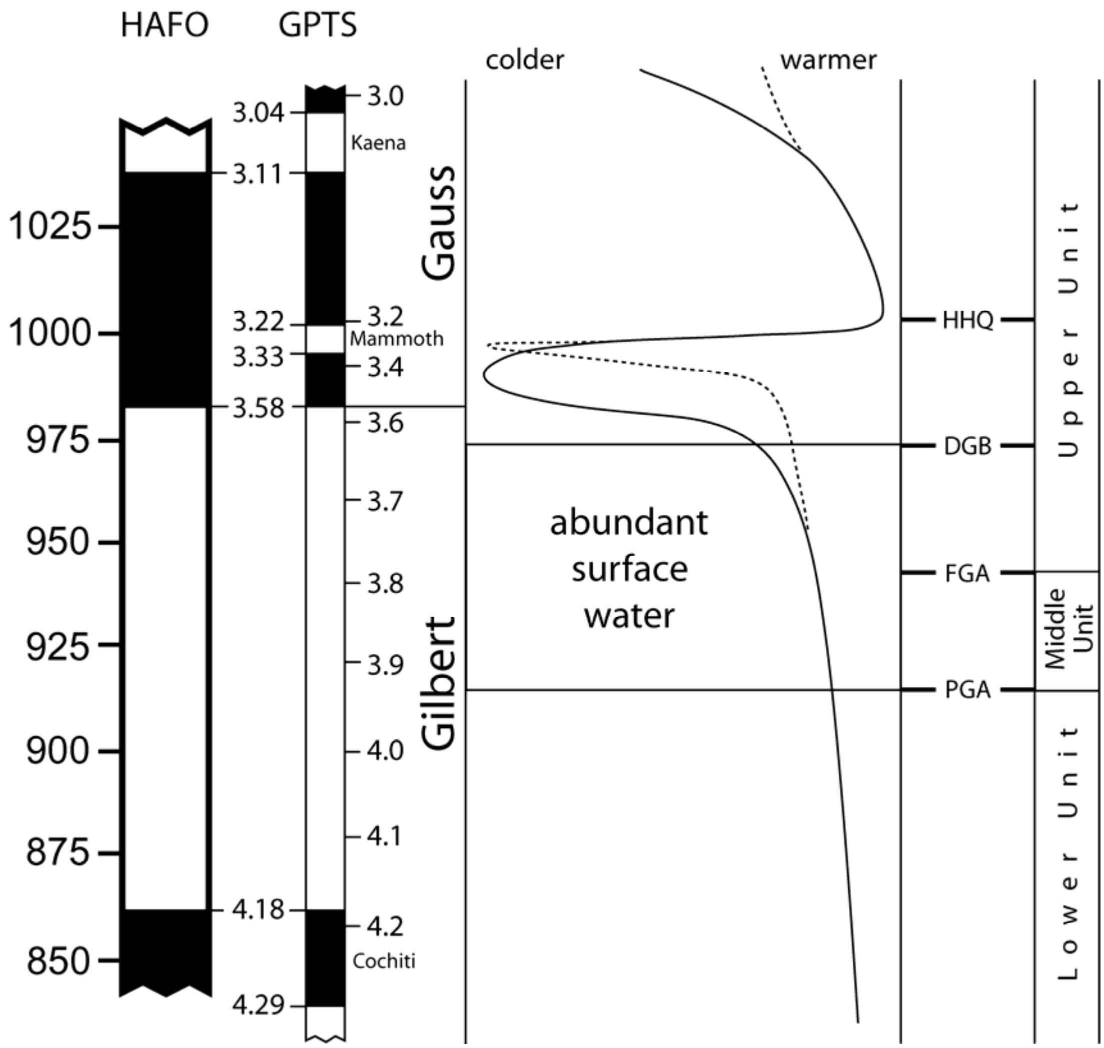

colder
warmer
Gauss
Gilbert
3.0
3.04
Kaena
3.11
3.2
3.22
Mammoth
3.33
3.4
3.58
3.6
3.8
4.0
4.18
4.2
Cochiti
4.29

marked the transition from warming to cooling occurs at 3.2 Ma, or possibly earlier at 3.25 Ma (Heusser and Morley, 1996). Contrary to this pattern of a warm peak at 3.2 Ma, Siesser (2001) provided data showing that interval to be a significant cold period in the Soloman Sea. However, the core was taken from ~9° south latitude, outside the region suggested by GCMs as similar to HAFO in the Pliocene. Also, the temporal resolution in Siesser (2001) varied from less than 10 ky to about 500 ky, and the cold peak at ~3.2 Ma is represented by only two data points. In the absence of these data points, there would be little change in temperature, except for a slight cooling trend from ~4.2 to ~2.6 Ma (Siesser, 2001).

The temperature pattern from oxygen isotopes is similar to that derived for microfossils abundance (see above), but there are two differences (Figure 3.1). The slow cooling in the lower part of the interval persisted longer, until about 3.45 Ma, according to isotopic analyses, before the onset of rapid cooling; the rapid cooling, based on isotopic data, lasted until just before 3.3 Ma. Two studies (Hodell and Warnke, 1991; Shackleton and Hall, 1995) indicated a different timing of the onset of rapid cooling (~3.5 Ma); this is earlier than other isotopic studies, but not as early as the microfossil abundance data. The other discrepancy occurs at the top of the interval; above 3.1 Ma the cooling suggested by isotopic evidence is not as rapid as that indicated by microfossils.

Because sediment deposition rates of the Glenns Ferry Formation vary between levels of known age (e.g., Hart and Brueseke, 1999), the timescale of Figure 3.1 was redrawn to match the stratigraphic record at HAFO (Figure 3.2). In

Figure 3.2. Temperature trend and surface water abundance at HAFO. The Pliocene temperature trend (Figure 3.1) is adjusted to the chronology of deposits at HAFO (from Chapter 2). Note that although the elevations are at a constant interval, the scale changes on the GPTS (after Berggren et al., 1995). Dates are in Ma; stratigraphic levels are in meters above mean sea level; discussion of radiometrically dated levels can be found in Chapter 2; subdivisions of the Glenns Ferry Formation (sensu Zakrzewski, 1969b; Bjork, 1970) are in the leftmost column. Abbreviations for some dated layers at HAFO: DGB, Deer Gulch Basalt; FGA, Fossil Gulch Ash; HHQ, Hagerman Horse Quarry; PGA, Peters Gulch Ash.


HAFO
GPTS
colder
warmer
3.0
3.04
Kaena
3.11
1025
Gauss
3.22
3.2
1000
Mammoth
3.33
3.4
3.58
3.6
975
3.7
950
abundant
surface
water
3.8
925
3.9
Gilbert
900
4.0
875
4.1
4.18
4.2
850
Cochiti
4.29
HHQ
DGB
FGA
PGA
Upper Unit
Middle Unit
Lower Unit

particular, deposition was slowest during the early portion of the Gauss magnetochron. This is the coldest interval represented at HAFO and is represented in the Glenns Ferry Formation at HAFO by significantly less stratigraphic section than equivalent durations of time elsewhere in the monument.

CONCLUSIONS

The Pliocene interval represented by the Glenns Ferry Formation at HAFO is generally characterized as a wetter and warmer time period than today. More specifically, the temperature pattern derived for HAFO indicates two cooling trends and one warming trend. Of particular interest is the occurrence of the Hagerman Horse Quarry (HHQ) at the end of a pronounced warming event. This extreme warming event could be responsible for the drought hypothesized to explain the densely fossiliferous beds at HHQ (Richmond and McDonald, 1998). Also of interest is the occurrence of the only warming trend (from the coolest interval) at HAFO during the period of slowest deposition, although it is unknown if the former is a cause of the latter.

The temperature pattern derived from deep-ocean cores as a proxy for Pliocene temperatures at HAFO matches the terrestrial isotopic data from the St. David Formation of Arizona. Modern climatic values differ dramatically between Arizona and Idaho, and values in the Pliocene were probably also different. However, the concordance of the temperature patterns suggests the same trend may be applicable to the Pliocene deposits throughout the Intermontane Plateau of the western United States. This pattern can be used as a starting place for climatic reconstructions of other terrestrial fossil localities until high-resolution local data can be shown to depict an alternative pattern.

Pliocene precipitation at HAFO is more difficult to assess, but a single interval of abundant surface water is here recognized. Although this wet period may be the result of increased rainfall at HAFO, the increase in precipitation may instead have occurred in areas that drained into southern Idaho. Alternatively, springs may have added groundwater into the HAFO ecosystem, as occurs abundantly today, or the wet conditions could result from flow being impeded further downstream. The wet interval should not be accepted as a simple proxy for increased precipitation, but the impact of a substantial increase in surface water can now be examined in a stratigraphic perspective.

Evaluation of faunal changes with stratigraphy at HAFO was previously hampered by two problems: 1) the difficulty of positioning localities in a relative framework and 2) the lack of high-resolution paleoclimate data. Chapter 2 alleviates much of the first problem by establishing the nature of most of the localities at HAFO and creating an idealized stratigraphic section on which almost all localities can be positioned. This chapter utilizes global climate models to determine which areas had patterns of climate changes in the Pliocene similar to that of the HAFO area. Deep sea records from these areas were used to establish patterns of temperature change. In light of these two advances, the abundant fossil remains at

HAFO can be compared through known intervals of time and during known intervals of environmental change.

CHAPTER 4. REVISION OF THE BLANCAN MAMMALS FROM HAGERMAN FOSSIL BEDS NATIONAL MONUMENT, IDAHO

ABSTRACT

The mammalian fossils from Hagerman Fossil Beds National Monument (HAFO), Idaho, are well known and previously were included in numerous taxonomic studies. In this chapter I summarize this great volume of literature and compile an updated list of the mammalian taxa present at HAFO. Questionable and rare records are critically evaluated, and nomenclatural changes are noted. A total of 55 species of mammals are documented from HAFO. *Baiomys minimus* and *Hemiauchenia gracilis* are reported from HAFO for the first time, and the presence of *Miracinonyx inexpectatus* is confirmed. The specimen previously described as from a tremarctine bear is reidentified as *Ursus abstrusus*.

INTRODUCTION

"The Hagerman fauna is probably the richest Blancan fauna known at present" (Kurtén and Anderson, 1980:13).

For more than seven decades, Hagerman Fossil Beds National Monument (HAFO), Idaho (Figure 4.1), has served as one of the most important sources of middle Pliocene paleontological data, particularly for mammalian fossils (McDonald et al., 1996). The exposures of the Glenns Ferry Formation within HAFO are part of the more extensive Idaho Group, which contains nine million years of relatively continuous section in southeastern Idaho and eastern Oregon (Malde, 1991). The sediments at HAFO are among the most densely fossiliferous areas of exposed Glenns Ferry Formation, both in number of specimens and distribution of localities.

The goal of this paper is to review the Pliocene mammals from the Glenns Ferry Formation at HAFO. The validity and nomenclature for each mammalian taxon previously reported is assessed and updated. Collections were also inspected for taxa previously unknown from HAFO. In total, 55 species of mammals are documented.

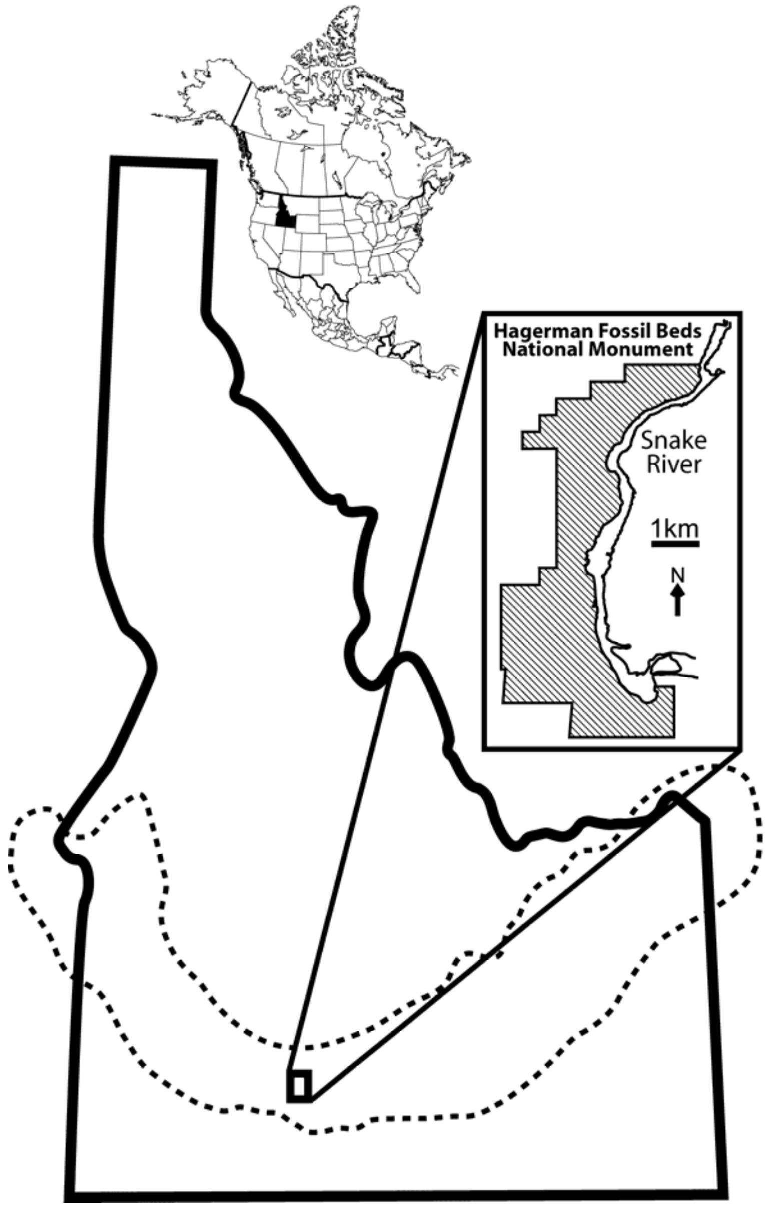


Figure 4.1. Location of Hagerman Fossil Beds National Monument within Idaho. The dotted line outlines the Snake River Plain-Yellowstone Plateau (sensu Leeman, 1982), but excludes the Owyhee Plateau in southwestern Idaho. The inset map shows the boundaries of HAFO to the west of the Snake River.

Brief History of Vertebrate Paleontology at HAFO

Study of the deposits at HAFO have continued for more than 70 years (McDonald, 1993), beginning with the early U. S. National Museum excavations from 1929 to 1934 (e.g., Gidley, 1930a, 1931). These early excavations yielded material that was described as new species of turtle (Gilmore, 1933), shrew (Gazin, 1933a), lagomorphs (Gazin, 1934a), carnivorans (Gazin, 1933b, 1934b, 1937), antilocaprid (Gazin, 1935a), peccary (Gazin, 1938), and the abundant Hagerman horse (Gidley, 1930b; Gazin, 1936). Work at HAFO was subsequently revived by the University of Michigan Museum of Paleontology with an emphasis on the microfauna. These efforts greatly refined our knowledge of the rodents (e.g., Hibbard, 1962, 1969; Hibbard and Zakrzewski, 1967; Zakrzewski, 1969b), shrews (Hibbard and Bjork, 1971), lagomorphs (e.g., Campbell, 1969), and carnivorans (e.g., Bjork, 1970). Today the fossil resources of HAFO are stewarded by the National Park Service. Most of these previous works focused primarily on morphology and alpha taxonomy (both part of the species-scale), but in a few cases included population-scale studies of abundant species such as the horses (age profiles: McDonald, 1996) and arvicoline rodents (succession: Zakrzewski, 1969b).

Nature and Age of Glenns Ferry Formation at HAFO

Pliocene vertebrates are recovered not only from in situ deposits at HAFO, but also from anthills, blowouts, and surface collections. Fossils from the Hagerman Horse Quarry, anthills, and blowout localities are considered to be essentially at the original stratigraphic level of deposition (Chapter 2). Fossils from the Hagerman Horse Quarry have a long history of research, including varying hypotheses of the method of deposition, but the in situ nature of the sediments is unquestioned. Species of modern ants belonging to *Pogonomyrmex* do gather fossils from within about a 2 m radius from their anthills (Scott, 1951), but the estimated maximum vertical movement is only 1.1 m, which is within the resolution of elevation possible at most HAFO localities. Vertebrate fossils from blowouts at HAFO are derived from single ~12-cm layers that are easily eroded and only found lateral to the blowout where it is still overlain by other layers. Fossils recovered as surface float generally should be excluded from stratigraphic comparisons because the only provenance data for them is that the level of recovery represents the lowest possible position.

The maximum age for the top of the Glenns Ferry Formation exposed at HAFO is 3.11 Ma and the minimum age for the lowermost exposures is 4.18 Ma (Chapter 2). It is unlikely that there is any Glenns Ferry Formation sediment that is younger than 3.04 Ma or older than 4.29 Ma at HAFO.

Paleoclimate in the Pliocene

The Pliocene interval represented by the Glenns Ferry Formation at HAFO is generally characterized as wetter and warmer than today. These conditions are similar to those predicted to result from anthropogenic warming in the near future, and therefore, temperature changes in the Pliocene are the subject of numerous studies. Slow cooling marked the time interval during which the lower portion of the Glenns Ferry Formation was deposited at HAFO (until 3.6 Ma). Cooling then accelerated until reaching a minimum temperature at 3.4 or 3.3 Ma. This cooling was followed by rapid warming that peaked about 3.2 Ma (Chapter 3).

Precipitation at HAFO in the Pliocene is more difficult to assess. Isotopic data are of limited use because of fractionation effects of the abundant surface water nearby and because the water originated from within a large area of undoubtedly differing conditions. An interval of abundant surface water in the middle portion of the Pliocene sequence at HAFO is indicated by sedimentological data (Chapter 3). The wet conditions could have resulted from increased precipitation in the HAFO area or in any area that drained into the Snake River, increased groundwater flow into the Hagerman ecosystem, or discharge being impeded downstream.

MATERIALS AND METHODS

The systematic paleontology compiles specific references to all fossil mammals (Table 4.1) from the Glenns Ferry Formation at Hagerman in the synonymy portion; other taxonomic considerations are discussed separately. Only publications in which specimens were identified to the species level (when possible) are included. For example, a publication stating that canids occur at HAFO is insufficient for inclusion here, unless Canidae is explicitly the most precise identification made.

Table 4.1. Pliocene mammals from Hagerman Fossil Beds National Monument.

Xenarthra

Megalonyx leptostomus

Insectivora

Sorex hagermanensis

Sorex powersi

Sorex meltoni

Sorex cf. *Sorex rexroadensis*

Paracryptotis gidleyi

Scapanus hagermanensis

Lagomorpha

Hypolagus edensis

Hypolagus gidleyi

Alilepus vagus

Rodentia

Sciuridae

Paenemarmota barbouri

Spermophilus sp. A

Spermophilus sp. B

Spermophilus sp. C

indeterminate Spermophilina

Geomyidae

Thomomys gidleyi

Pliogeomys parvus

Heteromyidae

Oregonomys magnus

Perognathus maldei

Prodipodomys idahoensis

Castoridae

Castor californicus

Procastoroides intermedius

Muridae

Sigmodontinae

Peromyscus hagermanensis

Baiomys aquilonius

Baiomys minimus

Neotoma cf. *Neotoma quadriplicata*

Arvicolinae

Ophiomys taylori

Cosomys primus

Ondatra minor

Mictomys vetus

Carnivora

Ursidae

Ursus abstrusus

Mustelida

Trigonictis macrodon

Trigonictis cookii

Taxidea sp.

Sminthosinis bowleri

Ferinestrix vorax

Satherium piscinarium

Buisnictis breviramus

Mustela rexroadensis

Felidae

Homotherium sp.

Megantereon hesperus

Puma lacustris

Lynx rexroadensis

Miracinonyx inexpectatus

Canidae

Canis lepophagus

Borophagus hilli

Perissodactyla

Equus shoshonensis

Artiodactyla

Platygonus pearcei

Ceratomeryx prenticei

Odocoileus sp.

Hemiauchenia blancoensis

Hemiauchenia gracilis

Camelops sp.

Megatylopus sp.

Proboscidea

Mammut americanum

Additionally, studies that compare faunal lists only at the generic level are excluded. References in the synonymy lists are only those that refer to material from HAFO.

Characters by which the taxon is recognized at HAFO are given in the identification sections. Although in many cases the identifying characters presented are equivalent to a diagnosis, this is not true for all cases. When non-inheritable characters such as geographic or chronologic constraints are incorporated, this is specified.

For most of the taxa represented at HAFO, I attempted to document the stratigraphic and geographic distribution outside of HAFO; for extremely abundant taxa the distribution is limited to Pliocene localities. Summaries of all localities mentioned in this text are presented in the appendices to this chapter. Just as HAFO contains hundreds of individual localities, many of the faunas discussed also contain multiple fossil-producing sites. Specific localities within these areas are not given here, but the citations given usually contain that information. States and geologic formations are not listed with each locality in the main text, but are given in the appendix. Use of North American land mammal ages follows Bell et al. (2004) for the Blancan, Irvingtonian, and Rancholabrean, and Tedford et al. (2004) for the Hemphillian, Clarendonian, and Barstovian.

Dental abbreviations: C, upper canine; c, lower canine; I, upper incisor; i, lower incisor; M, upper molar; m, lower molar; P, upper premolar; p, lower premolar. Institutional abbreviations: FHSM VP, Fort Hays, Sternberg Museum, Hays, KS; HAFO, Hagerman Fossil Beds National Monument, Hagerman, ID;

IMNH, Idaho Museum of Natural History, Pocatello, ID; UMMP V, University of Michigan Museum of Paleontology, Ann Arbor, MI; USNM, United States National Museum, Washington, D.C.

SYSTEMATIC PALEONTOLOGY

Xenarthra Cope, 1889

Megalonychidae Gervais, 1855

Megalonyx Harlan, 1825

Megalonyx leptostomus Cope, 1893

Megalonyx leptonyx? (Marsh). Gazin, 1935c: pp. 52-56, figs. 1-4; Gazin, 1936: p. 285, 288; J. Schultz, 1937: p. 85; Hibbard, 1941c: p. 87.

Megalonyx sp. Hirschfeld and Webb, 1968: pp. 231-234, fig. 5, tab. 7; Hibbard, 1972b: p. 127; Fry and Gustafson, 1974: p. 376; Gustafson, 1978: p. 34; figs. 19-20.

Megalonyx leptostomus Cope. McDonald, 1977: pp. 20-21, 163, 272, fig. 11, tab. 1, app. B, J, M, N, O; Conrad, 1980: pp. 177-178; Kurtén and Anderson, 1980: p. 136; Franz, 1981: p. 14; Sankey, 1991: p. 86-87; Lindsay et al., 1984: p. 466; McDonald et al., 1996: p. 42, fig. 11A; Currie, 1998: fig. 5A; Sankey, 2002: p. 75; Bell et al., 2004: p. 258.

Megalonix [sic]. Smith and Patterson, 1994: p. 299.

Identification of HAFO Material

As with most other North American fossil xenarthrans, *Megalonyx* on this continent probably represents an anagenic lineage delimited into chronospecies. *Megalonyx leptostomus* is intermediate in size between the larger and younger *Megalonyx wheatleyi* and the smaller and older *Megalonyx curvidens*, although isolated populations of *Megalonyx* are known to have undergone dwarfing (Hirschfeld and Webb, 1968; McDonald, 1977). The combination of size and the geological age are the dominant reasons for assigning specimens to *Megalonyx leptostomus* at most of the localities listed below. However, other characters (e.g., palate with more pronounced sigmoid shape) separate *Megalonyx leptostomus* from younger species of *Megalonyx* (McDonald, 1977)

Distribution

Megalonyx leptostomus is known from numerous Blancan localities across North America, both while megalonychids were the only ground sloths on the continent, and after the Great American Interchange, when mylodont and megathere sloths dispersed north. In addition to the type locality at Blanco (Cope, 1893), records of *Megalonyx leptostomus* were reported from 111 Ranch (Morgan and White, 2005; *Megalonyx* sp. of Galusha et al., 1984), Anza-Borrego Desert State Park (McDonald, 2006a), Buckeye Creek (Kelly, 1994), Cita Canyon (Hirschfeld and Webb, 1968; Hibbard, 1972b; G. Schultz, 1977b), Keefe Canyon (R. Martin et al., 2000 [although the appendix of their paper says "*M*. cf. *Megalonyx* *leptostomus*"]), Kuchta Sand Pit (Heaton and McDonald, 1993), Lisco (Voorhies and Corner, 1986), Rexroad 3 (R. Martin et al., 2000 [although the appendix of their paper says *M*. cf. *Megalonyx leptostomus*]), and Taunton (Morgan and Morgan, 1995; McDonald, 1998). In the late Blancan of Florida, *Megalonyx leptostomus* is known from De Soto Shell Pit, Haile 7C, Inglis1A, Kissimmee River, Macasphalt Shell Pit, and Santa Fe River 1 (Webb and Wilkins, 1984; Morgan and Hulbert, 1995; Morgan, 2005).

Tentative identifications were reported from Country Club (Morgan and White, 2005), Grand View (Conrad, 1980), and Tyson Ranch (Sankey, 1991, 2002) as *Megalonyx* cf. *Megalonyx leptostomus*, and from Arroyo de la Parida as *Megalonyx leptostomus*? (Morgan and Lucas, 2003) and *Megalonyx* cf. *Megalonyx leptostomus* (Morgan and Lucas, 2001b). Blancan records of *Megalonyx* sp. are known from Birch Creek (Hearst, 1999), Broadwater (Hibbard, 1972b), Hudspeth (Strain, 1966), Jackass Butte (Hirschfeld and Webb, 1968), Anza-Borrego Desert State Park (Downs and White, 1968), Procter Pits (Hirschfeld and Webb, 1968), and Red Light (Akersten, 1970); based on the age of these localities, the specimens may belong to *Megalonyx leptostomus*.

Remarks on Taxonomy

Gazin (1935b) identified the sloth material from HAFO as questionably belonging to the same species as Marsh's *Morotherium leptonyx*, but reassigned it to *Megalonyx*. *Megalonyx leptonyx* was later considered a nomen dubium because the type specimen was lost, the description was undiagnostic, and the age and locality data were uncertain (Hirschfeld and Webb, 1968). In spite of these problems, Shotwell (1970) subsequently identified *Megalonyx leptonyx* from Wild Horse Butte and Jackass Butte of the Grand View fauna. McDonald (1977) considered *M. leptonyx* a junior synonym of *Megalonyx leptostomus*, and subsequent authors have followed his taxonomy.

Comments on HAFO Material

The type specimen of *Morotherium leptonyx* (Marsh, 1874) may be derived from the Glenns Ferry Formation near Hagerman (Gazin, 1935c; Bjork, 1970), although Hay (1927) claimed the fossil was listed earlier by Leidy (1871) as originating from Castle Creek, Owyhee County, Idaho. It is unknown if "the fragment of a claw phalanx, apparently of a large, sloth-like animal, from Castle Creek, Idaho" (Leidy, 1871:365) is actually the specimen designated the type of *Morotherium leptonyx*. Additionally, there are multiple streams named Castle Creek currently known in Idaho, and in spite of the claim of Owyhee County by Hay (1927), Leidy (1871) does not specify. One further complication is that there are two streams named Castle Creek within Owyhee County that lie on sediments of the Glenns Ferry Formation (United States Geological Survey, 1973, 1992).

Although most recent authors assigned the HAFO sloth to *Megalonyx leptostomus*, some refrained from that decision. In a review of North American megalonychids Hirschfeld and Webb (1968) suggested that although the HAFO

Megalonyx was probably referable to *Megalonyx leptostomus*, specific assingment should be deferred until the species of *Megalonyx* could be delimited consistently. Additionally, when Gustafson (1978) named *Megalonyx rohrmanni* from White Bluffs he repeatedly described the HAFO *Megalonyx* as closer to *M. rohrmanni* than to *Megalonyx leptostomus*, but stopped short of referring the HAFO sloth to either species. Neither the HAFO nor White Bluffs *Megalonyx* is statistically smaller than *Megalonyx leptostomus* (using a two-tailed heteroscedastic t-test with 95% confidence levels) because of the very small sample sizes. The characters separating *M. rohrmanni* from *Megalonyx leptostomus* are on portions of the skull not known from HAFO; therefore, it is not possible currently to assess the relationship between the HAFO and White Bluffs sloths.

The slight differences between the HAFO *Megalonyx* and *Megalonyx leptostomus* from other localities are understandable if the view of a single evolving lineage of Pliocene-Pleistocene megalonychid sloths in North America is accurate. Separation of a lineage into chronospecies can result in the fossils derived from localities near the temporal limits of the taxon showing deviation from the norm. In the case of *Megalonyx leptostomus*, most specimens are from Blancan localities significantly younger than the HAFO deposits, which possibly contain the oldest records of the species (Bell et al., 2004).

Insectivora Cuvier, 1817

Soricidae Fischer von Waldheim, 1817

Sorex Linnaeus, 1758

Sorex hagermanensis Hibbard and Bjork, 1971

Sorex hagermanensis n. sp. Hibbard and Bjork, 1971: pp. 171-172, fig. 1a, b.

Sorex hagermanensis Hibbard and Bjork. Hibbard, 1972b: p. 125; Bown, 1980: pp. 99-100, 119; Kurtén and Anderson, 1980: p. 104; Franz, 1981: p. 13; McDonald et al., 1996: p. 42; Currie, 1998: p. 51; Hearst, 1999: p. 26; Mou, 1999: p. 60; Ruez, 2002: p. 101A.

Identification of HAFO Material

Assignment to *Sorex* is made based on the separation of the mandibular condyle into two articular facets with an interarticular area breadth moderate among the Soricinae, m3 slightly reduced with respect to other lower molars but with unreduced or only very slightly reduced talonid, presence of an entoconid crest on the m1, position of the mental foramen ventral to the m1, and pigmented teeth (Repenning, 1967b). *Sorex hagermanensis* is a large form of *Sorex* with an anterior mandibular foramen relatively anteriorly-shifted for the genus, and a small posterior mandibular foramen (Hibbard and Bjork, 1971). The m1 and m2 talonids project labially more than trigonids and there is a pronounced entoconid crest on the m2.

Distribution

Sorex hagermanensis is only known from the type specimen from HAFO (Hibbard and Bjork, 1971).

Remarks on Taxonomy

Although *Sorex hagermanensis* is only known from a single specimen at HAFO, *Sorex edwardsi* from the Hemphillian Lemoyne Quarry is extremely similar. *Sorex edwardsi* differs in having only a single mandibular foramen and a more lingually inflected lower mandibular condyle articular area (Bown, 1980).

Comments on HAFO Material

Sorex hagermanensis is one of the two large species of *Sorex* at HAFO (sensu Ruez, 2002); *Sorex powersi* is the other. In the decades since the recovery of the two large Hagerman *Sorex* taxa, no new specimens were recovered; *Sorex hagermanensis* is known only from the type specimen.

Sorex powersi Hibbard and Bjork, 1971

Sorex powersi n. sp. Hibbard and Bjork, 1971: pp. 172, fig. 1c, d.

Sorex powersi Hibbard and Bjork. Hibbard, 1972b: p. 125; Kurtén and Anderson, 1980: p. 104; Franz, 1981: p. 13; Gustafson, 1985b: pp. 88-89, tab. 3; McDonald et al., 1996: p. 42; Currie, 1998: p. 51; Hearst, 1999: p. 26; Mou, 1999, p. 60; Ruez, 2002: p. 101A.

Identification of HAFO Material

Sorex powersi is a large species of *Sorex* with two mandibular foramina, the posterior of which is larger. The m1 and m2 trigonids and talonids project labially to approximately the same extent. The m1 and m2 entoconid crests are greatly reduced compared to other species of *Sorex*. The talonid of the m3 of *Sorex powersi* was listed by Hibbard and Bjork (1971:172) as unreduced, but it is relatively narrower than in *Sorex hagermanensis*. Compared *Sorex hagermanensis*, *Sorex powersi* has a more slender horizontal ramus and a more posteriorly-placed anterior mandibular foramen.

Distribution

All known specimens of *Sorex powersi* are confined the states of Washington and Idaho, but they cover a wide temporal range. A single dentary of *Sorex powersi* from Blufftop is the oldest record; the slight differences in occlusal morphology between the Blufftop and HAFO specimens were ascribed to ontogenetic wear (Gustafson, 1985b). A much larger collection (~60 specimens) of *Sorex powersi* was reported from Birch Creek from Glenns Ferry sediments younger than those at HAFO (Hearst, 1999). These same specimens were also referred to "*Sorex* sp. aff. *Sorex powersi*" (Hearst, 1999:27), but this is presumably a typographical error because all other mentions of the material in that study are of *Sorex powersi* The temporal range between the Blufftop and Birch Creek localities is about 1.5 Ma, with HAFO lying between the two.

Remarks on Taxonomy

Two of the key characters used to identify *Sorex* (Repenning, 1967b) should be mentioned with regard to their development in *Sorex powersi*. There is variation within *Sorex* in the degree to which the talonid of the m3 is 'unreduced.' The talonid of the m3 in *Sorex powersi* is certainly reduced compared to other *Sorex*, including *S. hagermanensis*, but it does not approach the extremely diminished state seen in some specimens of *Paracryptotis* at HAFO. Additionally, the entoconid crest on the m1 and m2 of *Sorex powersi* is greatly reduced compared to that in other *Sorex*; *Paracryptotis*, however, lacks an entoconid crest. The dentition of *Sorex powersi* is morphologically intermediate between other species of *Sorex* and *Paracryptotis*, but *Paracryptotis* is approximately 40% larger than *Sorex powersi*, and has a lower mandibular condyle that is more offset lingually.

Comments on HAFO Material

Sorex powersi at HAFO is known only from the presence of two specimens – the holotype and paratype. Interestingly, these two specimens do not occur close to each other stratigraphically; they differ by over 80 m. Therefore, the two specimens of *Sorex powersi* have nearly the same stratigraphic range at HAFO as *Paracryptotis gidley* which is known from hundreds of specimens (Hibbard and Bjork, 1971).

Sorex meltoni Hibbard and Bjork, 1971

Sorex meltoni n. sp. Hibbard and Bjork, 1971: pp. 172-174, fig. 1e, f.

Sorex meltoni Hibbard and Bjork. Hibbard, 1972b: p. 125; Conrad, 1980: p. 177; Kurtén and Anderson, 1980: p. 104; Franz, 1981: p. 13; McDonald et al., 1996: p. 42; Currie, 1998: p. 51; Hearst, 1999: p. 26; Mou, 1999: pp. 58, 60; Ruez, 2002: p. 101A.

Identification of HAFO Material

Sorex meltoni (Figure 4.2) is a small shrew, about the size of *Sorex rexroadensis* and slightly smaller than the extant *Sorex cinereus.* It contains two mandibular foramina, and the mental foramen is ventral to the m1. The talonids of the m1 and m2 are reduced compared to extant (and most extinct) species of *Sorex*. Likewise, the entoconids of the m1 and m2 are less well-connected to the metaconids as compared to extant (and many extinct) species of *Sorex*. On the m1 there is a short entoconid crest extending posteriorly from the base of the entoconid, such that in older individuals of *Sorex meltoni* (such as the holotype, UMMP V55173), there is a connection with the metaconid. This connection does not appear in the m2, even with advanced wear, because the trigonid basin is lower. In all the above characters (from Hibbard and Bjork, 1971), *Sorex meltoni* matches the description of *Sorex rexroadensis*. The only difference given was the dentary being "not as deep and wide as that of *Sorex rexroadensis*" (Hibbard and Bjork, 1971:172). The depth of the horizontal ramus is actually the same in both taxa; the differences are confined to the ascending ramus. The breadth of the posterointernal ramal fossa (internal temporal fossa of some authors) is greater in *Sorex rexroadensis*, whereas the entire

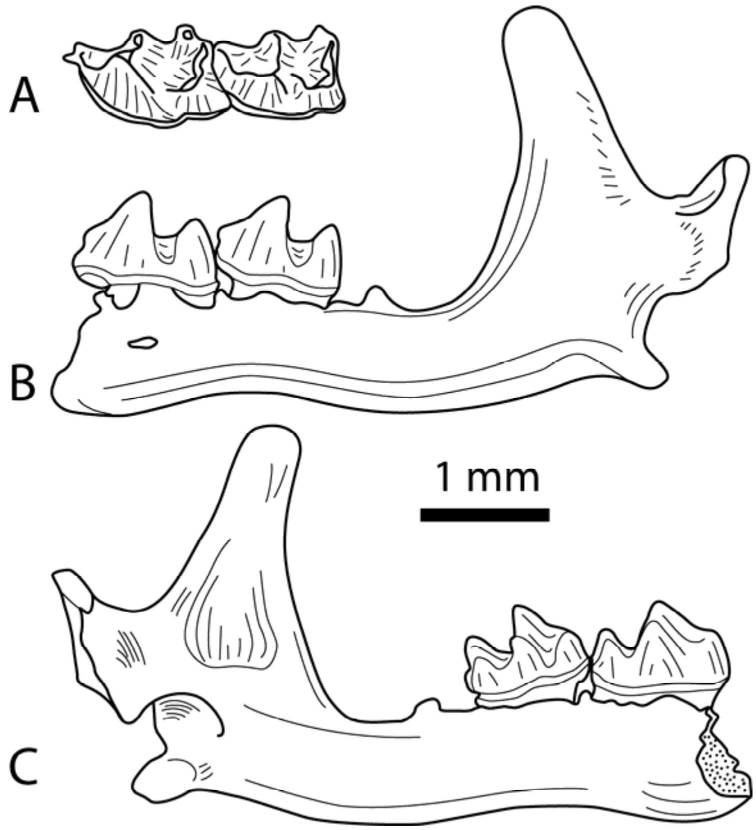


Figure 4.2. *Sorex meltoni*, HAFO 4698, left dentary. A, occlusal view of m1-2; B, labial view of dentary; C, lingual view of dentary.

ascending ramus is set back farther from the molars in *Sorex meltoni*. The upper sigmoid notch (between the coronoid process and the upper mandibular condyle) is deeper in *Sorex meltoni*, whereas the lower sigmoid notch (between the lower mandibular condyle and angular process) is deeper in *Sorex rexroadensis*. Additionally, *Sorex meltoni* differs in having a more reduced talonid on the m3and molars that are more brachyodont with a more developed cingulum.

Distribution

Until recently, the only known specimen of *Sorex meltoni* was the holotype from Hagerman. Recently, five specimens assigned to *Sorex meltoni* were described from a single locality within the early Blancan Panaca Formation of southern Nevada (Mou, 1999; Lindsay et al., 2002). The Panaca collection includes an M1 and p4, elements not currently known from HAFO. *Sorex* cf. *Sorex meltoni* is included in a faunal list of Taunton but is neither described nor illustrated (Morgan and Morgan, 1995). If the Taunton fossil is referable to *Sorex meltoni*, then that rare (at least at HAFO and Panaca) taxon has a geologic range of more than 2 Ma.

Remarks on Taxonomy

Size alone can separate *Sorex meltoni* and *Sorex rexroadensis* from all other species of *Sorex*, except the Hemphillian *Sorex yatkolai* from Lemoyne Quarry (Bown, 1980). *Sorex yatkolai* can be differentiated by the placement of the mental foramen ventral to the p4; in *Sorex meltoni* and *Sorex rexroadensis* the mental foramen is ventral to the m1.

Comments on HAFO Material

With the recent recovery of two dentaries of *Sorex meltoni* (one of which is illustrated in Figure 4.2), that taxon becomes the most abundant species of *Sorex* at HAFO with a total of three specimens. Measurements are presented in Table 4.2.

Sorex cf. *Sorex rexroadensis* Hibbard, 1953a

Sorex cf. *Sorex rexroadensis* Hibbard. Hibbard and Bjork, 1971: pp. 174-175.

Sorex cf. *Sorex rexroadensis* Hibbard. Hibbard, 1972b: p. 125; Bown, 1980: p. 101; McDonald et al., 1996: p. 42; Currie, 1998: p. 51; Ruez, 2002: p. 101A.

Sorex rexroadensis Hibbard. Bown, 1980: p. 99; Kurtén and Anderson, 1980: p.103; Franz, 1981: p. 13; Hearst, 1999: p. 26.

Identification of HAFO Material

See *Sorex hagermanensis* for identification to *Sorex*; see the section on *Sorex meltoni* for details on the identification of *Sorex rexroadensis*. The two Hagerman dentaries referred to *Sorex* cf. *Sorex rexroadensis* by Hibbard and Bjork (1971) have only a single mandibular foramen (ventral to the posterointernal ramal fossa); specimens of *Sorex rexroadensis* from Fox Canyon have two mandibular foramina.

Table 4.2. Measurements of *Sorex meltoni* from HAFO.

		UMMP V55028	HAFO 2329E	HAFO 4698
m1	length	1.16	1.23	1.11
	width	0.64	0.78	0.72
m2	length	1.02	1.00	0.92
	width	0.63	0.69	0.60

Distribution

Fossils matching the description of *Sorex rexroadensis* except in the number of mandibular foramina are only known from HAFO. *Sorex rexroadensis* is known only from Fox Canyon (Hibbard, 1953a; R. Martin et al., 2000).

Remarks on Taxonomy

More definitive identification of these dentaries must wait on determination of the importance of the number of mandibular foramina in species of *Sorex*. The single foramen in the HAFO specimens of *Sorex* cf. *Sorex rexroadensis* is located where the anterior mandibular foramen is in *Sorex rexroadensis* and *Sorex yatkolai*; the HAFO dentaries are therefore probably missing the posterior opening. In *Sorex rexroadensis* the anterior mandibular foramen is the more developed one, twice the width of the posterior foramen. The placement of the anterior mandibular foramen in *Sorex rexroadensis* and the HAFO *Sorex* cf. *Sorex rexroadensis* specimens is more anterior than in the other small species of *Sorex* at Hagerman, *Sorex meltoni*. If the development of the posterior mandibular foramen can be shown to vary in the sample of Fox Canyon *Sorex rexroadensis*, that population may be conspecific with the HAFO specimens.

Although *Sorex yatkolai* matches the HAFO *Sorex* cf. *Sorex rexroadensis* specimens, even in the position of a single mandibular foramen, the placement of the mental foramen differs. Of species of *Sorex*, only *Sorex yatkolai* has a mental foramen ventral to the p4 instead of the m1; within the Soricinae, only the late

Oligocene-early Miocene *Crocidosorex* and early Miocene *Antesorex* have the mental foramen ventral to the p4 (Repenning, 1967b; Bown, 1980). *Sorex yatkolai* differs from *Crocidosorex* and *Antesorex* in not having confluent mandibular condyles. Although living shrews may rarely "have the mental foramen significantly anterior to its position in other individuals from the same local population" (Repenning, 1967b:6), it is consistent in the three specimens known of *Sorex yatkolai*. Further study may likely prove that *Sorex yatkolai* belongs not to *Sorex*, but to a new group of soricines.

Paracryptotis Hibbard, 1950

Paracryptotis gidleyi (Gazin, 1933a)

Blarina gidleyi n. sp. Gazin, 1933a: pp. 142-144, fig. 1.

Blarina gidleyi Gazin. Gazin, 1936: pp. 285, 288; J. Schultz, 1937: p. 85; Hibbard, 1941c: p. 87; Hibbard, 1950: p. 127; Hibbard, 1957a: pp. 329-331, figs. 2c, d, e; Hibbard, 1958a: p. 246; Hibbard, 1958b: p. 12; Hibbard, 1959: p. 11; Repenning, 1967b: pp. 43-44, fig. 30.

Paracryptotis gidleyi Gazin. Hibbard and Bjork, 1971: pp. 175-179, figs. 1g, 2b, c, 3; Hibbard, 1972b: p. 125; Kurtén and Anderson, 1980: p. 110; Franz, 1981: p. 13; Cunningham, 1984: pp. 47, 51; Jones et al., 1984: pp. 57, 77-78, tab. 3; Lindsay et al., 1984: p. 462; Gustafson, 1985b: p. 89, tab. 3, tab. 2; McDonald et al., 1996: p. 42, fig. 11D; Currie, 1998: 51, fig. 5D; Ruez, 2002: p. 101A; Bell et al., 2004: p. 258.

Identification of HAFO Material

Shrew material can be identified to *Paracryptotis* by the broad mandibular interarticular area, entoconids of the m1 and m2 being well developed and isolated (by a valley between it and the hypolophid and by an absence of an entoconid crest), talonid of the m3 much reduced and closed to form a basin, and cingula on labial side of molars much larger than on lingual side, isolated hypocone on M1 and M2, and trapezoidal M2 with anterior border much longer (modified from Repenning, 1967b and Hibbard and Bjork, 1971). Hibbard and Bjork presented the specific diagnosis of *Paracryptotis gidleyi* as "P4 narrow anteriorly and with moderate posterior emargination, talonid of m1 and m2 is short, and m3 is reduced with talonid shorter than in *Paracryptotis rex*, but entire tooth is relatively longer compared to length of m1 than in *Paracryptotis rex*. Teeth not as robust as in *P. rex*" (1971:176). See discussion on these characters below.

Distribution

Paracryptotis gidleyi is known only from HAFO and Sand Point (Conrad, 1980). The other species of *Paracryptotis*, *Paracryptotis rex*, was named on material from Fox Canyon (Hibbard, 1950). It was subsequently recorded from Hemphillian deposits at Rome (Repenning, 1967b), and four Blancan sites: Beck Ranch (Dalquest, 1978), Blufftop (Gustafson, 1985b), Saw Rock Canyon (Hibbard and Bjork, 1971), and Wendell Fox (Hibbard and Bjork, 1971). Additionally, records of *Paracryptotis* sp. were reported from the Hemphillian localities Santee and Devils

Nest Airstrip (Voorhies, 1990) and the Blancan Otay Ranch California (Wagner et al., 2000).

Remarks on Taxonomy

In reassigning *Blarina gidleyi* to inclusion within *Paracryptotis*, Hibbard and Bjork (1971) outlined how such a movement was predicted decades earlier (Gazin, 1933a). This assignment was augmented by numerous points of similarity. Indeed, there is overlap in the diagnostic characters for *Paracryptotis gidleyi* (see above) and *Paracryptotis rex* (see Hibbard, 1950). Both have a P4 that is narrow anteriorly to the same degree. Additionally, although the P4 and M1 of *Paracryptotis rex* was described as lacking posterior emargination (Hibbard, 1950; Hibbard and Bjork, 1971), topotypic material from Fox Canyon clearly shows moderately developed posterior emargination (Hibbard, 1953a:fig. 4E) that matches that seen in HAFO *Paracryptotis gidleyi* (Hibbard and Bjork, 1971:fig. 3).

The talonids of the lower molars of *Paracryptotis gidleyi* are shorter than those in *P. rex*, but this is in part due to the overall difference in length of teeth (Hibbard and Bjork, 1971: tables 3-5). The percent of each molar occupied by the length of the talonid is a more accurate comparison. In such a comparison, *Paracryptotis gidleyi* exhibits only slightly shorter talonids on the m1 (38%) and m2 (37%) than on the respective teeth on *P. rex* (41% and 39%; calculated from data in Hibbard and Bjork, 1971: tables 3-5), but the difference is extremely small; both species have a relative talonid length of 31% of the m3.

The teeth of *Paracryptotis gidleyi* were described as “not as robust as in *P. rex*” (Hibbard and Bjork, 1971:176). If Hibbard and Bjork (1971) meant only the average length of the teeth, *P. rex* is indeed more robust; if, however, a width/length ratio is taken for each tooth, *Paracryptotis gidleyi* is more robust. In either case, however, there is significant overlap between the ranges of *Paracryptotis rex* and *Paracryptotis gidleyi*.

Although there are some metric differences between the averages of the populations of *Paracryptotis gidleyi* from HAFO and *Paracryptotis rex* from Fox Canyon, the overlap in both quantitative and qualitative characters inhibit confident assignment of individual specimens to one of these species. It is conceivable that these two populations are merely geographic variants, but this would require specimens from more localities and close examination of the *Paracryptotis rex* identified from Rome, Oregon.

Comments on HAFO Material

Although other species of shrews at HAFO are only known from three of fewer specimens (from the monument itself), *Paracryptotis gidleyi* is the most abundant insectivoran, with hundreds of fossils known. In spite of this current abundance, the historic placement of *Paracryptotis gidleyi* within *Blarina* was due to the lack of fossils; “It is possible that were more complete remains known the fossil form would be found to represent an undescribed genus, presumably related closely to *Blarina*” (Gazin, 1933a:144). Later, it was noted that the only fossil form to which *Paracryptotis rex* may be closely related was *Blarina gidleyi* and that the Hagerman fossils "perhaps belong to the genus *Paracryptotis*" (Hibbard, 1950: 127), but the assignment was deferred because upper dentition of the Hagerman taxon was not known at the time.

Interestingly, although *Sorex powersi* displays some *Paracryptotis*-like characters (see above), the m3 of *Paracryptotis gidleyi* was described as "within more *Sorex*-like variation of living *Blarina brevicauda*" (Repenning, 1967b:43). It is unclear whether this similarity is phylogenetic or an ecophenotypic expression.

Talpidae Fischer de Waldheim, 1817

Scapanus Pomel, 1848

Scapanus hagermanensis Hutchison, 1987

Talpid gen. and sp. indet. Hibbard and Bjork, 1971: p. 17; Hibbard, 1972b: p. 125.

Scapanus sp. Hibbard and Bjork, 1971: p. 17, fig. 2a; Hibbard, 1972b: p. 125.

Scapanus hagermanensis n. sp. Hutchison, 1987: pp. 1-3, fig. 1A, 2A.

Scapanus hagermanensis Hutchison. McDonald et al., 1996: p. 42; Currie, 1998: p. 51; Ruez, 2002: p. 101A.

Identification of HAFO Material

Scapanus hagermanensis has single rooted p1-3 and a distinctly double-rooted p4; antemolar region is long; the m1 has a precingulum with no enamel stretching down the roots; m1 trigonid is open and not anteroposteriorly compressed; molars are brachyodont for a talpid (Hutchison, 1987).

Distribution

The mole *Scapanus hagermanensis* is only known from sites within HAFO.

Remarks on Taxonomy

Hutchison (1987) assigned all Hagerman talpid material to the same species because all the fossils agreed in relative size. Although more material has come to light, his assessment is here judged still to be the most likely scenario.

Comments on HAFO Material

The fossil talpid from HAFO was first described (Hibbard and Bjork, 1971) from fragmentary humeri and an ulna allocated to *Scapanus* sp. and from the partial dentary that would later be the holotype of *Scapanus hagermanensis*. The dentition of the holotype is in poor condition, but the recent recovery of a well-preserved, isolated m1 (HAFO 6990) allows for Hutchison's original description (Hutchison, 1987) to be confirmed. Although *Scapanus hagermanensis* is similar to other species of *Scapanus* (*Scapanus*), but is unique in having a double-rooted p4.

Hutchison (1987) suggested that *Scapanus hagermanensis* was ancestral to extant *Scapanus orarius* and *Scapanus townsendii* based on the shared occurrence of an open and uncompressed trigonid on the m1. The recent recovery of a *Scapanus* *hagermanensis* radius (Figure 4.3) further supports Hutchison's (1987) phylogenetic suggestion as well as his indication of a postcranial morphological trend. Like *S. orarius* and *Scapanus townsendii*, the radius of *Scapanus hagermanensis* has a distally-directed ulnar articular facet, no bump on the posterior edge, and an expanded lunar articular facet. The robust shaft is common to all three taxa, but is more developed on *Scapanus hagermanensis* and *Scapanus townsendii*. The radius of *Scapanus hagermanensis* differs from the other species in having the lunar articular facet directed anteroproximally, rather than anteriorly; and in having a relatively small ulnar articular facet rather than the widely rounded one. The length of the radius shaft of *Scapanus hagermanensis* is short (9.5 mm), but closer to the values seen in *Scapanus orarius* (9.6-10.1 mm, n=7; Hutchison, 1968) than to *Scapanus townsendii* (10.8-13.2 mm, n=31; Hutchison, 1968). Therefore, the new specimen shows the same pattern as the material examined by Hutchison (1987): postcranial lengths are smallest in *Scapanus hagermanensis*, and elements are more robust in *Scapanus hagermanensis* and *Scapanus townsendii*.

Lagomorpha Brandt, 1855

Leporidae Gray, 1821

Hypolagus Dice, 1917

Hypolagus edensis Frick, 1921

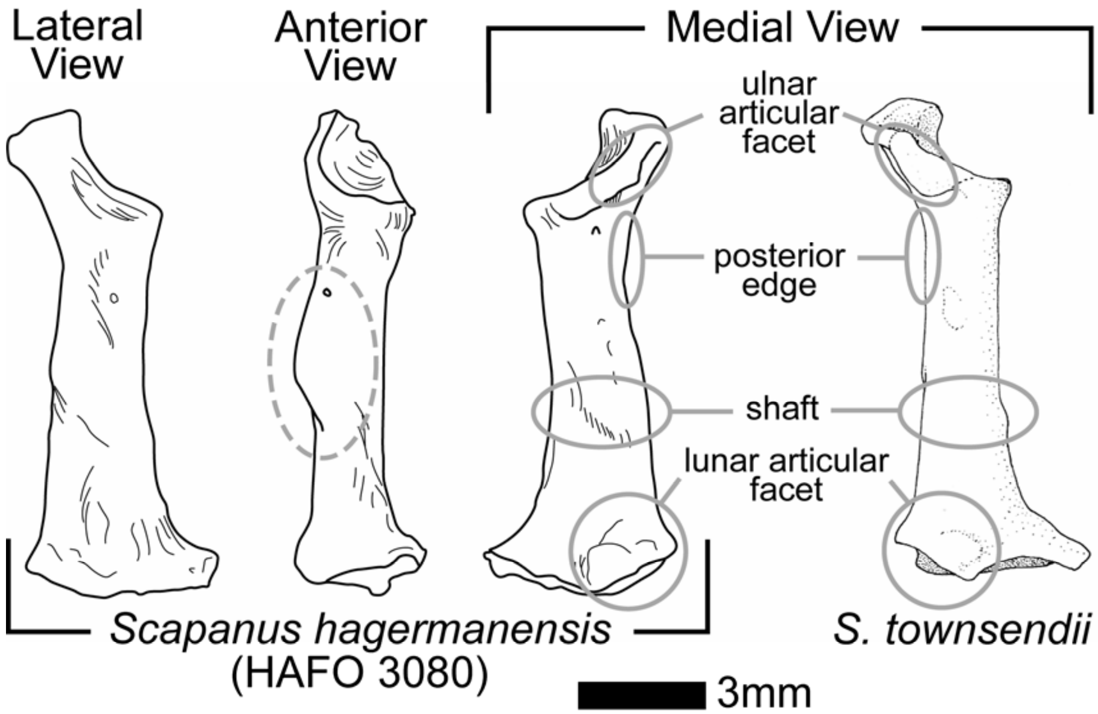


Figure 4.3. Radii of *Scapanus hagermanensis* (HAFO 3080) and modern *Scapanus townsendii* (after Hutchison, 1968). Features compared between *Scapanus hagermanensis* and modern *Scapanus* are labeled in the posterior views. The anterior view of *Scapanus hagermanensis* more clearly shows the extreme robust nature of the shaft in the dashed circle.

Hypolagus limnetus n. sp. Gazin, 1934a: p. 114-117, figs. 2, 3.

Hypolagus limnetus Gazin. Gazin, 1936: pp. 285, 288; J. Schultz, 1937: pp. 85, 106-107; Wilson, 1937a: p. 17; Wilson, 1937b: p. 38; Hibbard, 1941c: p. 87; Dawson, 1958: p. 49; Hibbard, 1958b: p. 20; Hibbard, 1959: p. 35; Campbell, 1969: pp. 99, 103, 110, plate I figs. 3, 9, plate II figs. 3, 7, 12, 13, tab. I; Hibbard, 1969: pp. 88-90, figs. 2G, Hibbard, 1972a: p. 81; Hibbard, 1972b: p. 126; Conrad, 1980: pp. 161-2, tab. 7; Kurtén and Anderson, 1980: p. 277; Franz, 1981: p. 22; Cunningham, 1984: pp. 47, 51; Gustafson, 1985b: tab. 3; Sankey, 1991: p. 136; McDonald et al., 1996: p. 42; Currie, 1998: p. 51; Bell et al., 2004: p. 258.

Hypolagus edensis Frick. White, 1987: pp. 436-437, 445; White and Morgan, 1995: p. 371; Mou, 1999: p. 65; Sankey, 2002: p. 85.

Identification of HAFO Material

Assignment to *Hypolagus* is based on the presence of leporid dentition with evergrowing cheekteeth and having a p3 lacking any anterior or lingual reentrants, but having cement-filled anteroexternal and posteroexternal reentrants, the latter extending across more than 40% of the width of the occlusal surface (White, 1987). *Hypolagus edensis* is a small species of *Hypolagus* and is identified by the presence on the p3 of a deep and narrow anteroexternal reentrant with smooth enamel that is symmetrical at the lingual limit of the fold (White, 1987; White and Morgan, 1995).

Distribution

Hypolagus edensis is known in the Hemphillian from Kern River (Gazin, 1934a; Wilson, 1937a; White, 1987), Mount Eden, (Frick, 1921), Pinole Junction (Frick, 1921; White, 1987), and Redington (White, 1987). Blancan records of *Hypolagus edensis* from California are known from Anza-Borrego Desert State Park (Remeika et al., 1995; Cassiliano, 1997; Jefferson, 2001; White et al., 2006), Arroyo Pequeno (White, 1987), Del Valle (White, 1987), Elk Hills (White, 1987), Mission Viejo (White, 1987), Otay Ranch (Wagner et al., 2000; listed as "*H. limnetus*" by Wagner et al., 2001), San Timoteo Formation (Albright, 1999), and Temecula Arkose (Pajak et al., 1996). Additional Blancan records of *Hypolagus edensis* occur at Ninefoot Rapids (Conrad, 1980; White, 1987), Panaca Formation (Mou, 1999; Reynolds and Lindsay, 1999; Lindsay et al., 2002), Red Corral (White, 1987), and Taunton (White and Morgan, 1995).

Remarks on Taxonomy

In a partial review of the Archaeolaginae, White (1987) synonymized *Hypolagus limnetus* with *Hypolagus edensis* without comment. Within the hypodigm of *Hypolagus edensis*, White explicitly included the type specimen of *Hypolagus limnetus*, USNM 12619, and other topotypic material from HAFO. However, elsewhere in the same paper, *Hypolagus limnetus* was included in a list of "valid taxa included in the subfamily Archaeolaginae" (White, 1987:425). It is clear from other portions of his work that White (1987) did not consider *Hypolagus* *limnetus* a valid species; I here follow his usage of *Hypolagus edensis* as the correct senior synonym.

Species-level identification of leporid fossils is often difficult with single specimens; instead, the mean values of populations are commonly used. Outliers can be especially problematic because it may not be possible to determine the 'mean value' with which it should be grouped. Unfortunately, this is not apparent from statements such as "Specimens of *Hypolagus edensis* and *Hypolagus furlongi* from Taunton are readily distinguished from one another by the degree to which AER [anteroexternal reentrant] is incised across the occlusal width of p3" (White and Morgan, 1995:367). Although the mean extents of the anteroexternal reentrant across the p3 are significantly different from each other, the observed ranges illustrate the problem. The anteroexternal reentrant of the p3 of *Hypolagus furlongi* extends across 20 to 26% of the occlusal surface in Taunton specimens; the corresponding range in *Hypolagus edensis* is 27 to 38% (White and Morgan, 1995). A difference of 1% in a single character is the only distinguishing feature in this example. A graph of these values (White and Morgan, 1995: fig. 4) is more problematic because it depicts both *Hypolagus furlongi* and *Hypolagus edensis* with a single specimen with an anteroexternal reentrant reaching 26% across the p3 occlusal surface; indeed there appears to be two specimens presented as *Hypolagus edensis* with values closer to the mean of *Hypolagus furlongi* than to the mean of *Hypolagus edensis*. In light of the fact that the penetrance of the anteroexternal reentrant is the only published character that is used to separate these two species, such intermediate specimens should best be regarded as an indeterminate form of *Hypolagus* when both *Hypolagus edensis* and *Hypolagus furlongi* co-occur, as in the Taunton fauna.

When fossils of each of these species are examined from other localities, the situation becomes even more problematic. The range of the anteroexternal reentrant extending across the p3 in *Hypolagus furlongi* is 15 to 29%; the range in *Hypolagus edensis* is 24 to 46% (White, 1987). Given this overlap, it is uncertain how identifications are made at localities that contain both *Hypolagus furlongi* and *Hypolagus edensis*, as in the case of Del Valle, Ninefoot Rapids, Red Corral, and Taunton (White, 1987; White and Morgan, 1995). This is only one example of the difficulty in naming fossil rabbits.

The similarity between *Hypolagus limnetus* (now *Hypolagus edensis*) and *Hypolagus furlongi* was noted by Gazin: "The species *Hypolagus limnetus* and *Hypolagus furlongi* are very close and the differences separating them may be only of geographic importance" (1934a:119). Gazin (1934a) did suggest other differences between *Hypolagus furlongi* and *Hypolagus limnetus*, most of which have become blurred with the discovery of new specimens. One of his suggestions, however, may hold true; the depth of the external anterior reentrant on the P2 is shallow in *Hypolagus furlongi*, but deep in *Hypolagus limnetus*. In the few P2s that I examined this seems to be accurate. Unfortunately, the association of upper and lower dentition as fossils is rare.

Comments on HAFO Material

In a comparison of North American Pleistocene (as then understood) fossil localities, three species of *Hypolagus* were listed as occurring at Hagerman – *Hypolagus* cf. *Hypolagus vetus* (now *Hypolagus gidleyi*), *Hypolagus limnetus* (now *Hypolagus edensis*), and *Hypolagus furlongi* (Hibbard, 1958b). Although individual specimens were not identified, the references for the faunal list of each locality were given; none of the references for Hagerman actually mentioned *Hypolagus furlongi*. The inclusion of *Hypolagus furlongi* by Hibbard is odd because his list indicates the presence of that species only at Hagerman. At that time *Hypolagus furlongi* was only known from the type locality – Grand View. It seems unlikely that Hibbard combined the faunas because other Grand View taxa are not treated that way. Another possibility is that Hibbard made the identification himself. Based on the similarity between *Hypolagus furlongi* and *Hypolagus edensis*, this appears possible. However based on later works on the Hagerman rabbits and personal observation, *Hypolagus furlongi* is not present at HAFO.

Hypolagus gidleyi White, 1987

Hypolagus near *H. vetus* (Kellogg). Gazin, 1934a: pp. 112-114, fig. 1; Gazin, 1936: pp. 285, 288; J. Schultz, 1937: p. 85; Wilson, 1937a: p. 12; Wilson, 1937b: p. 38; Hibbard, 1941c: p. 87; Miller, 1980: pp. 776, 778, 800.

Hypolagus cf. *H. vetus* (Kellogg). Dawson, 1958: p. 50; Hibbard, 1958b: p. 20; Hibbard, 1972a: p. 81; Hibbard, 1972b: p. 126; Conrad, 1980: p. 160, figs.

8B-E, tab. 6; Cunningham, 1984: pp. 47, 49, 51; White, 1984: pp. 47, 53-54; Gustafson, 1985b: tab. 3.

Hypolagus sp. aff. *H. vetus* (Kellogg). Campbell, 1969: p. 103, plate I figs. 1, 5, 6, 7, 11, 13, 15, plate II figs. 1, 2, 5, 8, 9, 10, 15, tabs. I-II; Hibbard, 1969: pp. 82-88, figs. 1A, B, 2A, E, F, H, H′, I, 3F, G, tab. I, II.

Hypolagus vetus Kellogg. Kurtén and Anderson, 1980: pp. 277-278, fig. 13.1A; McDonald et al., 1996: p. 42; Currie, 1998: p. 51; Sankey, 2002: p. 85; Bell et al., 2004: p. 258.

Hypolagus vestus [sic]. Franz, 1981: p. 22.

Hypolagus gidleyi n. sp. White, 1987: pp. 434-435, 445; figs. 7C.

Hypolagus gidleyi White. White and Morgan, 1995: pp. 368, 372; Currie, 1998: p. 51.

Identification of HAFO Material

See *Hypolagus edensis* for identification to *Hypolagus*. *Hypolagus gidleyi* is larger than *Hypolagus arizonensis*, *Hypolagus edensis*, *Hypolagus fontinalis*, *Hypolagus furlongi*, *Hypolagus tedfordi*, and *Hypolagus voorhiesi*; *Hypolagus gidleyi* is statistically larger than *Hypolagus vetus*, but measurements of dental elements show a large range of overlap between the two taxa. Likewise, although *Hypolagus gidleyi* was said to differ from *Hypolagus ringoldensis* by being significantly smaller in size (White, 1987:434), the ranges of the dental measurements are almost identical (White, 1987:tabs. 2, 3). *Hypolagus gidleyi* differs from *Hypolagus fontinalis*, *Hypolagus oregonensis*, *Hypolagus tedfordi*, and *Hypolagus vetus* in having straight thick enamel on the anterior wall of the posteroexternal reentrant on the p3; from *Hypolagus fontinalis*, *Hypolagus parviplicatus* and *Hypolagus tedfordi* in having a more deeply incised posteroexternal reentrant; from *Hypolagus arizonensis*, *Hypolagus regalis*, and *Hypolagus voorhiesi* in having a posteroexternal reentrant not deflected anteriorly; from *Hypolagus edensis* in having a shallower anteroexternal reentrant; and from *Hypolagus parviplicatus* in having a deeper anteroexternal reentrant (White, 1987).

Distribution

Hemphillian records of *Hypolagus gidleyi* are known from localities within the Chamita Formation (White, 1987), at Coffee Ranch (White, 1987) and at Washoe (Kelly, 1997). Blancan localities in the Glenns Ferry Formation reported to contain *Hypolagus gidleyi* are Flatiron Butte (Conrad, 1980; White, 1987), Grand View (White, 1987), Ninefoot Rapids (Conrad, 1980; White, 1987), Oreana (Conrad, 1980; White, 1987), and Sand Point (Conrad, 1980; White, 1987). The other Blancan records of *Hypolagus gidleyi* are from Buckeye Creek (Kelly, 1994), Cita Canyon (White, 1987), Red Corral (White, 1987), Taunton (White, 1987; White and Morgan, 1995), and Trench Canyon (White, 1987).

A single dentary with the diagnostic p3 was recovered from the early Irvingtonian Cucumber Area within the Froman Ferry sequence and referred to *Hypolagus gidleyi* (Repenning et al., 1995). Additionally, a report of *Hypolagus* cf.

Hypolagus gidleyi from Tijeras Arroyo (Lucas et al., 1993) may represent a second Irvingtonian occurrence (Repenning et al., 1995), although Morgan and Lucas (2000) and Lucas and Morgan (2001) retained the identification as *Hypolagus* cf. *Hypolagus gidleyi*.

The oldest known possible occurrence of *Hypolagus gidleyi* is in the Barstovian at Wood Mountain; although originally referred to *Hypolagus vetus* (Storer, 1975), these specimens were later identified as *Hypolagus* cf. *Hypolagus gidleyi* (White, 1987). However, these specimens have anterointernal and posterointernal reentrants. The presence of these reentrants on *Hypolagus apachensis* led to the suggestion that *Hypolagus apachensis* should not only be excluded from *Hypolagus*, but from the Archaeolaginae (White, 1987); this species is now placed in the Leporinae and recognized as *Pronotolagus apachensis* (White, 1991). Likewise the Wood Mountain specimens probably do not represent a form of *Hypolagus*. Localities in the Panaca Formation (Mou, 1999; Lindsay et al., 2002) and Mountainview (Morgan and Lucas, 2003) also contain specimens referred to *Hypolagus* cf. *Hypolagus gidleyi.*

Remarks on Taxonomy

In the diagnosis of *Hypolagus gidleyi* and the differentiation of this species from some others of *Hypolagus*, the presence of straight thick enamel on the anterior wall of the posteroexternal reentrant in 90% of p3s of *Hypolagus gidleyi* was emphasized as one of the distinguishing characters (White, 1987). Later on the same page, however, the same feature in *Hypolagus gidleyi* is described as straight in 82% of observed specimens (White, 1987:434). The thick enamel on the anterior wall of the posteroexternal reentrant of *Hypolagus vetus* is straight in only 10% of p3s (White, 1987:432). Although this character of the thick enamel is sufficient to separate most specimens, 10 to 18% of even the diagnostic teeth are potentially being misidentified. The P2s of *Hypolagus gidleyi* and *Hypolagus vetus* do not help to distinguish the taxa; the tooth is identical in each. Other leporid taxa could also be confused with these two; *Hypolagus ringoldensis* is similar in size and development of the anteroexternal reentrant. Both *Hypolagus ringoldensis* and *Hypolagus gidleyi* were described from the Taunton fauna (White and Morgan, 1995). The p3 of *Hypolagus gidleyi* is not known to have an anterior reentrant, but 14% of *Hypolagus ringoldensis* from Taunton possess this fold. The other diagnostic character is the penetrance of the posteroexternal reentrant across the occlusal surface of the p3 (53.5% across the surface in *Hypolagus gidleyi* and 59% in *Hypolagus ringoldensis*; (White and Morgan, 1995). This small difference does differentiate most specimens into one of two clusters, but there is nearly a 50% overlap in ranges of these values (White and Morgan, 1995:fig. 5). As discussed above for *Hypolagus edensis*, species-level discrimination of many leporid taxa is based on the average values; it is unclear how individual specimens are identified in many published studies.

Comments on HAFO Material

Hypolagus gidleyi is the most abundant lagomorph at HAFO. One of the early-collected specimens from HAFO (USNM 23573) was used half a century after discovery as the holotype for this species (White, 1987).

The HAFO material that would later be named *Hypolagus gidleyi* was examined and discussed as possibly more closely allied to *Hypolagus regalis* than to *Hypolagus vetus* (Dawson, 1958). With the benefit of additional specimens White (1987) was later able to distinguish *Hypolagus regalis* by the presence of an anteriorly expanded posteroexternal reentrant.

Alilepus Dice, 1931

Alilepus vagus Gazin, 1934a

Alilepus? *vagus* n. sp. Gazin, 1934a: pp. 119-120, fig. 5.

Alilepus? *vagus* Gazin. Gazin, 1936: pp. 285, 288; J. Schultz, 1937: p. 85; Wilson, 1937b: p. 38; Hibbard, 1941c: p. 87; Dawson, 1958: pp. 61-2; Hibbard, 1958b: p. 20; Hibbard, 1959: p. 15.

Pratilepus vagus (Gazin). Taylor, 1965: p. 75; Hibbard, 1969: pp. 90-96, figs. 1C, D, 3D, E, H, 4, 5A-D, tab. I; Campbell, 1969: pp. 99, 103-107, 109-110, plate I figs. 2, 4, 8, 12, 14, plate II figs. 4, 6, 11, tab. I, II; Hibbard, 1972a: p. 81; Hibbard, 1972b: p. 126; Conrad, 1980: pp. 134, 185; Kurtén and Anderson, 1980: p. 278, fig. 12.1B, I; Franz, 1981: p. 22; Gustafson, 1985b: tab. 3;

Sankey, 1991: p. 141; McDonald et al., 1996: p. 42, fig. 11C; Currie, 1998: fig. 5C; Bell et al., 2004: p. 258.

Alilepus vagus Gazin. White, 1991: p. 70-71, 87, fig. 4C; White and Morgan, 1995: pp. 370, 372; Currie, 1998: p. 51.

Identification of HAFO Material

This large leporid is identified as *Alilepus* based on the p3 lacking anterior reentrants, lacking or having only a slight anterointernal reentrant, and having a posterointernal reentrant (sometimes enclosed as an enamel lake), a broad and shallow anteroexternal reentrant, and a narrow and deep posteroexternal reentrant (modified from White, 1991). *Alilepus vagus* is larger than *Alilepus wilsoni*, and similar in size to *Alilepus hibbardi* (White, 1991). Although the p3 of *Alilepus vagus* was separated from *Alilepus hibbardi* by a "significantly more deeply incised PER [posteroexternal reentrant] on p3" (White, 1991:70), there is variation in that feature. *Alilepus hibbardi* is distinguished from *Alilepus vagus* by the unique presence of an enamel lake on the P3.

Distribution

Alilepus vagus is present in the Hemphillian at Santee (White, 1991) and in the Blancan at Buckeye Creek (Kelly, 1994), Grand View (White, 1991), and Taunton (White and Morgan, 1995).

Remarks on Taxonomy

Unlike the species of *Hypolagus* at HAFO, fossils of *Alilepus vagus* can be assigned unambiguously; however, higher taxonomic relationships in this case are problematic. Gazin (1934a) judged the taxon to be most similar to *Alilepus annectens* from the Pliocene of China and Mongolia. The HAFO rabbit differs in being smaller and having a broader anteroexternal reentrant on the p3 (Gazin, 1934a). The assignment to *Alilepus* was probably considered only tentative based at least in part on the fact that, at that time, *Alilepus* was not known from North America. Gazin did, however, make a point of noting that "a wide distribution for this genus would not be unexpected considering the presence in the living fauna of North America of the unique *Romerolagus*, the relations of which may be closer to such forms as *Alilepus* than to *Lepus* and *Sylvilagus*" (Gazin, 1934a:120).

The lack of other North American localities with *Alilepus* was also probably part of the reasoning for later assigning this species to *Pratilepus*. However, *Alilepus* and *Pratilepus* are also morphologicaly similar; "as far as the cheek teeth are concerned, it seems difficult to distinguish these two genera" (Qiu, 1987:382). *Pratilepus* and *Alilepus* both have a p3 lacking anterior reentrents, but with a deeply incised posterointernal reentrant; in the former, however, it is usually closed to form an enamel lake or coalesced with the posteroexternal reentrant (White, 1991). In the Hagerman leporine, the posterointernal reentrant is only closed into an enamel lake in less than a sixth of the known specimens (White and Morgan, 1995); I am not aware of any specimens where the enamel lake has joined with the posteroexternal reentrant. An allusion to the similarity between *Alilepus vagus* and *Pratilepus kansasensis* began the tendency of workers to doubt the affinities with *Alilepus*: "Further study of the additional specimens of *Alilepus*? *vagus* may reveal that the Hagerman leporine is more closely allied to *Pratilepus* than *Alilepus*" (Dawson, 1958:61-2). The first use of the combination *Pratilepus vagus* was actually in a study of fossil mollusks that listed some of the mammals occurring at the same sites (Taylor, 1966). The second usage of the combination was in a list of species provided as part of an overview of lagomorph evolution (Dawson, 1967). Neither of these authors gave any justification for the change. A detailed description of the rabbits from HAFO included *Pratilepus vagus*, but also did not discuss the taxonomy (Hibbard, 1969). In fact, the morphology of *Pratilepus vagus* was compared only to the other two lagomorphs from Hagerman, and to a lesser degree *Pratilepus kansasensis*; no comparisons were made with *Alilepus*. In the description of a large collection of *Alilepus annectens* (Qiu, 1987), specimens from Inner Mongolia were said to match the morphology of *Pratilepus kansasensis*, including in the development of the anteroexternal reentrant of the p3. This seems to be erroneous; *Alilepus* is well illustrated (Qiu, 1987), and comparison of these figures with *Pratilepus kansasensis* shows the latter to have a much deeper and more crenulate anteroexternal reentrant on the p3.

Apart from the questionably assigned Hagerman material, no specimens of *Alilepus* were identified from North America until 1991 (White, 1991). In reassigning the Hagerman leporine to *Alilepus*, White (1991) chose to emphasize the deeply incised anteroexternal reentrant and strongly crenulated enamel on the p3 of *Pratilepus kansasensis*; *Alilepus vagus* has a shallower anteroexternal reentrant and smoother enamel.

In addition to the depth of the posteroexternal reentrant, *Alilepus hibbardi* was differentiated from *Alilepus vagus* by the presence of an enamel lake on the P3 of the former (White, 1991). This feature is extremely unusually among leporids, and with the exception of the P2, upper dentition rarely allows for species-level identifications. The type skull of *Alilepus hibbardi* is the only specimen known of that taxon to preserve a P3, and that tooth is not known from *Alilepus vagus*. Therefore it is not possible to evaluate the strength of this character. Because the range of the depth of the posteroexternal reentrant between these two taxa overlaps considerably, the enamel lake on the P3 is the only distinguishing character between *Alilepus hibbardi* and *Alilepus vagus*.

All other North American specimens that were identified as *Alilepus*, other than *Alilepus vagus*, may not be correctly identified. *Alilepus wilsoni* differs in several respects from other species of *Alilepus* and the closely related *Pratilepus*, and instead matches the morphology of *Aluralagus virginiae*; further study may prove the two names synonymous. [The original description (White, 1991) gave the first spelling of the species as *Alilepus wilson*, although elsewhere in the paper *Alilepus wilsoni* was used. Precedence between the simultaneously published spellings was determined by the first reviser, in this case (White and Morgan, 1995). Although it is not known if this was done intentionally because there is no published statement to that effect, the usage of *Alilepus wilsoni* by White and Morgan (1995) does fufill the requirements of the International Code of Zoological Nomenclature (International Code of Zoological Nomenclature, 1999).] Teeth identified as *Alilepus* cf. *Alilepus wilsoni* from Taunton (White and Morgan, 1995), are certainly not referable to that species, and may not even be a form of *Alilepus*. Teeth from Anita were questionably assigned to *Alilepus* as ?*A. browni* (White, 1991), however, these specimens show tremendous variation and are possibly an assemblage of widely divergent forms. Two heavily eroded specimens from Deer Park B were identified as *Alilepus* sp. and described as "considerably smaller than those of *Alilepus wilsoni*, named by White (1991) from the Borchers l.f." (R. Martin et al., 2002a:1074). The Deer Park B teeth are actually much larger than every specimen identified as *Alilepus wilsoni*; instead they match the size of the teeth White (1991) assigned to *Alilepus hibbardi* and *Alilepus vagus*. The Deer Park B p3s were suggested as more similar to *Alilepus vagus* because of the isolation of the posterointernal reentrant into an enamel lake (R. Martin et al., 2002a), however, both *Alilepus hibbardi* and *Alilepus vagus* were described as containing specimens with and without enamel lakes (White, 1991). More importantly, the Deer Park B specimen that was figured (FHSM VP-14064) has thick enamel throughout the anteroexternal reentrant; I am not aware of this condition in any other leporine teeth.

Part of the problem in the systematics of *Alilepus* is the wide geographic distribution. Study of the group has yet to synthesize data from specimens from the Miocene and Pliocene of North America (e.g., White, 1991), Miocene of Asia (e.g., Qiu, 1987), Pliocene of Asia (e.g., Cai, 1989), and Miocene of Africa (Leakey et al., 1996) all together. The characters (size and depth of the anteroexternal reentrant) used by Gazin (1934a) to separate the Hagerman *Alilepus* from Old World forms worked in comparing only a single p3 from North America and only a few specimens from Asia, but many more specimens, showing variation, are now known from both continents. Specimens of *Alilepus annectens* figured by Qiu (1987) are indistinguishible from some *Alilepus* fossils from HAFO. *Alilepus vagus* includes specimens with the posterointernal reentrant closed to form an enamel lake. This character may be taxonomically useful, but it might also simply represent a temporal trend. The prevalence of enamel lakes is significantly greater in the large collection of *Alilepus* from Taunton than in the older deposits at Hagerman; the occurrence of enamel lakes in Clarendonian *Alilepus* is even rarer (White, 1991).

Comments on HAFO Material

Alilepus vagus is similar in size to another HAFO leporid, *Hypolagus gidleyi*. Although the p3 is readily distinguished between the two species, other elements (especially postcrania) are much more difficult to identify to that level. HAFO is one of the few fortuitous places where articulated skeletons of fossil lagomorphs occur. This allows for better determination of lagomorph postcrania identification than is possible in most cases, although as mentioned above, it is still only done with difficulty. Analysis of the postcranial skeletal elements of the HAFO rabbits (Campbell, 1969) showed *Hypolagus gidleyi* to most closely resemble modern *Lepus* *europaeus* in probable running habits. *Hypolagus edensis* limbs are similar, except in being smaller, and that species was interpreted as similar in running habit, although possibly not as fast as *Hypolagus gidleyi*. Because of postcranial similarity to modern *Sylvilagus floridanus*, *Alilepus vagus* was inferred to have similar running habitats (Campbell, 1969).

Rodentia Bowdich, 1821

Sciuridae Fischer de Waldheim, 1817

Paenemarmota Hibbard and Schultz, 1948

Paenemarmota barbouri Hibbard and Schultz, 1948

Marmot sp. Gazin, 1936: pp. 285, 288; Schultz, 1937: p. 84; Wilson, 1937b: p. 38; Hibbard, 1941c: p. 87.

Marmota sp. Bryant, 1945: pp. 340, 364.

Paenemarmota barbouri Hibbard and Schultz. Zakrzewski, 1969b: p. 4, fig. 2h; Hibbard, 1972b: p. 126; Kurtén and Anderson, 1980: p. 210; Franz, 1981: p. 15; Gustafson, 1985b: tab. 3; Nelson and Miller, 1990: pp. 35-36; McDonald et al., 1996: p. 42; Currie, 1998: p. 51; Zakrzewski, 1998: pp. 50-54, figs. 2-4, tab. 1-2; Gensler and Carpenter, 2006: p. 17.

Identification of HAFO Material

Species of *Paenemarmota* are the largest known sciurids. Dentition is similar to extant *Marmota*, but differs in being more hypsodont. Additionally, lower cheekteeth of *Paenemarmota* have rugose talonid basins, a basin trench (sensu Repenning, 1962) along ectolophid and metalophid margins, a protoconid that is taller and more robust than the parametaconid (sensu Bryant, 1945; equivalent to metaconid of Voorhies, 1988), and a well-developed metalophid. Upper cheekteeth of *Paenemarmota* differ from *Marmota* in having a well-developed metaconule only on the P4, a prominent posterior cingulum on P4, and a well-developed metaloph on the M3 (modified from Repenning, 1962, and Voorhies, 1988). An additional character listed by Voorhies (1988) to separate *Paenemarmota* is having a P4 as large as or larger than the M1. However, this is the same condition as in *Marmota* (Bryant, 1945). *Parapaenemarmota* shares the presence of a basin trench on the lower cheekteeth with *Paenemarmota*, but only the former has a distinct entoconid on the lower molars (J. Martin, 1998).

Paenemarmota barbouri is significantly larger than *Parapaenemarmota*, *Paenemarmota nevadensis*, and *Paenemarmota sawrockensis*, and is approximately the same size as *Paenemarmota mexicana* (see also the discussion below on the validity of *Paenemarmota mexicana*). The p4 of *Paenemarmota barbouri* is relatively larger than the tooth in *Paenemarmota sawrockensis*. Additionally, the metalophids on the lower cheekteeth are less hypsodont (therefore attaching to the metaconid at a lower level) and the mental foramen is more posteriorly placed in *Paenemarmota barbouri*, than it is in *Paenemarmota nevadensis*, *Paenemarmota sawrockensis*, and *Parapaenemarmota*.

Distribution

Paenemarmota barbouri is known from Blanco (Hibbard, 1972b; Dalquest, 1975; G. Schultz, 1977b), Broadwater (Hibbard, 1972b), Comosi Wash (Repenning, 1962), Fox Canyon (Hibbard, 1950; Repenning, 1962; R. Martin et al., 2000), Keefe Canyon, (R. Martin et al., 2000), Lisco (Hibbard and Schultz, 1948; Voorhies and Corner, 1986), Los Lunas (Tedford, 1981), and unspecified localities in the Gila Conglomerate (Repenning, 1989 in Nelson and Miller, 1990). Additionally, Kurtén and Anderson (1980) recognized *Paenemarmota barbouri* from White Bluffs, but elsewhere this material is only called *Paenemarmota* sp. (Gustafson, 1978). *Paenemarmota mexicana*, which according to some authors should be a junior synonym of *Paenemarmota barbouri*, occurs at La Goleta (Repenning, 1962; Miller and Carranza, 1984), Miñaca Mesa (Repenning, 1962; Lindsay, 1984), and Yepómera (Dalquest and Mooser, 1980; Lindsay, 1984; Lindsay and Jacobs, 1985).

Remarks on Taxonomy

Repenning (1962) placed all then-known specimens of *Paenemarmota* into *Paenemarmota barbouri*. *Marmota mexicana* was also included within *Paenemarmota barbouri*, but *Marmota nevadensis* was excluded and suggested as possibly more closely related to *Arctomyoides* than to extant marmots (Repenning, 1962). *Marmota sawrockensis* was described from Saw Rock Canyon, but the type specimen was compared only with *Marmota nevadensis* and not *Paenemarmota* (Hibbard, 1964). Based on additional material from Nebraska, *M. sawrockensis* was recombined as *Paenemarmota sawrockensis*, and the possibility was mentioned that additional material of *Marmota nevadensis* might prove that species should also be included within *Paenemarmota* (Voorhies, 1988). This suggestion was followed by Korth (1994), who included ?*Paenemarmota nevadensis* in a list of Tertiary sciurids, and by J. Martin (1998), who suggested that *Paenemarmota nevadensis* was the beginning of a lineage that included *Paenemarmota sawrockensis* and concluded with *Paenemarmota barbouri*.

Marmota mexicana was considered a junior synonym of *Paenemarmota barbouri* by some authors (Repenning, 1962; Kurtén and Anderson, 1980; and Voorhies, 1988), but was accorded full specific status (as *Paenemarmota mexicana*) elsewhere (Dalquest and Mooser, 1980; Nelson and Miller, 1990; and J. Martin, 1998). Those who consider the taxa distinct, cite as evidence for their taxonomic distinction the divided posterior valley in the M3 of *Paenemarmota mexicana* that is absent in *Paenemarmota barbouri* (Dalquest and Mooser, 1980).

In the description of a dentary of *Paenemarmota sawrockensis* from Utah, comparisons were made not only with *Paenemarmota barbouri*, *Paenemarmota mexicana*, and *Paenemarmota nevadensis*, but with two other large sciurids that were not previously suggested to be closely related to *Paenemarmota* (Nelson and Miller, 1990). *Marmota oregonensis* and *Spermophilus pattersoni* are smaller than all forms of *Paenemarmota*, but share the distinctive basin trench (sensu Repenning, 1962). The basin trench and the distinct entoconid were used to group these two species within a new taxon *Parapaenemarmota*, so named to emphasize the similarity to *Paenemarmota* (J. Martin, 1998).

Comments on HAFO Material

Stylopodials, zygopodials, and metapodials of *Paenemarmota barbouri* are approximately four times the length of those from the other sciurids occurring at HAFO. Unlike some of the other taxa known from HAFO, *Paenemarmota barbouri* is somewhat rare at HAFO and abundant elsewhere. Together, these factors explain the relatively light treatment of HAFO *Paenemarmota barbouri* in the published literature. Early workers only referred to the HAFO material as a large marmot. Zakrzewski (1969b, 1998) was the only one to describe *Paenemarmota barbouri* material from HAFO.

Spermophilus Cuvier, 1825

Spermophilus sp. A (small)

Citellus? sp. Wilson, 1933: pp. 119, 122, fig. 6; Wilson, 1937b: p. 38.

Citellid sp. Gazin, 1936: pp. 285, 288; J. Schultz, 1937: p. 84; Hibbard, 1941c: p. 87.

Citellus sp. Bryant, 1945: pp. 340, 357.

Citellus cf. *C. howelli* Hibbard. Zakrzewski, 1969b: p. 5, figs. 2b, d, f, g.

Spermophilus cf. *S. howelli* (Hibbard). Hibbard, 1972b: p. 126; Conrad, 1980: pp. 164-165, 294; McDonald et al., 1996: p. 42; Currie, 1998: p. 51.

Spermophilus howelli (Hibbard). Kurtén and Anderson, 1980: p. 212; Franz, 1981: p. 15; Kelly, 1994: p. 15; Hearst, 1999: p. 105; R. Martin et al., 2002b: p. 138.

Identification of HAFO Material

This small sciurid is assigned to *Spermophilus* based on the moderately hypsodont dentition, P4-M2 with broad V-shaped trigonid and metaloph unconnected to the protocone, M1-M2 subquadrate in outline, M3 slightly larger than M2, protolophid on the p4 very slight, trigonid of p4 significantly narrower than talonid, and metalophid extending from protoconid to parametaconid on the m1 and m2 (modified from Bryant, 1945). This small form of *Spermophilus* has the protoconid and hypoconid of lower cheekteeth separated by a deep notch. The P3 is relatively small for *Spermophilus*. *Spermophilus* sp. A is most similar in size to three named forms of *Spermophilus*: *Spermophilus meltoni*, *Spermophilus howelli*, and *Spermophilus meadensis.* These species are too poorly known to make any meaningful taxonomic statements about the HAFO material, but the type of *Sorex meltoni* may be distinct based on the parastyle of the P4 extending more than half the distance across the anterior surface toward the protocone, unlike the shorter parastyle of *Spermophilus howelli*, *Spermophilus meadensis*, and HAFO *Spermophilus* sp. A.

Distribution

Because HAFO *Spermophilus* sp. A appears most similar to *Spermophilus howelli*, *Spermophilus meltoni*, and *Spermophilus meadensis*, only the distributions for those three species are discussed here. *Spermophilus howelli* was described from Rexroad Locality 3 (Hibbard, 1941a, b; R. Martin et al., 2000) and subsequently at Fish Spring Flat (Kelly, 1994). All other localites said to contain *Spermophilus howelli*, Blanco (Kurtén and Anderson, 1980), Fox Canyon (R. Martin et al., 2000), and Pipe Creek Sinkhole (Farlow et al., 2001), also have published descriptions that only identify the material as *Spermophilus* cf. *Spermophilus howelli*: Blanco (Dalquest, 1975; Schultz, 1977b), Fox Canyon (R. Martin et al., 2002b), and Pipe Creek Sinkhole (R. Martin et al., 2002b). Additionally, *Spermophilus* cf. *Spermophilus howelli* was reported from Birch Creek (Hearst, 1999), Ninefoot Rapids (Conrad, 1980), and Taunton (Morgan and Morgan, 1995).

Spermophilus meltoni is known only from Sand Draw (Hibbard, 1972). *Spermophilus meadensis* was described from Borchers (Hibbard, 1941d) and listed as occurring at Medicine Hat (Churcher, 1984). *Spermophilus* cf. *Spermophilus meadensis* is known from the Generator Dome locality within Porcupine Cave (Goodwin, 2004).

Remarks on Taxonomy

When originally named, *Spermophilus howelli* was the smallest known Plio-Pleistocene species of *Spermophilus* (Hibbard, 1941a), and therefore size was the only differentiating character given. Currently, however, its small size is shared with another Blancan species, *Spermophilus meadensis* from Borchers (Hibbard, 1941d); *Spermophilus meltoni* from Sand Draw (Hibbard, 1972) is only slightly larger and broadly overlaps in size with *Speromophilus* cf. *Spermophilus howelli* from Fox Canyon (R. Martin et al., 2002b). Additionally, the topotypic material of *Sorex meltoni* is too worn to determine many features of occlusal morphology (Hibbard, 1972b; R. Martin et al., 2002b).

Comments on HAFO Material

Most of the sciurid material from HAFO seems referable to this small species of *Spermophilus*. It was referred to *Spermophilus* cf. *Spermophilus howelli* because much of the material from Hagerman was indistinguishable from *Spermophilus howelli* from Fox Canyon, but the HAFO specimens had a more well-developed trigonid pit on the p4 (Zakrzewski, 1969b). The Fox Canyon population was more recently considered as *Spermophilus* cf. *Spermophilus howelli* (R. Martin et al., 2002b). Therefore the tenuous allocation to species was made by comparison to a sample that may or may not represent *Spermophilus howelli*.

If *Spermophilus howelli* and *Spermophilus meadensis* are distinct species, the Hagerman *Spermophilus* sp. A possibly belongs to the *Spermophilus meadensis* based on the currently known temporal distribution of these species.

Spermophilus sp. B (large)

Citellus sp. (large). Zakrzewski, 1969b: pp. 5, 7, fig. 2a.

Spermophilus large species. Gustafson, 1985b: tab. 3.

Identification of HAFO Material

See *Spermophilus* sp. A for identification to *Spermophilus*. This large form of *Spermophilus* is morphologically similar to *Spermophilus rexroadensis*, but is about 35% larger and has a greatly reduced M3 metacone. *Spermophilus* sp. B is differentiated from *Spermophilus boothi* by its larger size, absence of mesostyle on M3, and greatly reduced M3 metacone. *Spermophilus* sp. B. is only slightly larger than *Spermophilus johnsoni*, which is intermediate in morphology with *Spermophilus boothi* and *Spermophilus* sp. B, particularly with regard to the development of the metaloph and metacone.

Distribution

Spermophilus rexroadensis is known from Rexroad Locality 3 (Hibbard, 1941a); *Spermophilus* cf. *Spermophilus rexroadensis* occurs at Fox Canyon (R. Martin, 2002b). *Spermophilus boothi* is present in the faunas from Sand Draw (Hibbard, 1972) and White Rock (Eshelman, 1975). Sand Draw (Hibbard, 1972) is the only locality known to contain *Spermophilus johnsoni*.

Remarks on Taxonomy

This large species of *Spermophilus* is only known from upper dentition. *Spermophilus finlayensis* from Hudspeth (Strain, 1966) is similar to *Spermophilus* *rexroadensis*, but *Spermophilus finlayensis* is not known from upper teeth. However, because the Hudspeth *Spermophilus* is smaller than *Spermophilus rexroadensis*, it is unlikely to be conspecific with the HAFO material.

Comments on HAFO Material

This large sciurid is known from HAFO by only three specimens. Its unique size among HAFO sciurids makes the recognition of these specimens relatively easy. The largest sciurid at HAFO, *Paenemarmota barbouri*, has cheekteeth nearly twice the length of this large *Spermophilus*, and that of the next smaller HAFO sciurid (*Spermophilus* sp. C) is approximately half the length.

Spermophilus sp. C (medium)

Citellus sp. (medium). Zakrzewski, 1969b: p. 7, fig. 2e.

Identification of HAFO Material

Two dentaries assigned to *Spermophilus* sp. C differ from *Spermophilus* sp. A in being larger in size (judging by the alveolar dimensions) and in having a more anteriorly compressed p4 (the metaconid and protoconid are closer). They differ from *Spermophilus* sp. B in being much smaller and in lacking a metalophid. *Spermophilus* sp. C matches the size of *Spermophilus rexroadensis*, but the p4 lacks the metalophid and has a larger hypoconid.

Comments on HAFO Material

This sciurid is represented at HAFO by two dentaries. One is edentulous and the other contains the p4.

Indeterminate Spermophilina Moore, 1959

Ammospermophilus or *Citellus* sp. (small). Zakrzewski, 1969b: p. 7, fig. 2C; Hibbard, 1972b: p. 126.

Ammospermophilus or *Spermophilus* sp. Gustafson, 1985b: tab. 3.

Identification of HAFO Material

This spermophiline is much smaller than any other from HAFO.

Comments on HAFO Material

A single dentary with heavily eroded p4-m1 is allocated to this taxon.

Geomyidae Bonaparte, 1845

Thomomys Wied-Neuwied, 1839

Thomomys gidleyi Wilson, 1933

Thomomys gidleyi n. sp. Wilson, 1933: p. 119, 122-123, figs. 4, 4a.

Thomomys gidleyi Wilson. Gazin, 1936: p. 285, 288; J. Schultz, 1937: p. 84; Wilson, 1937b: p. 38; Hibbard, 1958b: p. 14; Zakrzewski, 1969b: pp. 7-8, fig. 3; Hibbard, 1972b: p. 126; Gustafson, 1978: pp. 25-26, 54 tab. 6; Conrad, 1980: pp. 137, 165, 187, tab. 8; Kurtén and Anderson, 1980: p. 223; Franz, 1981: p. 16; Gustafson, 1985b: tab. 3; Pfaff, 1991: p. 117, tab. 18; Sankey, 1991: p. 120-121; McDonald et al., 1996: p. 42; Currie, 1998: p. 51; Albright, 1999: pp. 35-36; Sankey, 2002: p. 82.

Identification of HAFO Material

This geomyid is recognized as *Thomomys* by having evergrowing teeth with dentine tracts on the premolars extending nearly the entire crown height, upper molars anteroposteriorly constricted labially, lower molars constricted lingually, ungrooved incisors, and presence of enamel on the anterior edges of lower molars and on the posterior edge of upper premolars (modified from Albright, 1999.) *Thomomys gidleyi* is distinguished from other species of *Thomomys* by its smaller size, shallower temporal fossa, and broader retromolar fossa (Zakzewski, 1969b).

Distribution

Thomomys gidleyi is known from the San Timoteo Formation (Albright, 1999) and Otay Ranch (Wagner et al., 2000, 2001). Material identified as *Thomomys* cf. *Thomomys gidleyi* is reported from Ash Wash (Gensler, 2002), Taunton (Morgan and Morgan, 1995), Temecula Arkose (Pajak et al., 1996), Wild Horse Butte (Shotwell, 1967), and White Bluffs (Gustafson, 1978).

Remarks on Taxonomy

Thomomys gidleyi was separated from other species of *Thomomys* by Wilson (1933) by the lower molars coming to a gradual termination lingually rather than being constricted. This feature, however, is variable in both modern and fossil *Thomomys*, although a greater percentage of individuals in other *Thomomys* species are constricted than in *Thomomys gidleyi* (Zakrzewski, 1969b).

Comments on HAFO Material

Thomomys gidleyi is by far the more abundant geomyid from HAFO. This species may be ancestral to the modern *Thomomys talpoides* and *Thomomys bottae* (Zakrzewski, 1969b).

Pliogeomys Hibbard, 1954a

Pliogeomys parvus Zakrzewski, 1969b

Pliogeomys parvus n. sp. Zakrzewski, 1969b: p. 8-11, fig. 4.

Pliogeomys parvus Zakrzewski. Hibbard, 1972b: p. 126; Kurtén and Anderson, 1980: p. 226; Franz, 1981: p. 16; McDonald et al., 1996: p. 42; Albright, 1999: p. 39; Mou, 1999: pp. 83, 90.

Pliogeomys parva [sic]. Currie, 1998: p. 51.

Identification of HAFO Material

Pliogeomys has upper incisors with two grooves each, rooted cheekteeth, lower molars without enamel on the anterior edges, and upper molars without enamel on the posterior edges. *Pliogeomys parvus* may be distinguished from *Pliogeomys buisi* by its relatively narrow anterolophid of the p4 and relatively wide m1 labially; roots are better developed on *Pliogeomys buisi* (modified from Zakrzewski, 1969b).

Distribution

In addition to HAFO, *Pliogeomys parvus* is known from the Panaca Formation (Mou, 1999; Lindsay et al., 2002). The only other published Pliocene record of *Pliogeomys* is from Saw Rock Canyon (Hibbard, 1964). Renewed field efforts in Meade County, Kansas, have led some to consider those fossils as belonging instead to *Geomys* (R. Martin et al., 2002b), although Bell et al. (2004) retained the identification as *Pliogeomys*.

The other currently recognized species of *Pliogeomys*, *Pliogeomys buisi*, is found only at Buis Ranch (Hibbard, 1954a). *Pliogeomys* fossils said to represent a new species are known from Devils Nest Airstrip and Santee in the Ogallala Formation (Voorhies, 1990). *Pliogeomys carranzai* from Yepómera (Lindsay and Jacobs, 1985) is now considered a species of *Geomys* (R. Martin et al., 2002b).

Comments on HAFO Material

Pliogeomys parvus is the most geologically recent known geomyid with rooted teeth. The specimens from HAFO are the only described rooted geomyid teeth from the Blancan.

Heteromyidae Gray, 1868

Oregonomys Martin, 1984

Oregonomys magnus (Zakrzewski, 1969b)

Perognathus magnus n. sp. Zakrzewski, 1969b: pp. 11-12, fig. 5c.

Perognathus magnus Zakrzewski. Hibbard, 1972b: p. 126; Dalquest, 1978: p. 279; Kurtén and Anderson, 1980: p. 233; Franz, 1981: p. 17.

Oregonomys magnus (Zakrzewski). Martin, 1984: pp. 90, 92, 106, 118-120, figs. 11, 14g, tabs. 9, 12; McDonald et al., 1996: p. 42; Currie, 1998: p. 51; Hearst, 1999: p. 137; Mou, 1999: 95.

Identification of HAFO Material

This large heteromyid has a buccal cuspule on the protoloph of the three-rooted P4, lingual connection of lophs on the upper cheekteeth, and a molariform p4 which never forms an X-pattern. *Oregonomys magnus* is smaller and more hypsodont than *Oregonomys pebblespringensis* and *Oregonomys sargenti*. *Oregonomys magnus* has a P4 with a strongly inflected hypostyle and without accessory cuspules on the metaloph, M3 with a circular pattern, and p4 hypostylid larger than that of *Oregonomys pebblespringensis*, but smaller than that of *Oregonomys sargenti* (modified from Zakrzewski, 1969b; J. Martin, 1984.)

Distribution

Oregonomys magnus is only known from HAFO. There are two other reports of *Oregonomys* in the Pliocene: *Oregonomys* sp. from the Panaca Formation (Mou, 1999; Lindsay et al., 2002) and *Oregonomys* cf. *Oregonomys sargenti* from the White Narrows Formation (Reynolds and Lindsay, 1999). All other records of *Oregonomys* are Miocene (J. Martin, 1984; Voorhies, 1990; Becker and McDonald, 1998).

Remarks on Taxonomy

Oregonomys was erected to include *Perognathus magnus*, *Perognathus sargenti*, *Diprionomys agrarius*, and the new species *Oregonomys pebblespringsensis* (J. Martin, 1984). *Diprionomys agrarius* is now included within *Mioheteromys* (Korth, 1997).

Comments on HAFO Material

A single locality at HAFO containing the three fossils representing *Oregonomys magnus* is the youngest known occurrence of *Oregonomys*. This rare heteromyid was suggested as being saltatorial based on study of the more abundant *Oregonomys pebblespringensis* (J. Martin, 1984).

Perognathus Wied-Neuwied, 1839

Perognathus maldei Zakrzewski, 1969b

Perognathus maldei n. sp. Zakrzewski, 1969b: p. 12, fig. 5b.

Perognathus maldei Zakrzewski. Hibbard, 1972b: p. 126; Kurtén and Anderson, 1980: p. 233, figs. 12.5A, E; Franz, 1981: p. 17; Martin, 1984: pp. 93-97, 101, 104, figs. 2-5; Czaplewski, 1990: p. 14-17; McDonald et al., 1996: p. 42; Currie, 1998: p. 51; Albright, 1999: pp. 41, 44; Hearst, 1999: p. 137.

Perognathus gidleyi Hibbard. McDonald et al., 1996: p. 42.

Identification of HAFO Material

Perognathus maldei matches modern *Perognathus parvus* in all respects except in having a more quadrate p4 and a less robust masseteric crest (Zakrzewski, 1969b).

Distribution

All known specimens of *Perognathus maldei* are from HAFO. Material from Little Valley "compares in all the recognizable characteristics to *Pliogeomys parvus*" (Shotwell, 1967:12), but was conservatively called only *Perognathus* sp. because the Little Valley fauna is Miocene in age. The *Perognathus* from Little Valley might represent a second sample of *Perognathus maldei*.

Remarks on Taxonomy

Study of modern *Pliogeomys parvus* material is needed to verify the diagnostic characters of *Perognathus maldei*.

Comments on HAFO Material

There is one mention of a second species of *Perognathus* from HAFO – *Perognathus gidleyi* (McDonald et al., 1996:42). *Perognathus gidleyi* is morphologically similar to *Perognathus maldei* (the latter differs in having a posteriorly expanded protoconid) and occurs at both younger and older localities (Hibbard, 1941a, b; Tomida, 1987). I have not seen any specimens of *Perognathus gidleyi* from HAFO, and I do not consider that species present in the Hagerman faunas.

Prodipodomys Hibbard, 1939

Prodipodomys idahoensis Hibbard, 1962

Prodipodomys idahoensis n. sp. Hibbard, 1962: pp. 482-484, fig. 1c.

Prodipodomys idahoensis Hibbard. Zakrzewski, 1969b: pp. 12-13, fig. 5a, d; Hibbard, 1972a: p. 88; Hibbard, 1972b: p. 126; Conrad, 1980: p. 120; Kurtén and Anderson, 1980: p. 230; Franz, 1981: p. 16; Lindsay and Jacobs, 1985: pp. 12, 15; Tomida, 1987: p. 70; Czaplewski, 1990: pp. 19, 21-22; McDonald et al., 1996: p. 42; Currie, 1998: p. 51; Albright, 1999: p. 47; Hearst, 1999: p. 139; Mou, 1999: pp. 105, 135.

Identification of HAFO Material

This heteromyid has low crowned and high cusped cheekteeth with poorly developed dentine tracts and multiple roots (Zakrzewski, 1981); the P4 has a protocone and metacone connected centrally rather than labially as in *Dipodomys*, and lacks a posterior cingulum which is present in *Dipodomys* (Dalquest et al., 1992). The HAFO material is separated from *Cupidinimus* by being more hyposodont, having more reduced roots, and having a P4 that lacks a protostyle and has a more arcuate metaloph (Dalquest et al., 1992). Of the species of *Prodipodomys*, *Prodipodomys idahoensis* shows the greatest development of dentine tracts and greatest degree of hyposodonty.

Distribution

Pliocene records of *Prodipodomys idahoensis* are known from California Wash (Johnson et al., 1975; Mezzabotta, 1997), Chalk Flat (Conrad, 1980), San Timoteo Formation (Albright, 1999), Verde (Czaplewski, 1990), and Yepómera (Lindsay, 1984; Lindsay and Jacobs, 1985). Specimens identified from Wolf Ranch were originally identified as *Prodipodomys idahoensis* (Harrison, 1978; Lindsay and Jacobs, 1985), but later referred to as *Dipodomys hibbardi* based on the development of the dentine tracts and fusion of roots (Tomida, 1987; Czaplewski, 1990). Recently, both identifications were considered correct because both taxa were recognized from Wolf Ranch (Albright, 1999). Identification of *Prodipodomys idahoensis* from Panaca (Albright, 1999) was not supported in more thorough studies of material from that formation (Mou, 1999; Lindsay et al., 2002). *Prodipodomys* cf. *Prodipodomys idahoensis* is reported from the Pliocene Deer Park B (R. Martin et al., 2002a).

Among Pleistocene localities, *Prodipodomys idahoensis* is known from Java (R. Martin, 1989) and *Prodipodomys* cf. *Prodipodomys idahoensis* is reported from the San Timoteo Formation (Reynolds and Reeder, 1991). However, subsequent to both of those publications, several workers have claimed that the latest known *Prodipodomys* is from the late Pliocene Borchers fauna (Dalquest et al., 1992; Albright, 1999).

Remarks on Taxonomy

It is unclear how species of *Prodipodomys* are related to each other or to species of *Dipodomys* (Dalquest et al., 1992). The two groups of species were differentiated, in part, by the development of their dentine tracts (Zakrzewski, 1981), however, the specimens of *Prodipodomys idahoensis* from HAFO have dentine tracts higher than other records of *Prodipodomys idahoensis*, and instead more closely matches the development in *Dipodomys hibbardi* (Tomida, 1987). Additionally, although the lineage including *Prodipodomys idahoensis* is marked by dentine tracts and increasing hypsodonty, other species of *Prodipodomys* retain more primitive characters even though being roughly contemporaneous temporally (Albright, 1999).

Fossils ascribed to an undescribed species of *Prodipodomys* from Taunton by Dalquest et al. (1992) show the P4 occlusal morphology normally attributed to

Dipodomys – the metacone and protocone connecting labially. This differs from all other species of *Prodipodomys*. Further complicating the situation is the typical pattern of *Prodipodomys* (metacone and protocone connecting centrally) present in a modern species of *Dipodomys* – *Dipodomys elator* (Dalquest et al., 1992). The possible diphyly of *Dipodomys* (Dalquest et al., 1992) and paraphyly of *Prodipodomys* means that the nomenclature above the species level is also in need of revision.

Comments on HAFO Material

Specimens of *Prodipodomys idahoensis* from HAFO have the highest dentine tracts of any fossils attributed to *Prodipodomys*. Tomida (1987) called for closer study of the *Prodipodomys idahoensis* from HAFO, however, the additional material collected after Hibbard (1962) and Zakrzewski (1969b) has not revealed any new, informative characters.

Castoridae Gray 1821

Castor Linnaeus, 1758

Castor californicus Kellogg, 1911

Castor accessor? Hay. Gazin, 1936: pp. 285, 288; J. Schultz, 1937: p. 84; Hibbard, 1941c: p. 87; Hibbard, 1958b: p. 15.

Castor cf. *C. accessor*? Hay. Wilson, 1933: p. 119.

Castor sp. Wilson, 1937b: p. 38; Fichter, 1972: p. 103.

Castor cf. *Castor californicus* Kellogg. Stirton, 1935: pp. 446-447; Taylor, 1966: p. 75; Zakrzewski, 1969a: p. 653; Zakrzewski, 1969b: p. 14; Hibbard, 1972b: p. 126; Conrad, 1980: p. 190; Gustafson, 1985b: tab. 3;

Castor accessor Hay. Davis, 1939: p. 272; Shotwell, 1970: p. 41.

Castor cf. *C. accessor* Hay. Hibbard, 1959: p. 33; Fichter, 1972: pp. 5, tab. 1.

Castor californicus Kellogg. White, 1967: p. 21; Gustafson, 1978: p. 54; Kurtén and Anderson, 1980: p. 238; Franz, 1981: p. 17; Cunningham, 1984: p. 51; Pfaff, 1991: p. 119; Repenning et al., 1995: p. 27; McDonald et al., 1996: pp. 32, 42; Currie, 1998: pp. 19, 52; Bell et al., 2004: p. 258.

Identification of HAFO Material

This large castorid exceeds the size of modern species of *Castor*, which it matches closely in morphology. *Castor californicus* also differs from *Castor canadensis* and *Castor fiber* in having shorter striae on the upper cheeckteeth and shorter striids on the lower cheekteeth (Gustafson, 1978; Repenning et al., 1995).

Distribution

Castor californicus is known from Birch Creek (Hearst, 1999), Kettleman Hills Pecten Bed (Kellogg, 1911; Stirton, 1935; Woodring et al., 1940), and White Bluffs (Gustafson, 1978). All specimens of *Castor* from the Glenns Ferry Formation were considered to be referable to *Castor californicus* (Repenning et al., 1995), including previous identifications of *Castor accessor* from the Froman Ferry sequence (Hay, 1927), *Castor accessor* (Shotwell, 1970) and *Castor* cf. *Castor accessor* (Hibbard, 1959) from Grand View, and *Castor* cf. *Castor californicus* from Horn's Ranch (Stirton, 1935). *Castor* cf. *Castor californicus* was reported from Devils Nest Airstrip (Voorhies, 1990), El Golfo (Shaw, 1981; Lindsay, 1984), Grand View (Conrad, 1980), Mailbox (Voorhies, 1990), Pliohippus Draw vicinity (Matthew, 1932; Stirton, 1935), Sand Point (Conrad, 1980), Santee (Voorhies, 1990), and Taunton (Morgan and Morgan, 1995). *Castor* cf. *Castor accessor* was reported from Angus (L. Martin, 1969), however, because of the site's probable late Irvingtonian age (Bell et al., 2004) the beaver may more likely be *Castor canadensis*.

Remarks on Taxonomy

Based on the geographic and presumed temporal similarity between *Castor* at HAFO and the type specimen of *Castor accessor*, the HAFO material was tentatively assigned to that species in some early papers. After Stirton (1935) described additional topotypic material of *Castor californicus* and noted the similarities to material being recovered from near Hagerman, the large HAFO beaver was most often tenuously referred to that species. An implicit suggestion that *Castor accessor* should be considered a junior synonym (Gustafson, 1978:26), was supported by the observation that the *Castor californicus* and *Castor accessor* do not differ from each other more than intraspecific variation in modern *Castor* (Conrad, 1980). Repenning et al. (1995) extended the earlier name, *Castor californicus* to include all *Castor* from the Glenns Ferry Formation.

Comments on HAFO Material

The first appearance of the modern species *Castor canadensis* is at Haile 15A (Webb, 1974a; Morgan and Hulbert, 1995), which predates the latest identified record of *Castor californicus* at Froman Ferry (Repenning et al., 1995) by about 600 ka (see Morgan and Hulbert, 1995, and Bell et al., 2004, for biochronologic age of Haile 15A; see Chapter 2 for discussion of Froman Ferry age). If these identifications are correct, modern *Castor* cannot simply be the anagenetic descendant of *Castor californicus*. Detailed examination of variation within large samples of fossil *Castor*, such as from HAFO, may eventually help to clarify the relationship between these species.

Procastoroides Barbour and Schultz, 1937

Procastoroides intermedius (Zakrzewski, 1969b)

Procastoroides sp. Taylor, 1966: p. 75.

Dipoides intermedius n. sp. Zakrzewski, 1969b: pp. 14-16, figs. 5F-I.

Dipoides intermedius Zakrzewski. Hibbard, 1972b: p. 126; Gustafson, 1978: p. 27; Kurtén and Anderson, 1980: p. 235, fig. 12.6C; Franz, 1981: p. 17; Gustafson, 1985b: tab. 3; McDonald et al., 1996: p. 42; Currie, 1998: pp. 19, 52.

Procastoroides intermedius (Zakrzewski). Repenning et al., 1995: pp. 61, 71; Hearst, 1999: p. 123; Kelly and Lugaski, 1999: p. 9-10.

Protocastoroides [sic] *idahoensis* (Shotwell). Link et al., 2002: p. 105, fig. 5.

Protocastoroides [sic] *intermedius* (Zakrzewski). Link et al., 2002: p. 114.

Identification of HAFO Material

This material, the smaller of the two HAFO castorids, has a notched wear pattern on the upper incisors, unlike the single wear facet of *Castor*. The occlusal pattern of P4-M2 is a single well-defined S-shape as in *Castoroides*, *Procastoroides*, and *Dipoides*; the size of the HAFO castoroidine is larger than all known *Dipoides* and much smaller than all known *Castoroides*. *Procastoroides* is further distinguished from *Dipoides* by the presence of a complete metastria and metaflexus on the M3. *Procastoroides intermedius* is the smallest species of *Procastoroides* and also differs in lacking a complete parastriid on the p4. (Modified from Zakrzewski, 1969b; Gustafson, 1978; Hearst, 1999, Kelly and Lugaski, 1999; Korth, 2001).

Distribution

Procastoroides intermedius is currently confined to records from HAFO. The fossil beaver from Stathcona Fiord was listed as *Dipoides* cf. *Dipoides intermedius* (Harington, 1996, 2001, 2003), however, this material is not yet described, and elsewhere was only called *Dipoides* sp. (Hutchison and Harington, 2002; Rybczynski, 2003).

Remarks on Taxonomy

When named, the type of *Dipoides intermedius* was described as being intermediate in size between *Dipoides rexroadensis* and *Procastoroides sweeti* (Zakrzewski, 1969b). Based on the uniformity in size among other species of *Dipoides*, Repenning et al. (1995) considered *Dipoides intermedius* to instead be the smallest species of *Procastoroides*. That assignment is accepted here, but for different reasons. Original assignment of *Dipoides intermedius* was based in part on the lack of pseudostriids on lower cheekteeth and the lack of a complete parastriid on the p4, the presence of which is characteristic of *Procastoroides*. Abundant material identified as *Procastoroides* is now known to lack pseudostriids on the lower dentition (Hearst, 1999). The complete parastriid on the p4 is also characteristic of all six recognized species of *Dipoides* (e.g., Shotwell, 1955; Woodburne, 1961; Gustafson, 1978). Even *Dipoides wilsoni*, which lacks a paraflexid in some individuals, has a faint, but complete parastriid (Kelly and Lugaski, 1999). Therefore the same character that was previously used to exclude *Dipoides intermedius* from *Procastoroides* would also exclude it from *Dipoides*. So whereas the morphology of the p4 is somewhat ambiguous in its taxonomic affinities, there is a well-developed metastria on the M3 in *Procastoroides*, but it is unknown in any *Dipoides* (Woodburne, 1961; Zakrzewski, 1969b). Alternatively, the HAFO material may belong to a group of castoroidines distinct from both *Procastoroides* and *Dipoides*.

In a recent review of castorid relationships above the species level, *Procastoroides* was omitted from a list of recognized taxa and *Paracastoroides* was included (Korth, 2001:280). Because *Paracastoroides* was not described and *Procastoroides* was explicity recognized elsewhere in the same study, the use of *Paracastoroides* is here considered a nomen nudum.

Comments on HAFO Material

Although some castorids exhibit fossorial adaptations, *Dipoides* was suggested as similar to or exceeding modern *Castor* in terms of aquatic nature and wood-cutting behavior (Rybczynski, 2003). Because *Procastoroides* is suggested to be closer to *Dipoides* (and *Castoroides*) than to other beavers (Xu, 1995; Korth, 2001; Rybczynski, 2003), the ecological suggestions for *Dipoides* and *Procastoroides* may be similar.

Specimens of *Procastoroides intermedius* from HAFO are the youngest known records of *Procastoroides*. Stratigraphically higher in the Glenns Ferry Formation are *Procastoroides* sp. aff. *Procastoroides sweeti* from Birch Creek (Hearst, 1999) and *Procastoroides idahoensis* from Grand View (Shotwell, 1970). Hearst (1999) suggested that *Procastoroides intermedius* from HAFO and *Dipoides* sp. from Seneca (Martin and Schultz, 1984) may be juveniles of the species represented in Birch Creek by *Procastoroides* sp. aff. *Procastoroides sweeti*. That conclusion might have been based on only the holotype of *Procastoroides intermedius*, because in discussion of that species she states "*Procastoroides* *intermedius* is known from a single isolated P/4" (Hearst, 1999:123). There are actually multiple specimens of *Procastoroides intermedius* known. In addition to the holotype, which is a p4, the described and measured paratypes includes two more p4s (Zakrzewski, 1969b:14).

At Birch Creek, *Procastoroides* is the numerically dominant castorid (Hearst, 1999), whereas *Castor* is much more abundant in the deposits at HAFO. When discussing the castorids of HAFO, Hearst said "*Castor* fossils vastly outnumber the remains of another [sic] beavers, *Dipoides* and *Procastoroides*" (Hearst, 1999:108); it seems likely from the rest of her text that this is a typographical error and that she does not consider HAFO to contain three fossil beavers.

Use of "*Protocastoroides*" (Link et al., 2002:105, 114, fig. 5) appears to be a typographical error for *Procastoroides*. Inclusion of *Procastoroides idahoensis* in the HAFO fauna (Link et al., 2002:105, fig. 5) is also in error, although from elsewhere in the paper, it does seem to refer to *Prodipodomys idahoensis* as only occurring in younger deposits of the Glenns Ferry Formation.

Muridae Illiger, 1811

Sigmodontinae Wagner, 1843

Peromyscus Gloger, 1842

Peromyscus hagermanensis Hibbard, 1962

Peromyscus? Hibbard, 1959: p. 11.

Peromyscus hagermanensis n. sp. Hibbard, 1962: pp. 484-5, fig. 2.

Peromyscus hagermanensis Hibbard. Zakrzewski, 1969b: pp. 16-17, figs. 6A-B; Hibbard, 1972b: p. 127; Gustafson, 1978: p. 29; Conrad, 1980: p. 198; Kurtén and Anderson, 1980: p. 244; Franz, 1981: p. 18; Czaplewski, 1987: pp. 142-143, 152; Tomida, 1987: pp. 24-25, 31, 77-82; Sankey, 1991: pp. 121-122; McDonald et al., 1996: p. 42; Currie, 1998: p. 52; Albright, 1999: pp. 58-9; Mou, 1999; pp. 138, 148-149; Ruez, 2001: pp. 162-163; R. Martin et al., 2002: p. 1080; Sankey, 2002: p. 82.

Identification of HAFO Material

This material is referable to *Peromyscus* (sensu lato) due to the short coronoid process of the mandible, marked reduction of the M3, alternation of cusps, brachydont molars, narrow flexi and flexids, absence of a distinct labial cingulum, and conical metacone, paracone, entoconid, and metaconid (Ruez, 2001). It is assigned to *Peromyscus* (*Peromyscus*) based on the large number of accessory tubercles (especially the mesoloph, mesostyle, and parastyle) between the principal cusps, and with the anterior cingulum extending to the outer edge of the m1 and m2 (Tomida, 1987; Ruez, 2001).

Blancan through middle Irvingtonian records of *Peromyscus* (*Peromyscus*) differ from later species (except *P. eremicus*) in having the protoconid-entoconid junction offset lingually in m1-2 and the protocone-hypocone junction offset labially in M1, as in *Copemys*; ontogenetically old individuals show a straight connection (Lindsay, 1972; Tomida, 1987; Mou, 1999). Of this subgroup *Peromyscus* *hagermanensis* is smaller than *Peromyscus maximus*, *Peromyscus complexus*, and *Peromyscus sarmocophinus*, but similar in size to *Peromyscus nosher* (Gustafson, 1978; Tomida, 1987; Albright, 1999; Ruez, 2001). *Peromyscus complexus* is unique in having five projections coming off the paracone of the M2 (Albright, 1999). The M1 of *Peromyscus hagermanensis* differs from that of *Peromyscus maximus* in not having the anterocone as distinctly bilobed, a more anterior connection of the mesoloph to the mesocone rather than nearer to the hypocone, and presence of a much greater development of the anterolabial cingulum (Albright, 1999). *Peromyscus sarmocophinus* is the only one to have a posterolophulid on the m1 and mesolophids on all m1s and m2s; *Peromyscus hagermanensis* further differs in having a less well-developed mesostyle, longer anterolabial cingulum, and slightly less bilobed anterocone on the M1 (Ruez, 2001). The anterior cingula of upper and lower molars are much better developed in *Peromyscus hagermanensis* than in *Peromyscus nosher*; the anteroconid of the m1 of *Peromyscus nosher* is strongly bilobed, unlike in *Peromyscus hagermanensis* (Gustafson, 1978). *Peromyscus hagermanensis* differs from all the above in having a mesoloph and paralophule connect at the mesostyle in the M1 (Zakrzewski, 1969b).

Distribution

Peromyscus hagermanensis is known from 111 Ranch and Duncan in the Gila Conglomerate (Tomida, 1987) and the Panaca Formation (Mou, 1999; Lindsay et al., 2002). Specimens referred to *Peromyscus* cf. *Peromyscus hagermanensis* are known from Clarkdale (Czaplewski, 1987; Morgan and White, 2005), Deer Park B (R. Martin et al., 2002a), and San Timoteo Formation (Albright, 1999).

Remarks on Taxonomy

The five species of Blancan through middle Irvingtonian *Peromyscus* (*Peromyscus*) share an interesting mixture of characters present both in some modern forms of *Peromyscus* and in the extinct *Copemys*. (Although the offset connections typical of *Copemys* are not as strongly expressed in *Peromyscus nosher*, it does have the abundant accessory cuspules and lophs that are otherwise unknown among Blancan *Peromyscus*.) The modern *Peromyscus eremicus* may also belong to this group because it also has the connections typical of *Copemys* (Lindsay, personal communication in Tomida, 1987; and Mou, 1999). Because three of these species (*Peromyscus complexus*, *Peromyscus maximus*, and *Peromyscus nosher*) are known from less than 10 fossils, it may not yet be possible to examine the relationships between these taxa.

Comments on HAFO Material

Although Zakrzewski (1969b) noted differences between some specimens of *Peromyscus* from HAFO, he referred all the material to *Peromyscus hagermanensis*. I also cannot find any basis to support the presence of more than one species of *Peromyscus*.

Baiomys True, 1894

Baiomys aquilonius Zakrzewski, 1969b

Baiomys aquilonius n. sp. Zakrzewski, 1969b: p. 17, 19, figs. 6E-F.

Baiomys aquilonius Zakrzewski. Hibbard, 1972b: p. 127; Kurtén and Anderson, 1980: p. 247; Franz, 1981: p. 18; Tomida, 1987: p. 31, 87-88; McDonald et al., 1996: p. 42; Currie, 1998: p. 52; Albright, 1999: p. 63.

Identification of HAFO Material

This material is of a very small and brachydont cricetine with alternating, softly rounded cusps; cheektooth occlusal pattern is simple, lacking accessory cusps and a labial cingulum. This small species of *Baiomys* has an m1 with an expanded procingular area and distinct anteromedian stylid, and a reduced m3 (Zakrzewski, 1969b).

Distribution

Baiomys aquilonius only occurs at HAFO.

Remarks on Taxonomy

The diagnostic features of *Baiomys aquilonius* presented above are otherwise unknown among species of *Baiomys*. Based on the similarity in size and weakly developed cingula of the molars, *Baiomys aquilonius* may be most closely related to *Baiomys rexroadi*. *Baiomys rexroadi* is known from Beck Ranch (Dalquest, 1978), Deer Park B (R. Martin et al., 2002a), and Rexroad Locality 2a (Hibbard, 1941a). Although a dentary from Saw Rock was identified as *Baiomys rexroadi* (Hibbard, 1949), that species was not included in a later discussion of the fauna that recorded only one species of *Baiomys*, *Baiomys sawrockensis* (Hibbard, 1953b). Records of *Baiomys rexroadi* from Fox Canyon (Hibbard, 1950) was later split into two new species, *Reithrodontomys rexroadi* and *Baiomys kolbi* (Hibbard, 1952).

Comments on HAFO Material

The material from HAFO is the northern-most occurrence of *Baiomys*, either fossil or modern.

Baiomys minimus (Gidley, 1922)

Baiomys sp. (not *Baiomys aquilonius*). Zakrzewski, 1969b: p. 19, fig. 6G.

Baiomys sp. Hibbard, 1972b: p. 127; Kurtén and Anderson, 1980: p. 247; McDonald et al., 1996: p. 42; Currie, 1998: p. 52; Ruez, 2001: p. 166.

Identification of HAFO Material

Baiomys minimus differs from *Baiomys aquilonius* by having an unexpanded procingular area and the absence of an anteromedian stylid on the m1 (Zakrzewski, 1969b). *Baiomys minimus* is smaller than *Baiomys kolbi*, *Baiomys brachygnathus*, and *Baiomys musculus*; although similar in size to *Baiomys rexroadi*, *Baiomys aquilonius*, *Baiomys sawrockensis*, and *Baiomys taylori*, *Baiomys minimus* has better developed cingular ridges. *Baiomys mowi* is likewise similar in size, but differs in having narrower dentition and a reduced anterolabial cingulum on the m2 (Albright, 1999). The holotype of *Baiomys minimus* has a bilobed anteroconid on the m1 (Gidley, 1922), however, examination of a larger sample showed that this is not typical (Tomida, 1987). As in the majority of specimens of this larger sample, the HAFO *Baiomys minimus* has a single cusped anteroconid with only a faint anteromedian flexid.

Distribution

Outside of HAFO *Baiomys minimus* is known from the Benson (Gidley, 1922), Duncan (Tomida, 1987; Mezzabotta, 1997), McRae Wash (Johnson et al., 1975), Mendevil Ranch (Johnson et al., 1975), and Wolf Ranch (Johnson et al., 1975; Harisson, 1978) faunas in Arizona.

Remarks on Taxonomy

There are a large number of species of fossil *Baiomys* considering how poorly known these specimens are in the fossil record. Further complication is caused by the recognition of only lower dentition in many localities (Ruez, 2001). Continued efforts in Meade County, Kansas, by R. Martin et al. (e.g., 2002a), may eventually clarify the taxonomy of this group.

Comments on HAFO Material

Although *Baiomys minimus* is only known from HAFO by a single specimen, it does seem to be unambiguously distinct from the more abundant *Baiomys aquilonius*.

Neotoma Say and Ord, 1825

Neotoma cf. *Neotoma quadriplicata* (Hibbard, 1941a)

Neotoma sp. cf. *N quadriplicatus* (Hibbard). Zakrzewski, 1969b: p. 19; Hibbard, 1972b: p. 127; Gustafson, 1985b: tab. 3; McDonald et al., 1996: p. 42; Currie, 1998: p. 52.

Neotoma sp. cf. *Neotoma quadriplicata* (Hibbard). Kurtén and Anderson, 1980: p. 252; Tomida, 1987: pp. 24-25, 111-112; Zakrzewski, 1993: app. A.

Neotoma quadriplicata (Hibbard). Franz, 1981: p. 18; Albright, 1999: p. 75.

Identification of HAFO Material

Neotoma from HAFO is probably referable to *Neotoma* (*Paraneotoma*) based on the relatively brachydont dentition compared with other forms of *Neotoma*, absence of dentine tracts, and an unfused posterior pair of roots on upper molars (Hibbard, 1967; Zakrzewski, 1993); the lack of an m3 or M3 from HAFO precludes more definitive assignment. Among the species of *Neotoma* (*Paraneotoma*), the size of the HAFO *Neotoma* is most similar to *Neotoma quadriplicata*; it significantly exceeds the size of *Neotoma sawrockensis*, *Neotoma fossilis*, and *Neotoma vaughani*, and is similar, but slightly larger, in size to *Neotoma taylori* (Hibbard, 1967; Czaplewski, 1990; Zakrzewski, 1991). *Neotoma taylori* is further differentiated by being more hypsodont than the HAFO *Neotoma* (Tomida, 1987). *Neotoma leucopetrica* is much larger than the other species of *Neotoma* (Zakrzewski, 1991). The HAFO *Neotoma* differs from the topotypic material of *Neotoma quadriplicata* in having only three roots on the m1 (Zakrzewski, 1969b).

Distribution

Neotoma quadriplicata is known from numerous localities within Meade County, Kansas: Deer Park (Zakrzewski, 1991, 1993; R. Martin et al., 2000), Deer Park B (R. Martin et al., 2000, 2002a), Fox Canyon (Zakrzewski, 1993; R. Martin et al., 2000), Hornet (R. Martin et al., 2000), Keefe Canyon (R. Martin et al., 2000), Rexroad Locality 2 (Hibbard, 1941a), Rexroad Locality 3 (Hibbard, 1941a, b, c; Hibbard, 1970; R. Martin et al., 2000), Ripley B (R. Martin et al., 2000), and Wiens B (R. Martin et al., 2000). Additional records of *Neotoma quadriplicata* were reported from Beck Ranch (Dalquest, 1978; Zakrzewski, 1993), Country Club (Tomida, 1987; Zakrzewski, 1993), and Truth or Consequences (Repenning and May, 1986). *Neotoma* sp. cf. *Neotoma quadriplicata* was reported from Blanco (Schultz, 1977b; Zakrzewski, 1993), Temecula Arkose (Reynolds and Reynolds, 1993), Sand Draw (Zakrzewski, 1993), and White Bluffs (Gustafson, 1978; Zakrzewski, 1993).

Remarks on Taxonomy

More confident identification of HAFO *Neotoma* requires recovery of the third molars; the S-shaped occlusal pattern on the m3 is considered a distinctive character of *Neotoma* (*Paraneotoma*) and most M3s have four reentrant angles (Hibbard, 1967). Recovery of a *Neotoma* M3 from HAFO with a posterolingual fold would support more definitive assignment to *Neotoma quadriplicata*.

When the species *Parahodomys quadriplicatus* was transferred to within *Neotoma* (Hibbard, 1967), the specific epithet should have been emended to *quadriplicata* in order to agree in gender with *Neotoma* (International Commission on Zoological Nomenclature, 1964).

Comments on HAFO Material

Assigmment to *Neotoma* sp. cf. *Neotoma quadriplicata* is based largely on the closest similarity in size to *Neotoma quadriplicata* among *Neotoma* (*Paraneotoma*). Other *Neotoma* material in the Glenns Ferry Formation (at Birch Creek) is, unfortunately, also lacking in known species-level diagnostic characters (Hearst, 1999).

Arvicolinae Gray 1821

Ophiomys Hibbard and Zakrzewski, 1967

Ophiomys taylori (Hibbard, 1959)

Nebraskomys? *taylori* n. sp. Hibbard, 1959: pp. 5, 12-15.

Nebraskomys? *taylori* Hibbard. Taylor, 1966: p. 75.

Ophiomys taylori (Hibbard). Hibbard and Zakrzewski, 1967: pp. 262-277, figs. 1B-K, O-Q, 2A-C, tab. 1; Zakrzewski, 1969b: pp. 20-21, 27, fig. 6C, tab. 5; Shotwell, 1970: p. 65; Hibbard, 1972b: p. 127; Malde, 1972: p. D16; Fry and Gustafson, 1974: p. 376; Middleton, 1976: p. 10; Gustafson, 1978: pp. 31, 55; Kurtén and Anderson, 1980: pp. 13, 254; Franz, 1981: p. 19; Cunningham, 1984: p. 51; Gustafson, 1985b: p. 90, tab. 3; Barnosky, 1985: p. 264; Tomida, 1987: pp. 24-25, 121-122; McDonald et al., 1996: p. 42; Currie, 1998: p. 52; Hearst, 1999: pp. 159-160; Smith et al., 2000: p. 8; R. Martin, 2003: p. 402; Bell et al., 2004: p. 258.

Mimomys (*Ophiomys*) *taylori* (Hibbard). Repenning, 1987: p. 256; Repenning et al., 1995: p. 68; McDonald et al., 1996: p. 21; Wagner et al., 1997: p. 19; Albright, 1999: p. 82.

Mimomys taylori (Hibbard). Conrad, 1980: pp. 78, 123, 139, 297; Repenning, 2003: pp. 488-489, 492, 495, 497, fig. 17.6F-G.

Identification of HAFO Material

This small arvicoline is recognized as *Mimomys* (sensu lato; Repenning, 2003) based on the high-crowned, rooted teeth and an m1 with three triangles, well developed primary wings, and (usually) a *Mimomys* Kante; it is referable to *Ophiomys* (sensu Hibbard and Zakrzewski, 1967) by the lack of cementum in reentrants, lack of labial dentine tracts, absence of enamel pits on M3, and m1 having primary wings confluent with each other and the anterior loop.

Species-level identification follows Repenning (2003), so his nomenclature is used in this paragraph; see Remarks on Taxonomy for usage of *Ophiomys* for this species instead. *Mimomys* (*Cromeromys*) differs from other *Mimomys* in North America in having cementum in the reentrants. *Mimomys taylori* has higher dentine tracts on the lingual face of the anteroconid complex than *Mimomys* (*Ogmodontomys*), *Mimomys sawrockensis*, and '*Mimomys sawrockensis-taylori*'; dentine tracts in the HAFO material are shorter than in *Mimomys meadensis* (Repenning, 2003). Of these taxa, *Mimomys sawrockensis-taylori* and *Mimomys meadensis* have the dentine tracts expressed most similarly to *Mimomys taylori*. *Mimomys taylori* futher differs from '*Mimomys sawrockensis-taylori*' (sensu Repenning, 2003) because the latter occasionally has an enamel pit in the m3 and the former sometimes lacks a *Mimomys* Kante on the m1. The m1 of *Mimomys taylori* also differs from *Mimomys meadensis* in having an unreduced prism fold, less restriction between the primary wings and the anterior loop, higher rate of possessing an enamel islet, and better developed lingual root (Hibbard and Zakrzewski, 1967; Repenning, 2003).

None of the characters discussed so far differentiate *Ophiomys taylori* from the similar *Cosomys primus*, which also occurs at HAFO. In most m1s, *Cosomys primus* has a more complex anteroconid complex than *Ophiomys taylori*, although in both taxa the presence of an enamel pit, a prism fold, a *Mimomys* kante, and all other features due to enamel crenulation, are variably present. Development of these characters is seemingly as dependent on ontogenetic age as on taxonomic difference.

The most reliable character separating *Cosomys primus* and *Ophiomys taylori* is size (Repenning, 1967, 2003; Lich, 1990), but there are some teeth from HAFO that I cannot confidently assign to one or the other by this criterion. The Schmelzmuster of *Cosomys primus* described by Koenigswald (1980) was cited as separating that taxon from other forms of *Mimomys* (Repenning, 2003), however, the Schmelzmuster of *Ophiomys taylori* is unknown (Repenning, 2003:489).

Distribution

In a recent review of North American *Mimomys* (sensu lato), *Ophiomys taylori* was restricted to the Glenns Ferry Formation sequence at HAFO (Repenning, 2003). Records of *Ophiomys taylori* recorded from Sand Point (Hibbard and Zakrzewski, 1967; Smith et al., 2000) and Taunton (Gustafson, 1985b; Smith et al., 2000), and *Ophiomys* cf. *Ophiomys taylori* from Duncan (Tomida, 1987) were reassigned to *Mimomys meadensis* (Repenning, 2003). The Sand Point (Repenning, 1987) and Taunton (Morgan and Morgan, 1995) material was also earlier referred to as *Mimomys* (*Ophiomys*) *taylori-parvus* to indicate its transitional nature, however, that morphotype was later considered equivalent to *Mimomys meadensis* (Repenning, 2003).

Remarks on Taxonomy

Nomenclature of species attributed to *Mimomys* (sensu Repenning, 2003) has remained in a state of flux for decades. In the continually evolving taxonomy of this group, the taxon referred to here is most commonly included within *Ophiomys* (e.g., Hibbard and Zakrzewski, 1967), but *Ophiomys* itself is included within *Mimomys* by some authors (e.g., Repenning, 1980, 1987). More recently (Repenning, 2003), *Ophiomys* was considered monotypic (*Ophiomys parvus*) and other species commonly referred to the group were instead recombined as *Mimomys taylori* and *Mimomys meadensis*.

Species-level assignment as used by Repenning (2003) is accepted here, but the exact use of his nomenclature is not. Repenning (2003) proposed three divergent evolutionary lineages from his *Mimomys sawrockensis*. One lineage dispersed into the Great Plains, evolving into *Mimomys* (*Ogmodontomys*) *transitionalis*, *Mimomys* (*Ophiomys*) *poaphagus*, and *Hibbardomys*. The other two lineages remained west of the Rocky Mountains (at least initially). The larger derivative consisted of a single species, *Mimomys* (*Cosomys*) *primus*, whereas the lineage of the smaller form followed a sequence of gradational forms: *Mimomys sawrockensis-taylori*, *Mimomys taylori*, *Mimomys meadensis*, and *Ophiomys parvus*. In this scenario *Mimomys sawrockensis* is the ancestral stock of North American *Mimomys*, excluding *Mimomys* (*Cromeromys*), which was considered a later immigrant (Repenning, 2003). This scenario is accepted here, but there is no justification in explicitly recognizing a paraphyletic *Mimomys*. I consider *Mimomys taylori*, *Mimomys meadensis*, and *Ophiomys parvus* to all represent chronospecies of *Ophiomys*; I am unsure how to treat the specimens informally called *Mimomys sawrockensis-taylori*. Alternatively, it seems acceptable to assign all these species to *Mimomys*, including *Ophiomys parvus*. I prefer retaining the use of *Ophiomys* to maintain consistency within this well-described lineage (Hibbard and Zakrzewski, 1967; Repenning, 1987, 2003).

Comments on HAFO Material

In discussing the stratigraphic range of *Ophiomys taylori*, Repenning stated that, "*Mimomys taylori* ranges in age from about 3.6 to nearly 3.3 Ma" (2003:489). However, when discussing *Mimomy sawrockensis-taylori* from Blufftop he said, "it dates to ca. 3.9 Ma, late Blancan II, about 0.8 myr than the oldest *Mimomys taylori* from Hagerman, Idaho" (2003:488). The "0.8" is apparently a typographical error and should be "0.3," however, the dates for these localities do not match those used by others (e.g., Bell et al., 2004) because Repenning (2003) chose to restrict the usage of dates for the geomagnetic polarity time scale solely to radiometric dates rather than use the adjusted calibration more commonly employed (Berggren et al., 1995). Blufftop is located stratigraphically below the Cochiti event (Gustafson, 1985b), which occurred from 4.29 to 4.18 Ma (Berggren et al., 1995).

Cosomys Wilson, 1932

Cosomys primus Wilson, 1932

Cosomys primus Wilson. Hibbard, 1941c: p. 87; Hibbard, 1964: p. 123; Taylor, 1966: p. 75; Hibbard and Zakrzewski, 1967: p. 256; Zakrzewski, 1969b: p. 20-21, 24, 26, figs. 7B-C, 8K-T, 9, tab. 6; Hibbard, 1972b: p. 127; Zakrzewski, 1974: p. 291; Eshelman, 1975: p. 50; Koeningswald, 1980: p. 36, fig. 21; Kurtén and Anderson, 1980: p. 254, fig. 12.10B; Franz, 1981: p. 18; Cunningham, 1984: pp. 48-50; Koenigswald and Martin, 1984: p. 114, figs. 3, 4, 6; R. Martin, 1989: p. 439, fig. 3D; Lich, 1990: pp. 385-394, figs. 3, 4, 5, 6, 7, tab. 1, 2; Anderson, 1993: pp. 15-21; Czebieniak, 1993: pp. 65-69; Gingerich, 1993: pp. 96-98; Carroll, 1996: p. 58; R. Martin, 1996: p. 452; McDonald et al., 1996: p. 42, fig. 11E; Carroll, 1997: p. 88, fig. 5.2; Currie, 1998: 52, fig. 5E; Neuberger, 1998: p. 66A; R. Martin, 2003: p. 403, figs. 1D-G; Bell et al., 2004: p. 258; Koenigswald, 2004: p. 123.

Mimomys primus (Wilson). Hinton, 1932: pp. 280-281; Gazin, 1936: pp. 285, 288; Schultz, 1937: p. 84; Wilson, 1937b: pp. 38, 67; Repenning, 1998: pp. 63-64.

Mimomys (*Cosomys*) *primus* (Wilson). Wilson, 1933: pp. 119-120, 126-128; Hibbard, 1958a: p. 246; Hibbard, 1958b: p. 17; Hibbard, 1959: pp. 5, 9-12; Repenning, 1987: pp. 255-256; Repenning et al., 1995: p. 68; Mou, 1996: p. 152; Bell, 2000: p. 391; Repenning, 2003: pp. 497-499, fig. 17.4G, H

Identification of HAFO Material

Cosomys primus is larger than *Ophiomys taylori*, with which it co-occurs, with only a few specimens of intermediate size. See section on *Ophiomys taylori* (above) for more discussion on identification. *Cosomys* differs from *Ogmodontomys* by having a lingually curved anteroconid cap on the m1 with no development of secondary wings, and only two roots on the M3 (Repenning, 2003).

Distribution

Cosomys primus is known from Coso Mountains (Wilson, 1932), Buttonwillow (Repenning, 1987; Upper Etchegoin Formation of Hesse, 1934; Wilson, 1937b), and Kettleman Hills Pecten Bed (Repenning, 2003). Specimens from Saw Rock Canyon identified as *Cosomys primus* (Hibbard, 1949) were later used as the type material for *Ogmodontomys sawrockensis* (Hibbard, 1957b).

Remarks on Taxonomy

Cosomys primus was named on material from the Coso Mountains (Wilson, 1932); later the same year the possibility that the species is better attributed to *Mimomys* was suggested (Hinton, 1932). Supraspecific assignment of the taxon has been debated since (Bell et al., 2004).

Hinton transferred *Cosomys primus* to *Mimomys*, but this was based on his assertion that “there really is not room for a genus intermediate in character between *Mimomys* and *Arvicola*” (1932:280). Since then, some authors have treated the species as *Mimomys* (*Cosomys*) *primus*, although this opinion is certainly not in the majority as claimed by Repenning (2003:473) as evidenced by the references to the HAFO material listed above. *Cosomys*, as recognized here is the large western North

American lineage that diverged from the other lineages stemming from *Mimomys sawrockensis* or a related form; *Cosomys* is monotypic, with only *Cosomys primus* currently recognized.

Comments on HAFO Material

Cosomys primus is by far the most abundant taxon from the deposits at HAFO. Most of these specimens are from anthills and screen washing of sediments from blowouts, but a few fossils of *Cosomys primus* are known from in situ deposits such as the Hagerman Horse Quarry.

The m1 of *Cosomys primus* was examined from 10 localities at HAFO for quantitative and qualitative change (Lich, 1990; Anderson, 1993). Because no significant differences were found between populations from different stratigraphic levels, this rodent was interpreted as exhibiting stasis throughout the fossiliferous section at HAFO.

Ondatra Link 1795

Ondatra minor Wilson, 1933

Ondatra idahoensis minor n. ssp. Wilson, 1933: pp. 119, 134-135.

Ondatra idahoensis minor Wilson. Gazin, 1936: pp. 285, 288; Schultz, 1937: p. 84; Wilson, 1937b: p. 38.

Ondatra idahoensis Wilson. Errington, 1963: p. 544; Franz, 1981: p. 19.

Pliopotamys idahoensis minor (Wilson). Hibbard, 1941c: p. 87.

Dolomys minor (Wilson). Kretzoi, 1955: pp. 348-355.

Pliopotamys idahoensis (Wilson). Hibbard, 1956: p. 176.

Pliopotamys sp. Hibbard, 1959: p. 25-26; Koenigswald, 1980: p. 55.

Pliopotamys minor (Wilson). Hibbard, 1958a: p. 246; Hibbard, 1958b: p. 17; Hibbard, 1959: pp. 5, 11, 26-29, 33, fig. 6; Malde and Powers, 1962: p. 1208; Zakrzewski, 1969b: pp. 26-27, figs. 7A, D, 8A-E, G-J, 10, 11, tab. 7; Hibbard, 1972a: pp. 101-102; Hibbard, 1972b: p. 127; Zakrzewski, 1974: pp. 284-287, 290, fig. 1, tab. 1; Eshelman, 1975: tab. 13; Conrad, 1980: pp. 145, 149, tab. 9; Koenigswald, 1980: p. 55; Kurtén and Anderson, 1980: pp. 13, 265; Franz, 1981: p. 19; Cunningham, 1984: pp. 48-51; L. Martin, 1984: p. 535, fig. 7; Barnosky, 1985: pp. 257, 259; Gustafson, 1985b: p. 90, tab. 3; Czaplewski, 1987: p. 146; Repenning, 1987: pp. 255-256; L. Martin, 1993: fig. 10.7; Repenning et al., 1995: p. 15, 34, 67-68, 70; McDonald et al., 1996: pp. 21, 32, 42, fig. 11F; Viriot, 1996: pp. 577-582, figs. 2-3; Currie, 1998: p. 18, 52, fig. 5F; Neuberger, 1998: p. 66A; Hearst, 1999: p. 151; Bell, 2000: p. 391; Link et al., 2002: p. 105, 109, 114, fig. 3, 5; Bell et al., 2004: p. 258.

Ondatra zibethicus/minor. R. Martin, 1993: p. 247; R. Martin, 1996: pp. 437, 441, 445, 452; tab. 1.

Identification of HAFO Material

This material is of a hypsodont, rooted arvicoline rodent, with an occlusal pattern similar to that of modern *Ondatra zibethicus*, except in typically having only five triangles on the m1 between the posterior loop and anterior loop. *Ondatra minor* and *O. meadensis* differ from later species of *Ondatra* based on the fewer number of triangles on the m1, greater complexity of the anteroconid complex of the m1, greater confluence of first and second triangles on the m1, lack of cementum in reentrants, and poorly developed or absent dentine tracts (Ruez, 2001). *Ondatra minor* differs from *Ondatra meadensis* in being slightly smaller, having the fifth triangle opening into the anteroconid complex, more poorly developed (or lack of) dentine tracks, and lack of any cementum in reentrants (Zakrzewski, 1969; Nelson and Semken, 1970).

Distribution

Ondatra minor is known from Lisco (Voorhies and Corner, 1986), Palm Spring Formation of Anza-Borrego Desert State Park (Remeika et al., 1995; Cassiliano, 1997, 1999; White et al., 2006), Sand Point (Zakrzewski, 1969b; Conrad, 1980; R. Martin, 1996), and Taunton (Morgan and Morgan, 1995).

Records originally identified as an advanced form of *Ondatra minor* from Birch Creek (Repenning et al., 1995), were subsequently reidentified as an advanced *Ondatra meadensis* with the aid of a much greater sample size and the observation that ontogenetically older individuals did have cementum in the reentrants (Hearst, 1999). An advanced form of *Ondatra minor* was also reported from Ninefoot Rapids (Conrad, 1980; Fejfar and Repenning, 1998), but that material matches specimens from Birch Creek in degree of dentine tract development, size, and presence of cementum in the reentrants of teeth from ontogenetically older individuals (personal observation); the muskrat from Ninefoot Rapids is *Ondatra meadensis*.

Remarks on Taxonomy

Because the evolution of muskrats is commonly considered to progress anagenetically from *Ondatra minor* to modern *Ondatra zibethicus*, with some debatable number of intermediate chronospecies (e.g., L. Martin, 1979; Nelson and Semken, 1970), there are fossils that do not fit neatly into the formally named taxonomic bins. In cases such as this, R. Martin proposed "collapsing all known or highly suspected phyletic sequences into single-species lineages" (1993:233-234) and instead using chronomorphs to recognize the typical morphology represented in a single locality (Krishtalka and Stucky, 1985). As such, the muskrat from HAFO was called *Ondatra zibethicus/minor* (R. Martin, 1993, 1996). This methodology benefits the non-specialist by more easily identifying morphologies assumed to result from cladogenetic events from morphologies assumed to result from anagenetic change.

Although in theory, nearly every locality containing fossil muskrats could be termed a unique chronomorph using this taxonomic philosophy, the number recognized by R. Martin (1993, 1996) closely matches the species of muskrats recognized by most other workers (e.g., Nelson and Semken, 1970; L. Martin, 1993), except in including *Ondatra nebracensis* within *Ondatra zibethicus/zibethicus*. The "recognition of multiple species in a phyletic sequence also artificially bloats the record of biological diversity" (R. Martin, 1993:233), but this is merely an accounting problem. Perhaps more importantly, use of chronomorphs in nomenclature presupposes that it is possible to determine if different morphologies are a single phyletic sequence. Even in the case of muskrats, which are extremely well represented in many Pliocene and Pleistocene localities, there are temporal gaps of as much as 500 kyr (R. Martin, 1996). Further, although it seems possible that muskrat evolution is a phyletic sequence, such opinion is not universal. *Ondatra idahoensis* from the Great Plains was also hypothesized to have ecologically replaced *Ondatra minor* in the Glenns Ferry Formation (Repenning et al., 1995). The sequence of fossils in the Glenns Ferry Formation under this scenario matches that of a phyletic sequence in having *Ondatra idahoensis* derived from *Ondatra meadensis*, but it implies a separate evolution history for the Great Plains and Idaho populations of *Ondatra meadensis* resulting from a cladogenetic event. In fact, it is impossible to prove a phyletic sequence over cladogenesis followed by ecological replacement (as in Repenning et al., 1995 for muskrats), therefore I reject the use of chronomorph designation.

There is no justification for splitting the muskrat lineage into two taxa, *Ondatra* and a paraphyletic *Pliopotamys*. All species are here assigned to a monophyletic *Ondatra*.

Comments on HAFO Material

The lineage beginning with *Ondatra minor* and continuing with the extant *Ondatra zibethicus* is an often studied example in the evolutionary patterns of mammals due to the abundance of fossils from numerous sites and the multiple characters that show change (e.g., Nelson and Semken, 1970; R. Martin, 1996). The earliest occurrence of *Ondatra minor* is from HAFO, and most of the studies on muskrat evolution consider all specimens from HAFO as contemporaneous. The Glenns Ferry Formation at HAFO, however, preserves several hundred thousand years of this lineage (Chapter 2). Although the shape of *Ondatra minor* from HAFO was not seen to change with geologic age, the size does increase stratigraphicallly upward (Neuberger, 1998); this relatively short interval of muskrat evolution mirrors the increase in size noted for the entire lineage (e.g., L. Martin, 1979, R. Martin, 1993).

Mictomys Baird, 1857

Mictomys vetus (Wilson, 1933)

Mictomys vetus (Wilson). Ruez and Gensler, in press.

Identification of HAFO Material

Terminology follows Repenning (1992). Rootless molars with cement in reentrant angles; m1 with posterior loop, three triangles, and anterior cap; triangles 1 and 2 broadly confluent, and anterior cap-triangle 3 connection centered (or nearly so); triangles 1 and 3 more than twice the width of triangle 2 (after Fejfar and Repenning, 1998).

Distribution

Mictomys vetus is confined to Blancan deposits at 111 Ranch (Galusha et al., 1984; Tomida, 1987), Anza-Borrego Desert State Park (Zakrzewski, 1972; Cassiliano, 1997, 1999), Borchers (Hibbard, 1954c), California Wash (Mezzabotta, 1997), Froman Ferry sequence (Conrad, 1980; Repenning et al., 1995; Fejfar and Repenning, 1998), Porcupine Cave (Bell and Barnosky, 2000), Seneca (Martin and Schultz, 1985), Thayne (Fejfar and Repenning, 1998).

Remarks on Taxonomy

Following Fejfar and Repenning (1998), *Mictomys vetus* is here recognized as including the junior synonyms *Mictomys landesi* and *Mictomys anzaensis*. The three taxa previously were recognized as valid species within the subgenus *Metaxyomys* (Zakrzewski, 1972).

Comments on HAFO Material

Mictomys vetus from HAFO are the oldest records of the species by more than a million years (Ruez and Gensler, in press). However, this early occurrence does not preclude the evolutionary transition of *Plioctomys* into *Mictomys* as hypothesized by Fejfar and Repenning (1998). *Plioctomys* is known from even older deposits in Russia as *Plioctomys mimoformis* (Sukhov, 1976; Repenning and Grady, 1988).

Carnivora Bowdich, 1821

Ursidae Gray, 1825

Ursus Linnaeus, 1758

Ursus abstrusus Bjork, 1970

Ursus abstrusus n. sp. Bjork, 1970: p. 16-18, fig. 9b.

Tremactinae. Bjork, 1970: p. 18, fig. 9a; Galbreath, 1972: p. 786; McDonald et al., 1996: p. 42; Ruez, 2003: p. 67.

Ursus abstrusus Bjork. Galbreath, 1972: p. 786; Hibbard, 1972b: p. 128; Tedford and Gustafson, 1977: p. 622; Gustafson, 1978: p. 38; Conrad, 1980: p. 221; Kurtén and Anderson, 1980: p. 182; Franz, 1981: p. 25; Kelly, 1994: p. 7; McDonald et al., 1996: p. 42; Currie, 1998: p. 52; Hearst, 1999: pp. 101, 104; Harington, 2001: pp. 12-13; Tedford and Martin, 2001: pp. 315-317, figs 4b, 5c, d; Qiu, 2003: p. 23; Bell et al., 2004: p. 258; White and Morgan, 2005: p. 124.

Tremarctine sp. Hibbard, 1972b: p. 128.

Tremarctus [sic] sp. Lindsay et al., 1984: p. 463.

Tremarctos sp. Currie, 1998: p. 52; Morgan et al., 1997: p. 118.

Tremarctos floridanus. Hearst, 1999: p. 101, 104.

Identification of HAFO Material

The material is assigned to *Ursus* based on the lack of a premasseteric fossa, absence of accessory cuspules anterior to the metaconid of the m1, and lower incisors projected well in front of canine (Bjork, 1970). *Ursus abstrusus* is identified specifically almost entirely on a single m1. It has a long trigonid, single cusped metaconid, double cusped entoconid, and a small ridge between the hypoconid and double cusped entoconid that has a small cuspule near the hypoconid (Bjork, 1970).

Distribution

The other localities containing *Ursus abstrusus* are the Blancan sites Buckeye Creek (Kelly, 1994, 1997) and Strathcona Fiord (Harington, 1996, 2001, 2003; Hutchison and Harington, 2002; Tedford and Harington, 2003). *Ursus* cf. *Ursus abstrusus* was reported from White Bluffs (Gustaffson, 1978), and White Bluffs was given by Qiu (2003) as one of two localities to contain *Ursus abstrusus*, but these records were included in the new tremarctine species *Plionarctos harroldorum* (Tedford and Martin, 2001). Material from Cita Canyon originally identified as *Ursus* sp. (Johnston and Savage, 1955) was later considered as possibly not an ursine (Kurtén, 1963). However, Kurtén later referred the same material to *Ursus abstrusus* (Kurtén and Anderson, 1980).

Other Blancan records of *Ursus* from North America are *Ursus* sp. from Birch Creek (Hearst, 1999) and either *Ursus* cf. *U. americanus* (Cassiliano, 1999:174) or *Ursus americanus* (Cassiliano, 1999:178) from the Palm Spring Formation of Anza-Borrego Desert State Park.

Tremarctine bears are likewise rare in the Pliocene of North America. *Plionarctos harroldorum* occurs in the Pliocene at White Bluffs and *Plionarctos* cf. *Plionarctos harroldorum* is known from the stratigraphically higher Taunton fauna (Tedford and Gustafson, 2001). The next oldest tremarctine in North America is the *Tremarctos floridanus* reported from the Palm Spring Formation of Anza-Borrego Desert State Park (Shaw and Cox, 2006) at an estimated date of 2.7 Ma (Cassiliano, 1999). *Tremarctos* sp. was also listed higher in the Palm Spring Formation (~1.7 Ma; Cassiliano, 1999), but elsewhere *Tremarctos* does not appear until the Irvingtonian at El Golfo (Shaw, 1981; Lindsay, 1984); most records are late Irvingtonian or Rancholabrean. The more common North American tremarctine, *Arctodus* is listed as occurring in the middle Blancan Buckhorn fauna (Morgan and Sealey, 1995; reidentified as indeterminate Ursidae by Morgan et al., 1997), but otherwise is not known until the late Pliocene of California (Cassiliano, 1999), Arizona (Tomida, 1987), and Florida (Emslie, 1995).

Remarks on Taxonomy

Ursus abstrusus is more similar to contemporaneous forms in Eurasia than extant North American *Ursus* (Bjork, 1970; Tedford and Martin, 2001). The HAFO ursid does seem distinct from the Eurasian forms, but very little Pliocene material referable to *Ursus* is known from any part of North America. An assessment of variation for a more complete comparison to the Eurasian taxa is not currently possible.

Comments on HAFO Material

Only one specimen from HAFO was published and attributed to Tremarctinae (Bjork, 1970). This humerus (UMMP V49950) was referred to Tremarctinae based on the presence of entepicondylar foramen. However, primitive ursids, including Pliocene species of *Ursus*, possess this feature also (Erdbrink, 1953). Bjork (1970) described *Ursus abstrusus* as most like *Ursus boeckhi*. According to the phylogeny of Erdbrink (1953), *Ursus boeckhi* is the most primitive ursine and the most closely related taxon to tremarctine bears. Bjork did note that "there is a possibility that the humerus is that of *Ursus abstrusus* which is described above, but this cannot be proven until associated remains of jaw and limb material are discovered" (1970:18). Because associated material of early Eurasian *Ursus* is known (Erdbrink, 1953), and because there is no character on the supposed HAFO humerus that indicates affinities with tremarctines rather than ursines, all the Hagerman ursid material is conservatively referred to *Ursus abstrusus*.

Ursus abstrusus is the only currently known species of Blancan ursine in North America. It, or an ancestor, emigrated from Eurasia during the early Blancan with *Lynx*, *Homotherium*, and *Megantereon* (Qiu, 2003), other carnivorans present at HAFO.

A recently recovered dentary may raise the number of ursid speces at HAFO to two. This undescribed specimen is tentatively identified as *Agriotherium* (pers. comm., P. Gensler, 2006); I have not seen this dentary.

Mustelida Fisher de Waldheim, 1817

Trigonictis Hibbard, 1941a

Trigonictis macrodon (Cope, 1867)

Lutravus? *idahoensis* n. sp. Gazin, 1934b: pp. 137-142, fig 1, tab. 1.

Lutravus? *idahoensis* Gazin. Gazin, 1936: pp. 285, 288; Schultz, 1937: p. 84.

Canimartes? *idahoensis* (Gazin). Gazin, 1937: pp. 363-364; Hibbard, 1941b: p. 273; Hibbard, 1941c: p. 87; Hibbard, 1958b: p. 19; Repenning, 1967a: p. 296.

Trigonictis idahoensis (Gazin). Reig, 1957: p. 45; Zakrzewski, 1967: pp. 293-297; Bjork, 1970: pp. 22-24, fig. 12; Shotwell, 1970: p. 82; Galbreath, 1972: p. 786; Hibbard, 1972a: pp. 108-109; Hibbard, 1972b: p. 128; Gustafson, 1978: p. 39-41, fig. 23, tab. 14; Conrad, 1980: p. 223; Kurtén and Anderson, 1980: p. 155, fig. 11.4; Franz, 1981: p. 23; Owen, 2000, p. 281.

Trigonictis macrodon (Cope). Ray et al., 1981: pp. 3-8, figs. 2a, 3a-c, 5a-c; Anderson, 1984: p. 261; McDonald et al., 1996: p. 43, fig. 12B; Baskin, 1998: p. 164; Currie, 1998: p. 52, fig. 6B; Hearst, 1999: p. 44; Bell et al., 2004: p. 258.

Identification of HAFO Material

This large galictine mustelid has a single rooted P4 that is triangular in outline and has a conical protocone that connects via a well developed cingulum to a small hypocone and then to the metacone. The anterior cingulum shows slight emargination. The M1 has three roots, a reduced cingulum labial to the metacone, and a small metaconule. Lower premolars lack accessory cusps and have two roots. The m1 has a long trigonid, a short and broad-basined talonid, and moderately developed metaconid and hypoconid. *Trigonictis macrodon* differs from *Trigonictis cookii* only in the slightly larger size. (Zakrzewski, 1967; Bjork, 1970; Ray et al., 1981)

The most closely related taxa to *Trigonictis* are the modern neotropical galictines and the Blancan *Sminthosinis* (and possibly *Canimartes*). *Eira* differs from from other galictines in having a much shorter m1 relative to the p4 and by the protocone of the P4 separated from the trigon by a narrow neck (Schreuder, 1935; Ray et al., 1981); *Grisonella* and *Galictis* differ in lacking a metaconid on the m1 and having a basin in place of the protocone on the P4 (Zakrzewski, 1967; Ray et al., 1981). *Trigonictis* differs from all modern galictines in having a p2 with two roots, rather than one (Pilgrim, 1932; Ray et al., 1981). I am not aware of detailed comparison of North American galictines to Old World forms. A statement suggesting the inclusion of *Trigonictis kansasensis* within the Eurasian *Pannonictis* (Repenning, 1967) was incorrectly treated as synonmy of all *Trigonictis* within the Old Word group by some authors (e.g., Qiu, 2003). *Pannonictis* differs from

Trigonictis in having a basined talonid (Schreuder, 1935) and posteriorly expanded protocone on the P4 (Pilgrim, 1932), and a p2 with a single root (Pilgrim, 1932). *Canimartes* differs from *Trigonictis* in lacking the hypocone and having a constricted protocone on the P4 and possessing a M2 (Zakrzewski, 1967).

Distribution

Trigonictis macrodon occurs in many Blancan localities from diverse parts of the United States. In Florida, *Trigonictis macrodon* is known from De Soto Shell Pit (Morgan and Hulbert, 1995; Ruez, 2001; Morgan, 2005), Inglis 1A (Webb and Wilkins, 1984; Morgan and Hulbert, 1995; Ruez, 2001; Morgan, 2005), Macasphalt Shell Pit (Morgan and Ridgway, 1987; Morgan and Hulbert, 1995; Morgan, 2005), and Santa Fe River 8A (Ray et al., 1981; Anderson, 1984). Listings of *Trigonictis macrodon* from Leisey Shell Pits (Ruez, 2001) and Santa Fe River 1 (Morgan, 2005), and *Trigonictis* sp. from Santa Fe River 1A (Webb, 1976) and Santa Fe River 1B (Webb, 1976) are in error. Other records from east of the Mississippi River are known from the type locality (possibly the Brandywine Formation; Ray et al., 1981), Charles County, Maryland (Cope, 1867), and Smith Mill Run (Ray et al., 1981).

In the Great Plains region *Trigonictis macrodon* is known from Bevins Pit 2 (Ray et al., 1981; Anderson, 1984), Deer Park (Taylor, 1966; Hibbard, 1972b; Anderson, 1984; R. Martin et al., 2000), Hooker County, Nebraska (Ray et al., 1981), Lisco (Hibbard, 1972b; Anderson, 1984), Rexroad Locality 3 (Hibbard, 1941a, b, 1970, 1972b; Taylor, 1966; R. Martin et al., 2000), and Sand Draw (McGrew, 1944; Hibbard, 1972b; Skinner, 1972a; Anderson, 1984).

The southwest United States localities with *Trigonictis macrodon* are Bear Springs (Ray et al., 1981; Anderson, 1984; Tomida, 1987) and Palm Springs Formation in Anza-Borrego Desert State Park (Anderson, 1984; Vallecito Creek local fauna of Cassiliano, 1999; Murray, 2006a). *Trigonictis macrodon* occurs in the Pacific Northwest at Birch Creek (Hearst, 1999), Grand View (Conrad, 1980), Jackass Butte (Shotwell, 1970; Anderson, 1984), and White Bluffs (Ray et al., 1981; Anderson, 1984; *Trigonictis cookii* of Gustafson, 1978).

Specimens identified only as *Trigonictis* sp. were reported from Cita Canyon (Schultz, 1977b; Anderson, 1984), Devils Nest Airstrip, and Santee (Voorhies, 1990). Two other species in North American appear to be closely related to *Trigonictis* – *Sminthosinis*, which occurs at HAFO, and *Canimartes cumminsii*, described from Blanco (Cope, 1893; Schultz, 1977b). *Sminthosinis* is discussed below.

Remarks on Taxonomy

Use of the term galictine here follows the usage of Galictinae by Ray et al. (1981) and is considered the equivalent of Galictini of Baskin (1998). A recent analysis of mustelids did not find this group to monophyletic, due to a dramatically different position of *Trigonictis* (Owen, 2000). Most of the characters examined, however, were not scored for *Trigonictis* because the material is wanting.

Cope (1867) named the first known North American galictine *Galera macrodon*, the usage of which was followed by other workers (Leidy, 1869; Coues, 1877; Roger, 1887) to recognize the similarity with the Latin American tayra. In addition to *Galera*, the tayra was at various times assigned to *Mustela*, *Tayra*, *Gulo*, and *Galictis* in addition to the currently recognized *Eira barbara* (Presley, 2000). Cope's North American galictine was recombined as *Putorius macrodon* (Wortman, 1883; Cope and Wortman, 1884), but *Putorius* is now considered a subgenus of *Mustela* (Hall, 1951; Youngman, 1982). The species was listed as *Lutreola macrodon* without comment (Lucas et al., 1907), but others chose to recongnize the similarity to the grison by using *Grison macrodon* (Hay, 1919, 1923, 1929; Schreuder, 1935) or the more nomenclaturally correct (ICZN, 1956) *Galictis macrodon* (Nehring, 1886, 1901; Roger, 1896; Trouessart, 1897, 1904; Hay, 1902; Reig, 1957). After nearly a century of transient nomenclature, Cope's galictine was reviewed (Ray et al., 1981) and the name *Trigonictis macrodon* is now uniformly applied.

Two similar species of galictine mustelids (*Lutravus*? *idahoensis* and *Lutravus*? *cookii*) were described from HAFO (Gazin, 1934b), but both were soon reassigned to *Canimartes*? (Gazin, 1937). In the same year that the name *Trigonictis kansasensis* was proposed for material from Meade County, Kansas (Hibbard, 1941b), the material from HAFO previously referred questionably to *Canimartes* and *Lutravus* was suggested as belonging to *Trigonictis* (Hibbard, 1941c), however use of the combination *Trigonictis idahoensis* was not published until 16 years later

(Reig, 1957). The Kansas galictine was subsumed within *Trigonictis idahoensis* (Bjork, 1970), which itself was shown to be a junior synonym of *Trigonictis macrodon* (Ray et al., 1981).

Comments on HAFO Material

Because of the extreme similarity of *Trigonictis macrodon* and *Trigonictis cookii*, multiple authors have considered the possibility that the HAFO specimens represent a single species with high individual variation or pronounced sexual dimorphism. This possibility was explicity rejected by most (Gazin, 1934b; Bjork, 1970; Ray et al., 1981), although dimorphism in either *Trigonictis macrodon* or *Trigonictis cookii* was suggested based on the possibility of size groupings (Zakrzewski, 1967). Chronoclines of changing body size were proposed by others, with either an increase (Galbreath, 1972) or a decrease (Gustafson, 1978) in size with upward movement stratigraphically. Neither of these conflicting chronoclines appears valid because both species persist until the late Blancan, and these later occurrences match the size of the HAFO material (Ray et al., 1981).

Trigonictis cookii (Gazin, 1934b)

Lutravus? cookii n. gen. et n. sp. Gazin, 1934b: pp. 142-143, fig. 2, tab. 1.

Lutravus? *cookii* Gazin. Gazin, 1936: pp. 285, 288; Schultz, 1937: p. 84.

Canimartes? *cookii* (Gazin). Gazin, 1937: pp. 363-364; Hibbard, 1941b: p. 273; Hibbard, 1941c: p. 87; Hibbard, 1958b: p. 19; Repenning, 1967a: p. 296.

Galictis cooki (Gazin). Reig, 1957: pp. 42, 44-45.

Trigonictis cookii (Gazin). Zakrzewski, 1967: pp. 293-297; Hibbard, 1972a: p. 109; Kurtén and Anderson, 1980: 156; Franz, 1981: p. 23; Ray et al., 1981: pp. 27-30, fig. 7a, 7c, 7d, 7f; Anderson, 1984: p. 261; Hearst, 1999: p. 47, 49, 52, 54; Owen, 2000: p. 281; Bell et al., 2004: p. 258.

Trigonictis cooki (Gazin). Bjork, 1970: pp. 24-26, fig. 14; Shotwell, 1970: p. 82; Galbreath, 1972: p. 786; Hibbard, 1972b: p. 128; Gustafson, 1978: p. 39-40, 55, fig. 23, tab. 14; Berger, 1987: p. 7; McDonald et al., 1996: p. 43; Baskin, 1998: p. 165; Currie, 1998: p. 52.

Identification of HAFO Material

Identification to *Trigonictis* follows that listed above for *Trigonictis macrodon*. *Trigonictis cookii* is distinguished by its smaller size, but males of *Trigonictis cookii* might overlap in size with females of *Trigonictis macrodon* (Zakrzewski, 1967).

Distribution

Blancan localities containing *Trigonictis cookii* are Birch Creek (Hearst, 1999), Booth Draw (Frick Prospecting Locality 277), Broadwater (Ray et al., 1981), Haile 16A (Ray et al., 1981; Morgan and Hulbert, 1995; Morgan, 2005), Jackass Butte (Zakrzewski, 1967; Shotwell, 1970), Red Corral (Anderson, 1984), Taunton (Morgan and Morgan, 1995), and White Bluffs (Gustafson, 1978). Material from

Sand Draw identified as *Trigonictis cookii* (McGrew, 1944; Skinner, 1972a; Hibbard, 1972a, b) was instead referred to *Trigonictis macrodon* in a review of known *Trigonictis* specimens, although material elsewhere in the Keim was recognized as *Trigonictis cookii* (Ray et al., 1981). *Trigonictis cookii* is not currently known outside of the Blancan.

Remarks on Taxonomy

See comments above under *Trigonictis macrodon*.

Comments on HAFO Material

Trigonictis cookii is much less abundant than *Trigonictis macrodon*, both in general and specifically at HAFO. As discussed above, these two forms of *Trigonictis* were previously proposed as members of a chronocline in body size; in one case, *Trigonictis cookii* was suggested to be the direct ancestor to the smaller *Sminthosinis bowleri* (Galbreath, 1972).

Sminthosinis Bjork, 1970

Sminthosinis bowleri Bjork, 1970

Sminthosinis bowleri n. gen. et n. sp. Bjork, 1970: pp. 26-28, fig. 15.

Sminthosinis bowleri Bjork. Hibbard, 1972b: p. 128; Wagner, 1976: p. 109; Kurtén and Anderson, 1980: p. 156; Ray et al., 1981: pp. 9, 19, tab. 1; McDonald et al., 1996: p. 43; Baskin, 1998: p. 165.

Sminthosinus [sic] *bowleri*. Galbreath, 1972: p. 786; Kurtén and Anderson, 1980: p. 156; Franz, 1981: p. 23; Anderson, 1984: p. 262; Currie, 1998: p. 52; Hearst, 1999: p. 54; Yensen and Tarifa, 2003: p. 3.

Identification of HAFO Material

This small mustelid has a single rooted, vestigial P1, a P4 with a large cup-shaped protocone and slight cingulum, and an m1 lacking a metaconule, but with a metaconid almost directly labial to the protoconid (Bjork, 1970). *Sminthosinis bowleri* is similar to *Trigonictis*, and the species was suggested as possibly belong to that group (Bjork, 1970; Galbreath, 1972). *Trigonictis* differs from *Sminthosinis bowleri* in having a strong cingulum on upper cheekteeth and having a metaconule on the m1.

Distribution

Sminthosinis bowleri is known from Broadwater (Anderson, 1984) in addition to HAFO. Although *Sminthosinis* is monospecific, *Sminthosinis* sp. was reported from Santee (Voorhies, 1990). Additionally, material said to be either an undescribed species of *Sminthosinis* or a small *Trigonicits* is known from the Hemphillian Turlock Lake (Wagner, 1976; Baskin, 1998).

Remarks on Taxonomy

Sminthosinis was suggested as having a sister taxon relationship with the modern *Galictis* (Bjork, 1970; Yensen and Tarifa, 2003). *Galictis* is morphologically similar to the limited known material of *Sminthsosinis* and differs primarily in having a well-developed hypocone on the P4; *Sminthosinis* lacks this cusp completely (Owen, 2000).

Comments on HAFO Material

As seen in the list of references to this mustelid from HAFO, the name is misspelled as often as it is written correctly. *Sminthosinus* [sic] was used presumedly in reference to *Sminthosinis bowleri* specimens from HAFO (Owen, 2000). As indicated in the synonymy list above, the rate of misspellings seems to be increasing.

As mentioned above, *Sminthosinis* was suggested to be the terminal form of a chronomorph in decreasing size (Galbreath, 1972). This mustelid was also mentioned as the beginning of a lineage leading to the extant *Galicits cuja* (Bjork, 1970; Yensen and Tarifa, 2003). *Sminthosinis* was also proposed to have ecologically replaced *Trigonictis* at HAFO higher in the section concurrent with a change in rodent assemblage (Bjork, 1970).

Ferinestrix Bjork, 1970

Ferinestrix vorax Bjork, 1970

Ferinestrix vorax n. gen. et n. sp.; Bjork, 1970: pp. 19-22, fig. 11.

Ferinestrix vorax Bjork. Galbreath, 1972: p. 786; Hibbard, 1972b: p. 128; Kurtén and Anderson, 1980: p. 155; Franz, 1981: p. 23; Anderson, 1984: p. 261; McDonald et al., 1996: p. 42; Baskin, 1998: p. 164; Currie, 1998: p. 52; Hearst, 1999: p. 59; Owen, 2000: p. 272.

Identification of HAFO Material

This robust mustelid, has a relatively small p4, relatively large m1 (almost half the length of the overall lower cheektooth length) with large trigonid and basined talonid and a long and narrow mandibular condyle (Bjork, 1970). *Ferinestrix vorax* is most similar to *Gulo* and *Plesiogulo*, but differs in having a more greatly curved ventral border of the mandible, more pronounced dorsolateral inflection of the posteroventral portion of the mandible, more deeply incised inferior notch of the mandible, and a p4 unconstricted medially (Bjork, 1970).

Distribution

Ferinestrix vorax is only known from HAFO. Material from Unwily Coyote Site was originally referred to *Ferinestrix* (Bjork, 1996), but that identification was later emended to *Ferinestrix*? (Bjork, 1997) because the skeletal elements from the Unwily Coyote Site are not known from HAFO and no direct comparison could be made. Two edentulous mandible fragments, several vertebral centra and a proximal rib portion from Birch Creek were identified as *Ferinestrix*? based on the very large size of that mustelid material (Hearst, 1999). *Ferinestrix* sp. was tentatively identified from 111 Ranch (Morgan and White, 2005; White and Morgan, 2005), but that material has not been described.

Remarks on Taxonomy

Ferinestrix is monospecific and appears to be most closely related to *Gulo* and *Plesiogulo* (Bjork, 1970).

Comments on HAFO Material

The known material, a single dentary and a left femur, are not associated; the two localities are separated stratigraphically by approximately 50 m of stratigraphic section.

Taxidea Waterhouse, 1838

Taxidea sp.

Taxidea sp. Bjork, 1970: pp. 28-30, fig. 16a; Galbreath, 1972: p. 786; Hibbard, 1972b: p. 128; Wagner, 1976: pp. 110, 122; Conrad, 1980: pp. 225-226; Franz, 1981: p. 23; Sankey, 1991: p. 97; McDonald et al., 1996: p. 43; Baskin, 1998: p. 161; Currie, 1998: p. 52; Morgan et al., 1998: p. 243; Owen, 2000: p. 280; Sankey, 2002: p. 78.

Taxidea taxus (Schreber). Kurtén and Anderson, 1980: p. 157.

Identification of HAFO Material

The single mandibular fragment from HAFO identified as *Taxidea* was recognized based on the slight sulcus on the dorsolateral surface of the horizontal ramus and the relatively low lateral enamel margin on the p4 (Bjork, 1970).

Distribution

When the specimen from HAFO was described, fossils of *Taxidea* were poorly known (Bjork, 1970:29); they are now known from many localities (Morgan et al., 1997; Baskin, 1998). Pliocene records of *Taxidea taxus* were reported from Anita (Anderson, 1984; *Taxidea robustus* of Hay, 1921), Anza-Borrego Desert State Park (Murray, 2006a), Jones and Keefe Canyon (R. Martin et al., 2000), Rexroad Locality 3 (Hibbard, 1941b; Hibbard, 1970; Wagner, 1976; R. Martin et al., 2000), and Tyson Ranch (Sankey, 1991, 2002). See Anderson (1984) for a summary of the more numerous Pleistocene occurrences. Pliocene fossils assigned to *Taxidea* cf. *Taxidea taxus* are known from Beck Ranch (Dalquest, 1978), Deer Park (Hibbard, 1956), Deer Park B (Martin et al., 2000), and Sand Draw (McGrew, 1944; Wagner, 1976).

Pliocene fossils identified only as *Taxidea* sp. occur at Buckhorn (Morgan et al., 1997), Cita Canyon (Schultz, 1977b), Grand View (Conrad, 1980), Hatch (Morgan and Lucas, 2003), Panaca Formation (Mou, 1999; Reynolds and Lindsay, 1999; Lindsay et al., 2002), Red Light (Akersten, 1970), San Simon Power Line (Tomida, 1987), Taunton (Morgan and Morgan, 1995), and Tonuco Mountain

(Morgan et al., 1998). Kurtén and Anderson (1980) considered all records of Blancan *Taxidea* sp. to represent *Taxidea taxus*, claiming the larger teeth with heavy cingula on the Blancan form only warranted subspecific differentiation. Two Hemphillian sites, Yepómera and Courtney Pit, have the earliest records of *Taxidea* (Owen, 2006)

Remarks on Taxonomy

In addition to the single modern species of *Taxidea*, *Taxidea mexicana* was named from a fossil differing from the extant North American badger in having a relatively smaller canine and more anterior placement of the m1 metaconid (Drescher, 1939). Although *Taxidea mexicana* was later considered by Hall (1944) to be synonymous with *Taxidea taxus sonoriensis* some authors retained the use of *T. mexicana* as a distinct form (Stock, 1948; Wilson, 1967; Bjork, 1970; Lindsay, 1984).

Comments on HAFO Material

Taxidea at HAFO is represented by a single specimen. It is not possible to determine if the specimen can be assigned to one of the currently recognized species.

Satherium Gazin, 1934b

Satherium piscinarium (Leidy, 1873)

Lutra (*Satherium*) *piscinaria* Leidy. Gazin, 1934b: pp. 144-147, figs. 3-4, tab. 2; Gazin, 1936: pp. 285, 288; J. Schultz, 1937: p. 84; Hibbard, 1941c: p. 87; Hibbard, 1958b: p. 19; Hibbard, 1959: pp. 33, 37.

Satherium piscinaria (Leidy). Bjork, 1970: pp. 31-39, figs. 18, 20, 21; Galbreath, 1972: p. 786; Conrad, 1980: pp. 228-229; Kelly, 1994: p. 7; McDonald et al., 1996: pp. 32, 42, fig. 12C; Currie, 1998: pp. 19, 51, fig. 6C; Bell et al., 2004: p. 258.

Satherium priscinarium [sic] (Leidy). Hibbard, 1972b: p. 128.

Satherium piscinarium (Leidy). Bjork, 1973: p. 33; Kurtén and Anderson, 1980: p. 158, figs. 11.6A, B; Franz, 1981: p. 23; Sankey, 1991: pp. 100, 103-104, tab. 13; Baskin, 1998: p. 161; Hearst, 1999: pp. 54, 56; Sankey, 2002: pp. 78-79.

Identification of HAFO Material

Material is referable to *Satherium* based on the vestigial p1, p4 with a posterior accessory cusp, m1 with a greatly enlarged talonid relative to trigonid length, P4 with a well-developed parastylar cusp, and M1 lacking accessory cusps (Owen, 2000). *Satherium piscinarium* differs from *Satherium ingens* in being significantly smaller (Gazin, 1934b). A P4 from Rexroad Locality 3 referred to *Satherium ingens*? further differs from *Satherium piscinarium* by the presence of a pronounced transverse ridge in the middle of the protoconal shelf (Bjork, 1973).

Distribution

Satherium piscinarium is restricted to the Blancan and is found at Birch Creek (Hearst, 1999), Broadwater (Barbour and Schultz, 1937), De Soto Shell Pit (Morgan and Hulbert, 1995; Ruez, 2001), Murphy (Sankey, 1990), Rexroad Locality 3 (Hibbard, 1970; Bjork, 1973; R. Martin et al., 2000), Sand Draw (Hibbard, 1972b), Sinker Creek (Leidy, 1873), Taunton (Morgan and Morgan, 1995), and Tyson Ranch (Sankey, 1991, 2002). Identification of *Satherium* sp. from Haile 15A (Webb, 1974a; Robertson, 1976) was later emended to *Satherium piscinarium* (Kurtén and Anderson, 1980; Morgan and Hulbert, 1995; Morgan, 2005). *Satherium* sp. was identified from the Palm Spring Formation at Anza-Borrego Desert State Park (Anderson, 1984; Remeika et al., 1995), and the material was later reconsidered as probably *Satherium piscinarium* (Murray, 2006a; McDonald, 2006b). Cassiliano (1999, 2006) did not list *Satherium* as occurring in Anza-Borrego Desert State Park, but did include "cf. *Lutra canadensis*" (1999:174) and "*Lutra canadensis*" (2006:367), which is probably the same material.

Remarks on Taxonomy

Lutra (*Satherium*) was named to include two fossil taxa from Idaho – *Lutra* (*Satherium*) *piscinaria* (including HAFO specimens) and the larger *Lutra* (*Satherium*) *ingens* from Grand View (Gazin, 1934b). Based on material from Broadwater, *Satherium* was elevated in rank and suggested as distinct from *Lutra* (Barbour and Schultz, 1937), however, the combination *Satherium piscinaria* was not followed until description of the abundant material from HAFO (Bjork, 1970). Shortly after, the spelling of the specific epithet was corrected to *piscinarium* (Bjork, 1973).

Satherium piscinarium (Figure 4.4) and *Satherium ingens* are quite similar, and discovery of additional specimens caused some to consider the possibility that the two forms were conspecific (Bjork, 1970; Shotwell, 1970). Although some later authors explicitly considered *Satherium ingens* a junior synonym (Kurtén and Anderson, 1980; Hearst, 1999), most have not followed this suggestion. I consider the forms distinct based on the difference in size and the morphology of the P4.

Satherium may share a common ancestry with modern otters, rather than being directly ancestral to them (Gazin, 1934b). In spite of earlier placement of *Satherium piscinarium* within *Lutra*, *Satherium* is as distinct from *Lutra* as is *Pteronura* (Bjork, 1970), and of these two groups of modern otters *Satherium* is more likely to be included within *Pteronura* (Bjork, 1973). In a phylogenetic analysis of mustelids, the preferred tree had *Satherium* in a polytomy with *Pteronura*, *Lutra*, *Lontra*, and *Aonyx* (Owen, 2000).

Comments on HAFO Material

The deposits at HAFO contain abundant remains of *Satherium piscinarium* which were described in detail (Bjork, 1970). The endocranial cast of a lutrine said to be smaller than *Satherium* (Bjork, 1970) is here assigned to *Satherium piscinarium*. This cast is only slightly smaller than that expected from the single

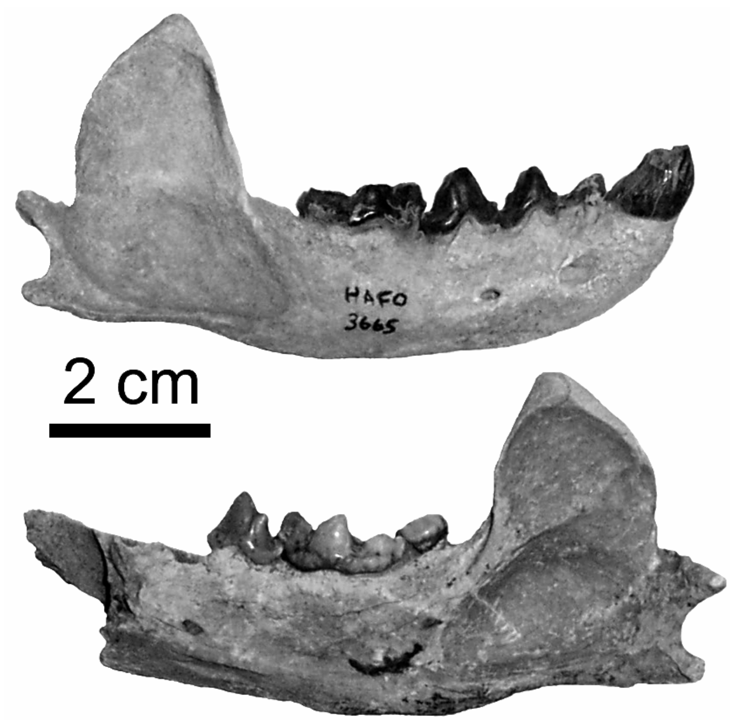


Figure 4.4. *Satherium piscinarium* from HAFO. Top, HAFO 3665, right dentary, labial view; bottom, HAFO 4930, left dentary, labial view.

known skull of *Satherium piscinarium* that preserves the braincase (USNM 23266). *Satherium piscinarium* is the only lutrine at HAFO indicated by the abundant osteological and dental remains.

Buisnictis Hibbard, 1950

Buisnictis breviramus (Hibbard, 1941)

Buisnictis breviramus (Hibbard). Bjork, 1970: 30-31, fig. 16b; Galbreath, 1972: p. 786; Hibbard, 1972b: p. 128; Kurtén and Anderson, 1980: p. 161; Franz, 1981: p. 24; McDonald et al., 1996: p. 43; Baskin, 1998: p. 160; Currie, 1998: p. 52; Owen, 2000: p. 271; Stevens and Stevens, 2003: p. 199; Wang et al., 2005: p. 944.

Identification of HAFO Material

This material is referred to Mephitini (= Mephitimorpha sensu Owen, 2000) based on the absence of p1 and the presence of a four-rooted m1 with elongate paraconid, elongate talonid, and labially expanded protoconid separated from hypoconid by narrow notch (modified from Bjork, 1973; Baskin, 1998). Assignment to *Buisnictis* is based on the entoconid separated from a reduced metaconid by a broad, deep notch on the m1 (Baskin, 1998). *Buisnictis breviramus* differs from *Buisnictis meadensis* and *Buisnictis chisoensis* by its significantly smaller size; *Buisnicis burrowsi* is larger than the *Buisnictis* specimens from HAFO, but is similar in size to other specimens of *Buisnictis breviramus* (Bjork, 1970; Hibbard, 1972a;

Stevens and Stevens, 2003). *Buisnictis breviramus* differs from *Buisnictis burrowsi* in having a more robust metaconid on the m1 (Hibbard, 1972a).

Distribution

Buisnictis breviramus is known from the Rexroad Formation in Kansas at Rexroad Locality 3 (Hibbard, 1941a, 1954a) and Wendell Fox (Bjork, 1973). Other records of *Buisnictis breviramus* are from Cita Canyon (Schultz, 1977b) and Beck Ranch (Dalquest, 1978). Fossils identified as *Buisnictis* cf. *Buisnictis breviramus* occur at Taunton (Morgan and Morgan, 1995).

Remarks on Taxonomy

Originally named as *Brachyprotoma breviramus* because of the presumed relationship with Pleistocene *Brachyprotoma* (Hibbard, 1941b), the species was recombined as *Buisnictis breviramus* during the description of *Buisnictis meadensis* from Fox Canyon (Hibbard, 1950). These two species of *Buisnictis* were later considered conspecific (Hibbard, 1954c).

Buisnictis schoffi was named based on material from Buis Ranch (Hibbard, 1954a). Based on the similarity in size, Bjork (1970) removed the *Buisnictis* material from Fox Canyon from *Buisnictis breviramus* and instead considered it, along with specimens from Buis Ranch and Saw Rock Canyon, referable to *Buisnictis schoffi*. If the specimens from Fox Canyon and Buis Ranch are the same species, *Buisnictis meadensis* has priority over *Buisnictis schoffi*. Although subsequent authors have followed Bjork (1970) in treating the Fox Canyon and Buis Ranch specimens as conspecific, most have unfortunately retained the use of *Buisnictis schoffi* (e.g., Kurtén and Anderson, 1980; Voorhies, 1990; Baskin, 1998). Stevens and Stevens (2003) correctly noted the usage of *Buisnictis meadensis*, but erred in attributing this usage to Skinner and Hibbard (1972) and Baskin (1998).

Two other species of *Buisnictis* are recognized: *Buisnictis burrowsi* from Sand Draw (Hibbard, 1972b) and *Buisnictis chisoensis* from Screw Bean (Stevens and Stevens, 2003). Screw Bean is early Hemphillian in age; *Buisnictis chisonensis* from Screw Bean is the only record of *Buisnictis* outside of the Blancan.

Comments on HAFO Material

Only two specimens of *Buisnictis breviramus* are known from HAFO.

Mustela Linnaeus, 1758

Mustela rexroadensis Hibbard, 1950

Mustela gazini n. sp. Hibbard, 1958a: pp. 245-246, figs. 1A, B.

Mustela gazini Hibbard. Hibbard, 1959: p. 11.

Mustela rexroadensis Hibbard. Bjork, 1970: pp. 18-19, fig. 10d; Galbreath, 1972: p. 786; Hibbard, 1972b: p. 128; Conrad, 1980: p. 223; Kurtén and Anderson, 1980: p. 149; Franz, 1981: p. 22; Anderson, 1984: p. 258; Lindsay et al., 1984: p. 469; McDonald et al., 1996: p. 42, fig. 12A; Baskin, 1998: p. 164;

Currie, 1998: p. 52, fig. 6A; Hearst, 1999: pp. 41, 43; Bell et al., 2004: p. 258.

Mustelid [sic] sp. Hibbard, 1972b: p. 128.

Mustela gazina [sic] Hibbard. McDonald et al., 1996: p. 31.

Identification of HAFO Material

Mustela rexroadensis is extremely similar to the extant *Mustela frenata*, but differs in having relatively narrower p3 and p4, and a compressed paraconid on the m1 (Hibbard, 1958a; Bjork, 1970; Kurtén and Anderson, 1980).

Distribution

Fossils assigned to *Mustela rexroadensis* occur at Beck Ranch (Dalquest, 1978), Fox Canyon (Hibbard, 1950), Saw Rock Canyon (R. Martin et al., 2000), and White Rock (Anderson, 1984). Other similar material was identified as *Mustela rexroadensis*? from Rexroad Locality 3 (R. Martin et al., 2000), *Mustela* cf. *Mustela rexroadensis* from Taunton (Morgan and Morgan, 1995) and Santee (Voorhies, 1990), and *Mustela* sp. aff. *Mustela rexroadensis* from Birch Creek (Hearst, 1999).

Remarks on Taxonomy

Mustela gazini, named on material from HAFO, differed from the holotype of *Mustela rexroadensis* in not having the carnassial notch as tightly closed and in being larger in size (Hibbard, 1958a). Examination of additional topotypic material of *Mustela rexroadensis* from Fox Canyon revealed the holotype to be somewhat unique in the morphology of the carnassial notch (Bjork, 1970).

Comments on HAFO Material

Bjork (1970:tab. 5) listed measurements for the available dentition of *Mustela rexroadensis* from HAFO and Fox Canyon. There was no significant difference in the transverse width of lower teeth between the two sites, but the HAFO material was shown to have a significantly greater anteroposterior length of the m1. More specifically, the difference in length was accounted for entirely by the trigonid length of the HAFO material being 27% greater.

Felidae Fischer de Waldheim, 1817

Homotherium Fabrini, 1890

Homotherium sp.

Ischyrosmilus sp. Bjork, 1970: pp. 45-46, fig. 25a; Galbreath, 1972: p. 786; Sankey, 1991: p. 116; Repenning et al., 1995: p. 20; McDonald et al., 1996: p. 43; Currie, 1998: p. 52.

Homotheriini gen. and sp. indet. Hibbard, 1972b: p. 129.

Ischyrosmilus ischyrus (Merriam). Kurtén and Anderson, 1980: p. 188; Franz, 1981: p. 25.

Homotherium? L. Martin, 1998: p. 241.

Identification of HAFO Material

Species of *Homotherium* are the largest felids in the Pliocene of North America; species of *Dinofelis* and the *Megantereon-Smilodon* lineage have only slightly shorter limbs. Metacarpals of *Homotherium* are more gracile than those of *Megantereon-Smilodon* and *Dinofelis* and further differ in having a much more anteroposteriorly elongate proximal articular surface (modified from Bjork, 1970; Werdelin and Lewis, 2001). Upper canines of *Homotherium* are coarsely serrated; those of *Megantereon* and *Dinofelis* are unserrrated and only late Pleistocene forms of *Smilodon* have visible serratations (Berta, 1987; L. Martin, 1998).

Distribution

Fossils referred to *Homotherium* are known from dozens of sites in North American, Africa, Europe, and Asia. The distribution of Pliocene *Homotherium* in North America was briefly summarized by L. Martin (1998).

Remarks on Taxonomy

Although *Homotherium* is known from many sites, the systematics of the group is poorly known. *Ischyrosmilus* (Merriam, 1918) was synonymized with *Homotherium* by Beaumont (1978) and with *Dinobastis* by Berta and Galiano (1983), revalidated by Churcher (1984), and synonymized again with *Homotherium* by L. Martin et al. (1988). The name *Ischyrosmilus* was employed for both the HAFO specimens and material from the younger Froman Ferry, but no comments were presented on the taxonomic arguments made by the authors above (Repenning et al., 1995). I here follow L. Martin (1998) in placing North American forms previously described as *Ischyrosmilus*, *Homotherium*, and *Dinobastis* within *Homotherium*.

The number of species within this group is likewise problematic. Kurtén and Anderson (1980) recognized *Ischyrosmilus* as distinct from *Homotherium*, but considered *Ischyrosmilus idahoensis*, *Ischyrosmilus johnstoni*, and *Ischyrosmilus crusafonti* as junior synonyms of size-variable *Ischyrosmilus ischyrus*. Hearst (1999) extended synonymy within this group and considered all North American *Homotherium* to be conspecific with the Old World form, *Homotherium crenatidens*. At the other extreme, L. Martin (1998) considered *Homotherium ischyrus*, *Homotherium idahoensis*, *Homotherium crusafonti*, and *Homotherium johnstoni* to all be valid species from the Pliocene of North America.

Comments on HAFO Material

In a review of the HAFO carnivorans, only a single metacarpal was identified as *Homotherium* (Bjork, 1970). I identified an additional partial metacarpal (HAFO 4973) from a large felid more gracile than other large Pliocene felids; I consider this specimen to also be referable to *Homotherium*. Additional evidence for the presence of *Homotherium* at HAFO is an upper canine (HAFO 2478) with coarsely serrated edges anteriorly and posteriorly, and without the extreme elongation seen in *Megantereon-Smilodon*. Unfortunately, this specimen can not be umabiguously recognized as *Homotherium* because the recently described *Xenosmilus* had canines similar in size and serration (L. Martin et al., 2000). The only published specimens of *Xenosmilus* are from Haile 21A in Florida (L. Martin et al., 2000), which is at least two million years younger than any Glenns Ferry Formation sediments at HAFO (Bell et al., 2004). Other possible records of *Xenosmilus* in New Mexico (Morgan and White, 2005) and Uruguay (Mones and Rinderknecht, 2004), however, could extend the temporal range of the genus.

Megantereon Croizet and Jobert, 1828

Megantereon hesperus (Gazin, 1933b)

Machairodus? *hesperus* n. sp. Gazin, 1933b: p. 254-256, fig. 3.

Machairodus? *hesperus* Gazin. Gazin, 1936: pp. 285, 288; Schultz, 1937: p. 84; Hibbard, 1941c: p. 87; Bjork, 1970: p. 45; Hibbard, 1972b: p. 129; Sankey, 1991: p. 116; McDonald et al., 1996: p. 43; Currie, 1998: p. 52.

Machairodus? *herperus* [sic] Gazin. Bjork, 1970: p. 4.

Megantereon hesperus (Gazin). Schultz and Martin, 1970: pp. 34, 36-37; Kurtén and Anderson, 1980: p. 186; Franz, 1981: p. 25; Berta and Galiano, 1983: pp. 893-895; Lindsay et al., 1984: pp. 464, 470.

Machairodontinae. Galbreath, 1972: p. 786.

Meganteron [sic] *hesperus* (Gazin). Vanderhill, 1986: tab. 5.3.7; L. Martin, 1998: p. 239.

Macheirodus [sic] *hesperus* Gazin. Currie, 1998: p. vi.

Identification of HAFO Material

Megantereon differs from other machairodonts, except *Smilodon*, in having an enlarged glenoid process, large postorbital process, elongate and unserrated upper canines, reduced protocone on P4, and mandibular flange; *Megantereon* has limbs similar to *Smilodon*, more gracile than *Xenosmilus*, and shorter and more robust than other machairodonts. *Megantereon* is separated from *Smilodon* by having relatively smaller incisors, relatively shorter upper canines, less developed ectoparastyle on P4, relatively large p3 compared to p4, and larger mandibular flange. *Megantereon hesperus* can be distinguished from other *Megantereon* species by the larger lower canine and p3, and the more developed ridge at the anterior edge of the mandibular flange (Berta and Galiano, 1983). Limb elements (Figure 4.5) are shorter and more robust than those of *Homotherium* from HAFO.

Distribution

Other Blancan sites with *Megantereon hesperus* are Broadwater (Schultz and Martin, 1970; Berta and Galiano, 1983) and Rexroad Locality 3 (Berta and Galiano, 1983). Material referred to *Megantereon hesperus* from the Blancan Florida localities Santa Fe 1B and Haile 15A (Kurtén and Anderson, 1980) was reidentified as *Smilodon gracilis* (Morgan and Hulbert, 1995). Likewise, fossils from the Palm Spring Formation of Anza-Borrego Desert State Park were identified both as *Megantereon hesperus* (L. Martin, 1998) and *Smilodon gracilis* (Cassiliano, 1999, 2006; Jefferson and Remeika, 2006; Shaw and Cox, 2006), and fossils from White

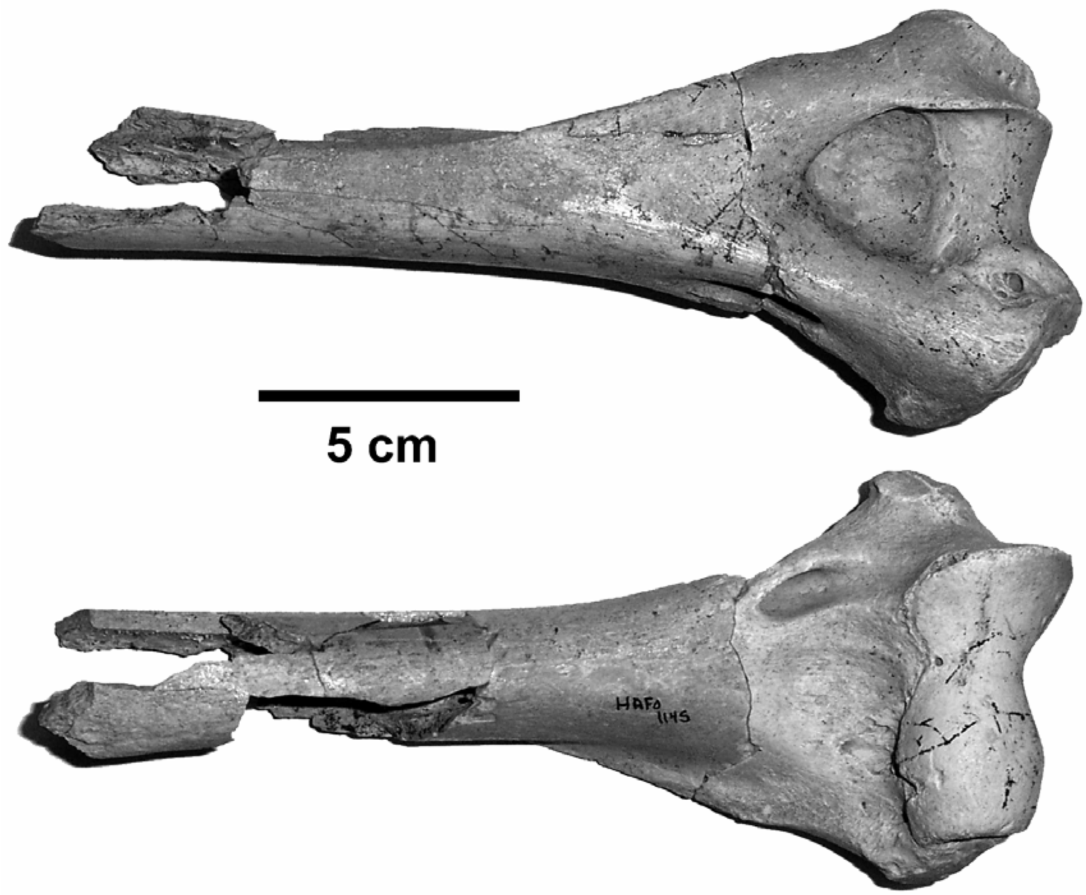


Figure 4.5. Distal portion of a right humerus of *Megantereon hesperus*, HAFO 1145.

Top, posterior view; bottom, anterior view.

Rock identified as aff. *Smilodon* (Eshelman, 1975) were also listed as *Meganereon hesperus* (L. Martin, 1998). Because *Megantereon hesperus* was suggested as evolving into *Smilodon gracilis* (Berta, 1987), transitional forms in late Blancan localities are difficult to distinguish.

Hemphillian records of *Megantereon hesperus* are known from three Palmetto Fauna localities in the Bone Valley Formation of Florida (Berta and Galiano, 1983). In addition, L. Martin (1998) listed *Megantereon hesperus* as occurring at Redington, White Cone, Wikieup, and Yepómera (Lindsay et al., 1984; L. Martin, 1998); these records are not yet described. Old World records of *Megantereon* (as *M. cultridens*) are first known in the early middle Pliocene (Berta, 1987).

Remarks on Taxonomy

The similarity of *Megantereon hesperus* to Old World forms was noted immediately, but assignment to *Machairodus* was made instead because *Megantereon* was not previously known to occur in North America (Gazin, 1933b). Assignment of this species to *Machairodus* was soon questioned, both on morphological grounds and on the range extension required if *Machairodus* was to be recognized in the Blancan (Schultz, 1937).

After the use of *Machairodus* was restricted to specimens in the Hemphillian of North America (Mawby, 1960), all Blancan records of *Machairodus* were transferred to *Megantereon hesperus*, and it was suggested that new material would probably show the North American specimens to be conspecific with the Old World *Megantereon cultridens* (Schultz and Martin, 1970). Subsequent material actually supported the taxonomic distinctness of *Megantereon hesperus* (L. Martin, 1998).

Comments on HAFO Material

The deposits at HAFO were said to contain the last record of *Megantereon hesperus* in North America (Lindsay et al., 1984), but more recently the latest occurrence was given as Rexroad Locality 3 (Bell et al., 2004). Few specimens of *Megantereon hesperus* are known from HAFO, and fewer have specific locality data. The specimens that can confidently be placed stratigraphically occur low in the section at HAFO, and are most likely older than fossils from Rexroad Locality 3.

The large felid humerus in Figure 4.5 (HAFO 1145) was found at the base of a hill that later produced more pieces of the same specimen, plus a large felid canine (HAFO 2478) and scapholunar (HAFO 2479); the association of three specimens from a large felid(s), which are otherwise rare at HAFO, suggests the possibility of a single individual (pers. comm., G. McDonald, 2007). I have identified the canine as *Homotherium* sp. based on the presence of serrations, which are absent in *Megantereon* (Berta, 1987; L. Martin, 1998). The humerus is here attributed to *Megantereon* because it has more enlarged lateral and medial condyles and a recessed groove distal to the entepicondylar formaen (Geraads et al., 2004; Peigné et al., 2005).

Puma Jardine, 1834

Puma lacustris (Gazin, 1933b)

Felis lacustris n. sp. Gazin, 1933b: p. 251-254, figs. 1-2.

Felis lacustris Gazin. Gazin, 1936: pp. 285, 288; Schultz, 1937: p. 84; Hibbard, 1941b: pp. 274-275; Hibbard, 1941c: p. 87; Gazin, 1942: p. 504; Hibbard, 1959: p. 33; Stephens, 1959: Savage, 1960: pp. 318, 339; Bjork, 1970: pp. 39-44, figs. 22-24 (in part); Shotwell, 1970: p. 83; Hibbard, 1972b: p. 128; Schultz and Martin, 1972: p. 202; Bjork, 1973: p. 35; Dalquest, 1978: pp. 292-293; Gustafson, 1978: p. 41, tab. 15; Conrad, 1980: pp. 154, 231; Kurtén and Anderson, 1980: p. 195; Miller, 1980: pp. 787, 800; Franz, 1981: p. 27; Werdelin, 1985: pp. 201-206; Vanderhill, 1986: p. 142, tab. 5.3.6; Czaplewski, 1987: p. 147; Sankey, 1991: p. 112; Repenning et al., 1995: pp. 24-25, 73; Carranza-Castañeda and Miller, 1996: p. 513; McDonald et al., 1996: 32, fig. 12D-E; Morgan et al., 1997: p. 117; Currie, 1998: pp. 19, 51, figs. 6D, E; Smith and Patterson, 1994: p. 299; Sanders, 2002: p. 62; Sankey, 2002: pp. 80-81.

Felis lacrustris [sic]. Galbreath, 1972: p. 786.

Puma lacustris (Gazin). Glass and Martin, 1978: pp. 83-84; L. Martin, 1998: p. 238; Seymour, 1999: p. 459.

Identification of HAFO Material

This felid material is distinct from machairodonts by the unenlarged, rounded canines with deep external grooves. *Puma* is distinct from other felines by the small domed head, relatively small carnassials, heavily built dentaries, and relative short, robust limbs (L. Martin, 1998). *Puma lacustris* further differs from *Lynx* in possessing a P2, albeit small. *Puma* has bifurcate roots on the dP4 and a shallow external pterygoid fossa, whereas *Felis* has fused roots on the dP4 and a deep external pterygoid fossa (Salles, 1992). Other *Puma* material not represented at HAFO can be distinguished from *Felis* by morphological characters published elsewhere (Hemmer, 1978; Salles, 1992; Ewer, 1998). *Puma lacustris* is smaller than *Puma concolor* and is typically larger than the *Lynx rexroadensis* from HAFO, but this difference varies by element (Werdelin, 1985). Accurate identification of much material from these two felids requires multivariate analysis (Seymour, 1999), and in most cases, only dentaries and skulls with teeth are diagnostic (Werdelin, 1985).

Distribution

There are many references to both *Puma lacustris* and *Lynx rexroadensis* in the literature, but the vast majority of these studies have not used the multivariate methods shown to differentiate much of the material assigned to these two felids. Because multivariate analysis has reclassified much of the material assigned to these species and to *Lynx issiodorensis kurteni*, only taxonomic determinations made with those methods are given here. In addition to HAFO, *Puma lacustris* was recognized at Overton by Werdelin (1985:202, 210, fig. 20) and Kurtén (1976). A dentary from Cita Canyon was previously identified as being nearly identical, both qualitatively and quantitatively, to the type specimen of *Felis lacustris* (Johnston and Savage, 1955; Werdelin, 1981). Additional specimens were later noted from Collins and Duncan (Seymour, 1999).

Numerous other localities were said to include *Puma lacustris*, but these specimens were either too fragmentary to allow for species-level identification, undiagnostic, or reidentified as *Lynx rexroadensis*: 111 Ranch (Morgan and White, 2005), Anza-Borrego Desert State Park (Murray, 2006a; Vallecito Creek fauna of Cassiliano, 1999), Beck Ranch (Dalquest, 1978), Blanco (Dalquest, 1975), Jackass Butte (Shotwell, 1970), Rexroad Locality 3 (Hibbard, 1941b), Taunton (Tedford and Gustafson, 1977; Morgan and Morgan, 1995), Tyson Ranch (Sankey, 1991, 2002), and Virden (Tedford, 1981). Other more tentative references were made on material from Birch Creek (Hearst, 1999), Curtis Ranch (Gazin, 1942), and Las Tunas (Miller, 1980).

Remarks on Taxonomy

The overall similarity between *Puma lacustris* and *Lynx rexroadensis* has long been recognized (e.g., Stephens, 1959; Savage, 1960; Bjork, 1970; Werdelin, 1981), but I am aware of only a single instance in which the two were proposed as conspecific (Kurtén and Anderson, 1980). This general similarity is the reason many authors have assumed that *Puma lacustris* and *Lynx rexroadensis* were very closely related; this assumption was part of the impediment to classifying these felids.

A hypothesized close relationship between *Puma lacustris* and the lynx group, because of the similarity between *Lynx rexroadensis* and the other species of the lynx group (Savage, 1960), was heavily criticized (Bjork, 1970; Glass and Martin, 1978; Werdelin, 1981; Seymour, 1999). Likewise, *Lynx rexroadensis* was explicitly exluded by Werdelin (1981) from inclusion within *Lynx* because *Puma lacustris* was not considered referable to that group.

Bjork (1970) was critical of assigning *Puma lacustris* to *Puma*, but it was subsequently shown that *Puma lacustris* has relative proportions of the teeth indistinguishable from *Puma concolor* (Glass and Martin, 1978). A discriminant function analysis on extant specimens of *Leopardus*, *Puma*, and *Lynx* was used to classify extinct small Miocene and Pliocene cats of North and South America (Seymour, 1999). The type specimen of *Felis lacustris* fell only within the 95% confidence ellipse of extant *Puma* upper dentition in all analyses.

Comments on HAFO Material

Early study of the small felid material from HAFO noted the two size groups (Gazin, 1942), however, most subsequent references to *Puma lacustris* from HAFO recognize only a single species of small felid from the Glenns Ferry Formation. Generally, the larger elements are likely referable to *Puma lacustris* and the smaller elements probably represent *Lynx rexroadensis*; unfortunately, even relatively complete fossils of some elements often can not be identified definitively to species (Figure 4.6).

Repenning et al. (1995) suggested that "the progressively increasing similarity to puma in younger parts of the Glenns Ferry Formation suggests that the cats of the Glenns Ferry Formation are the previously unknown origin of *Puma concolor*" (1995:25), but this close relationship was actually proposed years earlier (Glass and Martin; 1978). I agree with Repenning et al. (1995), however, other authors have suggested *Miracinonyx inexpectatus* to be ancestral to *Puma concolor* (e.g., Van Valkenburgh et al., 1990).

Lynx Kerr, 1792

Lynx rexroadensis (Stephens, 1959)

Felis lacustris Gazin (in part). Gazin, 1933b: p. 251; Bjork, 1970: pp. 39-44.

Felis sp. Bjork, 1970: pp. 44-45, fig. 25c; Galbreath, 1972: p. 786.

Felis rexroadensis Stephens. Werdelin, 1985: p. 202; Seymour, 1999: pp. 899-902.

Lynx rexroadensis (Stephens). L. Martin, 1998: p. 238.

Identification of HAFO Material

This felid material is distinct from machairodonts by the unenlarged, rounded canines with deep external grooves. *Lynx* differs from other small felines in always lacking a P2 and having three lateral grooves on the upper canines (L. Martin, 1998).

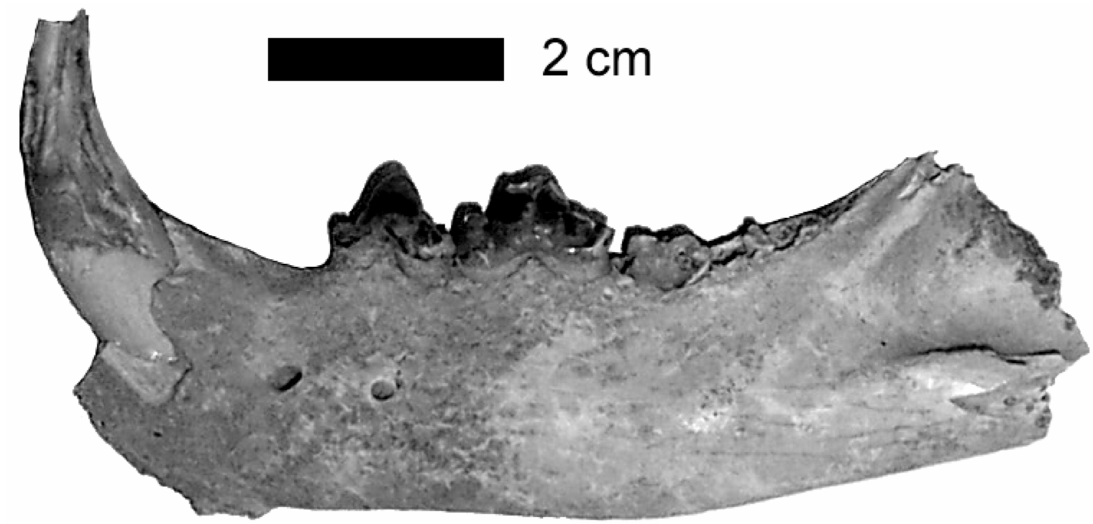


Figure 4.6. Lateral view of the left dentary of either *Puma lacustris* or *Lynx rexroadensis*, HAFO 4845.

Lynx also has a deep external pterygoid fossa, whereas *Felis* has a shallow one (Salles, 1992). *Lynx rexroadensis* is very similar to *Puma lacustris*, but is slightly smaller. Accurate identification of some elements of *Lynx rexroadensis* requires the use of multivariate analysis (Seymour, 1999).

Distribution

As in the case of *Puma lacustris*, only taxonomic determinations made using multivariate analysis are listed here as records of *Lynx rexroadensis*. Werdelin (1985) identified *Lynx rexroadensis* from Anza-Borrego Desert State Park, Borchers, Buis Ranch, Comosi Wash, Curtis Ranch, Grand View, Mullen, Rexroad Formation, and Palmetto Fauna, in addition to HAFO. To this list, Seymour (1999) added a specimen from the Mount Eden Formation of California.

Specimens identified as *Lynx* cf. *Lynx rexroadensis* (Akersten, 1972) are not complete enough to identify specifically (Werdelin, 1985). I do not know whether fossils identified as *Lynx rexroadensis* from Poggi Canyon (Wagner et al., 2001; Otay Ranch of Wagner et al., 2000) are sufficiently complete to identify to species.

Remarks on Taxonomy

The extant lynxes are recognized as a monophyletic group within *Lynx* (Salles, 1992; Wozencraft, 1989, 1993), and the diagnostic dental character of the group is the absence of the P2 (Werdelin, 1981). It is unclear how extinct species relate to the crown group of *Lynx* or how many extinct species of *Lynx* are known;

most North American Miocene and Pliocene small felids have at some point been included within the lynx group (Seymour, 1999).

The superspecific assignment of *Lynx rexroadensis* has vascillated between inclusions in *Lynx* (Kurtén, 1957; Glass and Martin, 1978, Hulbert, 1992) to explicit exclusion from *Lynx* (Werdelin, 1987). Discriminant analysis showed *Lynx rexroadensis* to be closest to the range of extant *Lynx* but could not rule out the possibility of assignment to *Leopardus*; *Lynx rexroadensis* was distinct, however, from *Puma* (Seymour, 1999). Usage of *Lynx rexroadensis* here follows L. Martin (1998) who identified three grooves on the upper canine of this species.

Comments on HAFO Material

Specimens of a small felid from HAFO other than *Puma lacustris* were first identified in 1985 (Werdelin, 1985), but the occurrence of more than a single species of small felid was not mentioned by most authors who later discussed this fauna. Not only does *Lynx rexroadensis* occur at HAFO, it is numerically the dominant felid, with approximately twice the abundance of *Puma lacustris* (Seymour, 1999). The machairodont species and *Miracionyx* are less abundant then either small felid (personal observation). Even the paratype of *Puma lacustris* was later referred to *Lynx rexroadensis* (Seymour, 1999).

Miracinonyx Van Valkenburgh et al., 1990

Miracinonyx inexpectatus (Cope, 1895)

Acionyx studeri (Adams). Werdelin, 1985: p. 201-202.

Identification of HAFO Material

The single specimen of this material has a p3 more anteroposteriorly elongated than other felines, and a relatively shorter lower diastema. The length of the p3 is as long as the largest *Puma lacustris* from HAFO, but the width of the same tooth is as short as in *Lynx rexroadensis* (modified from Bjork, 1970; Werdelin, 1985). The anteroposterior elongation most closely matches that of a specimen of *Miracinonyx inexpectatus* from Hamilton Cave.

Distribution

Specimens referable to *Miracinonyx inexpectatus* are known from Cavetown, Cita Canyon, Conard Fissure, Cumberland Cave, Hamilton Cave, Inglis 1A, Port Kennedy Cave, and Saratoga (Van Valkenburgh et al., 1990). That list excluded previous records of *Miracinonyx inexpectatus* reported from Blanco and Overton (Kurtén, 1976) that were later reidentified as *Puma lacustris* (Werdelin, 1985). Kurtén (1976) additionally listed material of *Miracinonyx inexpectatus* from Curtis Ranch, Gilliland, Mullen, and phosphate beds near Charleston, South Carolina. Specimens from the Anza-Borrego Desert State Park were identified as *Acinonyx* sp. (Jefferson and Tejada-Flores, 1995) but were reassigned to *Miracinonyx inexpectatus* (Shaw and Cox, 2006); *Acinonyx* is not known from North America (Van Valkenburgh et al., 1990).

Specimens more tentatively identified as *Miracinonyx* cf. *Miracinonyx inexpectatus* are known from Rancho Viejo (Carranza-Castañeda and Miller, 1996), Ladds Quarry (Ray, 1967), and Porcupine Cave (Anderson, 2004); *Miracinonyx* sp. was listed as present in the fauna from 111 Ranch (White and Morgan, 2005). The closely related *Miracinonyx trumani* is known from Crypt Cave (Orr, 1969) and Natural Trap Cave (L. Martin et al., 1977).

Remarks on Taxonomy

The feline material from Port Kennedy Cave named as *Crocuta inexpectatus* (Cope, 1895) was reassigned to both *Uncia inexpectatus* (Cope, 1899) and *Felis* (*Puma*) *inexpectatus* (Simpson, 1941) before being considered a nomen dubium and renamed *Felis studeri* based on specimens from Cita Canyon (Savage, 1960). Debate has continued since then on whether the material from Port Kennedy Cave should be considered the type material based on priority (e.g., Kurtén, 1976, Van Valkenburgh et al., 1990; Morgan and Hulbert, 1997), or whether those specimens are too fragmentary and Cita Canyon should be considered the type locality (as *Miracinonyx studeri*; e.g., Adams, 1979, Carranza-Castañeda and Miller, 1996). The higher level nomenclature was later modified to *Acinonyx* (*Miracinonyx*) to indicate the suggested relationship between the American and Old World cheetah (Adams, 1979). The American cheetahs are now referred to *Miracinonyx* as *Miracinonyx inexpectatus* and *Miracinonyx trumani* (Van Valkenburgh et al., 1990).

Comments on HAFO Material

Werdelin (1985) noted that according to his ratio diagram based on lower dentition, the Hagerman material generally falls into two groups, but a single specimen (USNM 12613) did not fit either pattern and "may instead pertain to *Acinonyx studeri*" (1985:202) because of its anteroposterior elongation of the p3. Such elongation of the lower dentition is characteristic of cheetahs (*Acinonyx*), at least among old world cats (O'Regan, 2002). Table 4.3 shows the measurements the feline p3s from HAFO and some other North American material. *Lynx rexroadensis* are the smallest specimens; p3s of *Puma lacustris* and USNM 12613 are similar in length. Neither *Puma lacustris* nor *Lynx rexroadensis* have a length to width ratio near that of USNM 12613. The only p3 relatively similar in size with as much anteroposterior elongation of which I am aware is part of USNM 401092 (Table 4.3), from Hamilton Cave and identified as *Miracinonyx inexpectatus* (Van Valkenburgh et al., 1990). A dentary with p3 identified as *Miracinonyx inexpectatus*? (UF 21604) from Inglis 1A (Morgan and Seymour, 1997) is closer in size to USNM 12613 from HAFO, but doesn't show the extreme anteroposterior elongation. The elongation is much more similar to *Puma lacustris* from HAFO (Table 4.3). Because some postcranial material from Inglis 1A was described as belonging to either *Puma lacustris* or *Lynx rexroadensis* (Werdelin, 1985), it seems possible that this dentary from Inglis 1A may also be attributable to *Puma lacustris*.

Cheetahs first appear in the Old World (as *Aciononyx*) at about 3.5 Ma (Adams, 1979) and in North America (as *Miracinonyx*) at about 3.6 Ma. Because

Table 4.3. Measurments of the p3 of several felids. Length (l) and width (w) are in mm).

specimen	identification	locality	l	w	l/w
USNM 12613[1]	*Miracinonyx inexpectatus*	HAFO	11.6	5.3	2.19
USNM 12611[2]	*Puma lacustris*	HAFO	12.5	6.5	1.92
USNM 13743L[1]	*Puma lacustris*	HAFO	11.4	6.6	1.73
USNM 13743R[1]	*Puma lacustris*	HAFO	11.6	6.4	1.81
USNM 25130[1]	*Lynx rexroadensis*	HAFO	11.0	5.7	1.93
USNM 12612[1]	*Lynx rexroadensis*	HAFO	10.3	5.3	1.94
HAFO 94[3]	*Lynx rexroadensis*	HAFO	9.1	4.7	1.94
USNM 401092[4]	*Miracinonyx inexpectatus*	Hamilton Cave	14.6	7.0	2.09
UF 21604[5]	*Miracinonyx inexpectatus*?	Inglis1A	12.6	7.2	1.75
15 specimens[3]	*Puma concolor*	recent	13.1	7.1	1.85
20 specimens[5]	*Puma concolor*	recent	11.9	6.4	1.86

Measurements from [1]Bjork, 1970; [2]Gazin 1933b; [3]Seymour, 1999; [4]Van Valkenburgh et al., 1990; [5]Morgan and Seymour, 1997.

there is no specific locality data for the specimen of *Miracinonyx inexpectatus* from HAFO, its possible status as the earliest cheetah cannot be evaluated.

Canidae Gray, 1821

Canis Linnaeus, 1758

Canis lepophagus Johnston, 1938

Canid sp. Gazin, 1936: pp. 285, 288; Schultz, 1937: p. 84; Hibbard, 1941c: p. 87.

Canis cf. *C. latrans* Say. Fine, 1964: pp. 483-485, fig. 1.

Canis lepophagus Johnston. Bjork, 1970: pp. 13-16, fig. 8; Galbreath, 1972: p. 786; Hibbard, 1972a: p. 107; Hibbard, 1972b: p. 128; Gustafson, 1978: p. 37; Conrad, 1980: pp. 151, 211, tab. 10; Kurtén and Anderson, 1980: p. 167; Franz, 1981: p. 24; Gustafson, 1985b: p. 90, tab. 3; Sankey, 1991: p. 109; McDonald et al., 1996: pp. 32, 42; Currie, 1998: pp. 19, 51; Morgan et al., 1998: p. 243; Munthe, 1998: p. 133; Hearst, 1999: p. 37; Sankey, 2002: p. 80; Bell et al., 2004: p. 258.

Canis lepophagus Johnston or *Canis priscolatrans* Cope. Kurtén, 1974: pp. 26, 28.

Identification of HAFO Material

This canid is referred to Caninae based on its small, simply premolars, humerus lacking an entepicondylar foramen, greatly reduced first metatarsal, and m2 with posterior cingulum, enlarged anterolabial cingulum, and metaconid taller than protoconid (Munthe, 1998). Species of *Canis* are the largest canines in North

America and have incisors with accessory cusps. Additionally, *Canis* differs from *Vulpes* by having relatively short canines and relatively large cheekteeth (Munthe, 1998). *Canis lephophagus* and *Canis latrans* are the smallest species of *Canis* (excluding domesticated forms) and extremely similar to each other, with *Canis lepophagus* being the more gracile of the two (Johnston, 1938; Bjork, 1970). Differences in the brain case may adequately separate *Canis lepophagus* and *Canis latrans* (Johnston, 1938; Bever, 2005), but such material is not available from HAFO. *Canis lepophagus* does not have more anteroposteriorly elongate dentition than *Canis latrans* (contra Bjork, 1970). A calcaneum from HAFO matches *Canis latrans* and *Canis lephophagus* except in lacking the well-defined notch between the sustentacular tali and cuboid facet (Bjork, 1970); this character has proved useful in other faunas as well (Bjork, 1973). There is no evidence for more than one species of *Canis* at HAFO.

Distribution

Canis lepophagus was widespread in the Blancan of North America, but specimens are relatively rare in the eastern United States, with specimens only known from the Florida localities Santa Fe River 1 (Nowak, 2002; Morgan, 2005), and possibly Macasphalt Shell Pit (Morgan and Hulbert, 1995). Kansas localities with *Canis lepophagus* are mostly from the Rexroad Formation at Deer Park (R. Martin et al., 2000), Keefe Canyon (R. Martin et al., 2000), Rexroad Locality 2 (Hibbard, 1938; Hibbard, 1970), Rexroad Locality 3 (Hibbard, 1941b; Hibbard, 1970; R. Martin et al., 2000), and Wendell Fox (Bjork, 1973), but records are also reported from the Crooked Creek Formation at Borchers (R. Martin et al., 2000). Other localities in the Great Plains with *Canis lepophagus* are Big Spring (Bever, 2005), Blanco (Dalquest, 1975), Broadwater (Barbour and Schultz, 1937), Cita Canyon (Johnston, 1938; Bever, 2005), Lisco (Schultz and Stout, 1948), Red Corral (Nowak, 1979), and Sand Draw (Hibbard, 1972b).

The Pacific Northwest localities containing *Canis lephophagus* are Birch Creek (Hearst, 1999), Grand View (Conrad, 1980), Taunton (Morgan and Morgan, 1995), and Tyson Ranch (Sankey, 1991). In the southwestern United States *Canis lepophagus* is known from 111 Ranch (Galusha et al., 1984), Black Ranch (Nowak, 1979), Panaca Formation (Mou, 1999; Reynolds and Lindsay, 1999; but *Canis* sp. in Lindsay et al., 2002), Tonuco Mountians (Morgan et al., 1998), and Virden (Morgan and White, 2005).

The small *Canis* at Anza-Borrego Desert State Park was said to "probably represent *Canis lepophagus*" (Murray, 2006a). The *Canis* at Bear Springs is attributable to either *Canis lepophagus* or *Canis ferox* (Morgan and White, 2005). *Canis* cf. *Canis lepophagus* was identified in the Blancan of Texas at Beck Ranch (Dalquest, 1978) and Red Light (Akersten, 1970), and the Hemphillian of Nebraska at Santee and Devils Nest Airstrip (Voorhies, 1990).

Remarks on Taxonomy

In a multivariate analysis of *Canis latrans* from California, the known mandibles of *Canis lepophagus* were included (Giles, 1960); based on that study, *Canis lepophagus* was suggested to differ only subspecifically from modern coyotes. Whether *Canis lepophagus* is indeed a distinct species is unclear, although most authors have retained use of the name for the small *Canis* material from the Blancan.

Comments on HAFO Material

With the exception of the calcaneum mentioned above, I know of no character that adequately separates the HAFO material from the modern species *Canis latrans*. Further, the relatively well sampled Pliocene-Pleistocene faunas of North America do not support the presence of an unchanging lineage of *Canis* since about 4 Ma. Known Blancan specimens of *Canis* are small, coyote-sized specimens; latest Blancan/early Irvingtonian *Canis* is significantly larger and are generally referred to as *Canis priscolatrans* (Kurtén, 1974), and this canine is in turn replaced in the late Irvingtonian by the larger *Canis armbrusteri* (Nowak, 2002). This lineage is assumed to split into the three species of *Canis* abundant in the Rancholabrean (Nowak, 2002): *Canis latrans* (small), *Canis edwardii* (medium), and *Canis dirus* (large). Given the currently lack of small *Canis* in the Irvingtonian, *Canis lepophagus* is retained as distinct.

The *Canis lepophagus* material from HAFO contains one unusual specimen: a partial dentary with a twinned p2 (Fine, 1964). Only one of the p2s is present, the other being indicated by the presence of two alveoli offset labially.

Borophagus Cope, 1892

Borophagus hilli (Johnston, 1939)

Hyaenognathus sp. or *Borophagus* sp. Gazin, 1936: pp. 285, 288; Hibbard, 1941c: p. 87.

Borophagus sp. J. Schultz, 1937: p. 84; Bjork, 1970: p. 16; Galbreath, 1972: p. 786; Hibbard, 1972b: p. 128; Conrad, 1980: p. 212, tab. 11; Franz, 1981: p. 24; McDonald et al., 1996: pp. 32, 42; Currie, 1998: p. 52.

Hyaenidae? Bjork, 1970: p. 46, fig. 25b; Hibbard, 1972b: p. 128; Lindsay et al., 1984: p. 470; McDonald et al., 1996: 43.

Borophagus direptor (Matthew). Kurtén and Anderson, 1980: pp. 165-166.

Borophagini. Berta, 1981: p. 353.

Hyaenidae. Currie, 1998: p. 52.

Borophagus diversidens Cope. Munthe, 1998: p. 137.

Borophagus hilli (Johnston). Wang et al., 1999: p. 297; Morgan and Lucas, 2003: pp. 294, 309; Bell et al., 2004: p. 258.

Identification of HAFO Material

This large canid is referable to Borophaginae based on having a large metaconid on the m2, large and closely spaced premolars, incisors with accessory cusps, and robust limbs. Characters that allow the HAFO material to be recognized as *Borophagus* are the large p4 relative to other premolars and lower carnassial, p4 transverse diameter nearly equal to that of m1 trigonid, p4 tall crowned and posteriorly sloped, and mandibular ramus short and robust with large masseteric fossa and weak symphyseal bulge. *Borophagus hilli* is distinguished from *Borophagus secundus* and more primitive species of *Borophagus* in having a p4 width equal to that of the m1 trigonid, shortening of the m1 talonid, m2 metaconid lower than m2 protoconid, and more massive dentary under the toothrow. *Borophagus hilli* is distinguished from the more advanced *B. diversidens* in having a posterior accessory cusplet on the p4, less reduced metaconids and entoconids on lower molars, and a larger m2 (Wang et al., 1999).

Distribution

A recent review of the Borophaginae (Wang et al., 1999), changed many previous identifications of *Borophagus* and *Osteoborus*. In addition to the HAFO specimens, material assigned to *Borophagus hilli* by Wang et al. (1999) is from Axtel Ranch, Christian Place Quarry (= Christian Ranch), Cuchillo Negro Creek, Las Tunas, Palmetto Fauna, Saw Rock Canyon, and White Bluffs.

Remarks on Taxonomy

Osteoborus hilli (Johnston, 1939) was synonymized with *Borophagus direptor* by Kurtén and Anderson (1980). The species was resurrected by Wang et al. (1999), who considered *Osteoborus* a junior synonym of *Borophagus*.

Comments on HAFO Material

A dP4 (USNM 24931) from the HHQ was previously identified as belonging to a hyaenid, although the differences between it and known hyaenid material elsewhere was noted (Bjork, 1970). In a study of the hyaena *Chasmaporthetes ossifragus* from Florida, Berta (1981), reviewed the occurrences of hyaenids in North America, and reassigned USNM 24931 to Borophagini, possibly without knowledge that Galbreath (1972) had previously reported a personal communication from Bjork that the premolar is definitely not from a hyaenid.

Borophagus material at HAFO is rare, and most of the assigned specimens do not contain the specific diagnostic characters, but instead represent a canid much larger than the more abundant *Canis lepophagus*.

Wang et al. (1999:339) indicated that *Borophagus hilli* went extinct just before 4 Ma, but *Borophagus* material from Hagerman is known from much younger strata, including the HHQ at about about 3.2 Ma (Chapter 2). These records from HAFO are the youngest known occurrences of *Borophagus hilli* (Bell et al., 2004).

Perissodactyla Owen, 1848

Equidae Gray, 1821

Equus Linneaus, 1758

Equus shoshonensis (Gidley, 1930b)

Plesippus shoshonensis n. sp. Gidley, 1930b: pp. 301-3, pl. 18.

Plesippus shoshonensis Gidley. Gazin, 1933b: p. 251; Gazin, 1935a: p. 390; Gazin, 1935c: p. 52; Gazin, 1936: pp. 281-282, 284-285, 288-314, figs. 21-24, tabs. 1-5; plates 23-33; Schultz, 1936: pp. 3, 8, fig. 1e, 3b; Schultz, 1937: pp. 83, 85, 99; Gazin, 1938: p. 41; Hibbard, 1941c: p. 87; Gazin, 1942: p. 495; Hibbard, 1958b: p. 23; Hibbard, 1959: pp. 33, 37; White, 1967: p. 20; Repenning et al., 1995: pp. 41-46, 74, figs. 10B, C; Albright, 1999: p. 98; Eisenmann and Kuznetsova, 2004: p. 538.

Plesippus shoshonense [sic] Gidley. Gazin, 1935a: p. 390.

Equus shoshonensis (Gidley). Stirton, 1942: p. 636; Akersten, 1970: p. 36, tabs. 12-14, 16-17; Winans, 1985: pp. 152-154, 168, fig. 26; Berger, 1987: pp. ii, 1-3, 7, 13-19, 29, 37-38, 46, 59-60, 62-67, fig. 5-21, tab. 1-4; Eisenmann and Deng, 2005: pp. 113, fig. 1-8, tab. 1, 3.

Equus (*Plesippus*) *shoshonensis* (Gidley). Howe, 1970: pp. 959-960; Malde and Powers, 1962: p. 1208; Fry and Gustafson, 1974: p. 377.

Equus (*Dolichohippus*) *simplicidens* Cope. Hibbard, 1972b: p. 129; Skinner, 1972b: pp. 118-123; Gustafson, 1978: p. 43-45, fig. 25; Conrad, 1980: tab. 13; Kurtén and Anderson, 1980: p. 14; Gustafson, 1985b: p. 90, tab. 3; McDonald et al., 1996: p. 43; MacFadden, 1998: p. 552.

Plesippuso [sic]. Macdonald and Macdonald, 1974: p. 71.

Equus simplicidens Cope. Kurtén and Anderson, 1980: p. 287, figs. 14.1B, 14.3A; Franz, 1981: p. 27; Cunningham, 1984: pp. 1, 9, 47-50; Winans, 1989: pp. 292-3; Sankey, 1991: pp. 145, 155, tabs. 21-23; Eisenmann, 1992: pp. 161-162, tab. 2; MacFadden, 1992: pp. 73-74, fig. 4.14; Azzaroli and Voorhies, 1993: pp. 176, 178-180, 185, plate 1 figs 1-2, tabs. 1-3; McDonald, 1993: p. 323-325; Kelly, 1994: p. 12; Bentley and Oakley, 1995: p. 67; McDonald, 1996: pp. 134-146; McDonald et al., 1996: p. 18, 32; Kelly, 1997: p. 18-20; Currie, 1998: pp. iv, x, 16, 51, photos 5, 6; McDonald, 1998: p. 58; Richmond and McDonald, 1998: pp. 103-104; Deng and Xue, 1999: p. 136; Hart and Brueseke, 1999: p. 3; Richmond et al., 1999: 70A; Wallace, 1999: p. 33; Robertson, 2001: p. 63; Baxter and Henbest, 2002a: pp. 45, 52; Baxter and Henbest, 2002b: 189, 196; Brusatte, 2002: pp. 46, 48; Link et al., 2002: p. 109; McDonald, 2002a: pp. 14-17, 19; McDonald, 2002b: pp. 40-43, 45-47; Robertson and Gensler, 2002: p. 276; Sankey, 2002: pp. 87-88, fig. 23B Thompson et al., 2002: p. 56A; Bishop, 2003: p. 197; Jolly and Robertson, 2003: p. 33; O'Kelley and Robertson, 2003: p. 33; Parker, 2003: fig. 1-5; Bell et al., 2004: p. 258; Wallace, 2004: p. 41; Webb et al., 2004: p. 528; Prothero, 2006: p. 245.

Equus shoshoniensis [sic] Gidley. Winans, 1989: pp. 271-275 (in reference to type material only).

Equus simplicidens Cope or *Plesippus shoshonensis* Gidley. Lee et al., 1995: p. 13.

Pliohippus sp. Kohn et al., 2002: p. 155.

Equus simplicidens or *Plesippus shoshonensis*. Sennett, 2002: p. 24.

Equus (Plesippus) simplicidens Cope. Scott, 2004: p. 264, 273, 279, fig. 20.9.

Identification of HAFO Material

Of the five groups of North American native *Equus* recognized by Winans (1985, 1989), *Equus shoshoensis* differs from *Equus francisi* in having more robust limbs (especially in comparison of the metapodials), from *Equus francisi* and *Equus alaskae* in significantly longer skull length, and from *Equus scotti* and *Equus laurentius* (=*Equus mexicanus* sensu Winans, 1989) in having a narrower rostrum. In these multivariate analyses, all early Blancan *Equus*, including the HAFO horse, were assigned to either *Equus shoshonensis* (Winans, 1985) or *Equus simplicidens* (Winans, 1989).

Equus shoshonensis is differentiated from *Equus simplicidens* by the deeper folding of the facial pits, the more posteriorly-positioned orbits, the relatively longer and more curved upper molars with elongated and tapering protocones that shortern in length through ontogenetic wear, and the lower molars with ectoflexid penetrating the isthmus (Gidley, 1930b; Winans, 1985; Repenning et al., 1995). Three other species of equids were described from localities higher in the Glenns Ferry Formation than the HAFO deposits: *Equus idahoensis*, *Equus stenonis anguinus* and *Plesippus fromanius*. *Equus shoshonensis* differs from *Equus idahoensis* in its smaller size and less pronounced protoconal grooves on the upper cheekteeth

(Shotwell, 1970; Albright, 1999). *Equus stenonis anguinus* and *Equus fromanius* were described as the immediate descendant and terminal species in a lineage beginning with the HAFO *Equus shoshonensis* (Azzaroli and Voorhies, 1993; Repenning et al., 1995); *Equus shoshonensis* differs from these descendant forms by its smaller size, shorter limbs, more caudal position of the posterior palatine foramina, and ectoflexids of the lower cheek teeth pentrating the isthmus.

Distribution

I can not provide an accurate assessment of the distribution of *Equus shoshonensis* based on published records because the species was long included in *Equus simplicidens* with most other early Blancan specimens of *Equus* (sensu lato). It is unclear if this species occurs any place other than at HAFO.

Remarks on Taxonomy

Resurrection of *Equus shoshonensis* and separation of it from *Equus simplicidens* is based primarily on the morphology of the protocone on upper cheekteeth. The HAFO horse has an elongate protocone that tapers with ontogenetic wear, whereas the holotype of *E. simplicidens* and other topotypic material exhibits a short protocone at all stages of wear (Repenning et al., 1995). Further, Repenning et al. (1995) suggested *Plesippus* was also valid and used it for *Plesippus shoshonensis*, *Plesippus stenonis*, *Plesippus fromanius*, and *Plesippus idahoensis*. However, in the justification for doing so, *Plesippus* was explicitly recognized as a grade restricted by geography to taxa in North America. This is especially problematic in the case of a single species occurring in multiple continents, as in the case of using *Equus stenonis* for the Old Word records, but *Plesippus stenonis* for New World fossils (Repenning et al., 1995:47; *Allohippus stenonis* was independently suggested for the Old World form (Eisenmann and Kuznetsova, 2004). In the absence of any morphological synapomorphy for *Plesippus*, the HAFO horse is here referred to as *Equus shoshonensis*. This does not, however, imply that I disagree with the evolutionary scenario suggested by Repenning et al. (1995). Scott (2006) chose to recognize *Plesippus* as a subgenus of *Equus* for the North American zebra-like horses, but acknowledged the problematic taxonomic history.

For additional discussion on the nomenclature of Pliocene *Equus* (sensu lato) in North America see also Winans (1985), Kelly (1994, 1997), and Albright (1999).

Comments on HAFO Material

The *Equus shoshonensis* material at HAFO occurs throughout the fossiliferous layers of Glenns Ferry Formation, but elements not collected as surface float are rare, with the notable exception of the Hagerman Horse Quarry. Skulls and skeletons of *Equus shoshonensis* from the HHQ can now be found on exhibit in dozens of natural history museums, due largely to the efforts of the USNM.

Artiodactyla Owen, 1848

Tayassuidae Palmer, 1897

Platygonus Le Conte, 1848

Platygonus pearcei Gazin, 1938

Platygonus n. sp. Gazin, 1936: pp. 285, 288; Schultz, 1937: p. 85.

Platygonus pearcei n. sp. Gazin, 1938: pp. 41-48, figs. 1-3, tab. 1.

Platygonus pearcei Gazin. Hibbard, 1941c: p. 87; Gazin, 1942: p. 495; Hibbard, 1958b: p. 21; Shotwell, 1970: pp. 95-96; Hibbard, 1972b: p. 129; Gustafson, 1978: pp. 45-48, 55, tab. 17; Conrad, 1980: pp. 255, 259, tab. 14; Kurtén and Anderson, 1980: p. 297; Franz, 1981: pp. 28-29; Lindsay et al., 1984: p. 472; Sankey, 1991: p. 158; McDonald et al., 1996: pp. 32, 42; Morgan et al., 1997: p. 119; Currie, 1998: p. 52; Wright, 1998: p. 397; Hearst, 1999: pp. 193-194; Sankey, 2002: p. 89; Bell et al., 2004: p. 258; Gensler and Carpenter, 2006: p. 17.

Identification of HAFO Material

This peccary is referred to *Platygonus* based on the p2 with metaconid, p4 with hypoconid and metaconid, medially fused metatarsals 3 and 4, large posterior aperture of atrium of maxillopalatine labyrinth, and reduced posterior cusps on premolars (Wright, 1998). *Platygonus pearcei* differs from all other species of *Platygonus* by possessing an i3, having a larger heel on the M3 and m3, and having more gracile limbs (Gazin, 1938; Hearst, 1999).

Distribution

Specimens referred to *Platygonus pearcei* are restricted to the Pacific Northwest: Taunton (Wright, 1998), Three Mile East (Sankey, 2002), Tyson Ranch (Sankey, 2002), and White Bluffs (Gustafson, 1978; Lindsay et al., 1984). *Platygonus* cf. *Platygonus pearcei* is reported from Buckeye Creek (Kelly, 1997), and specimens of *Platygonus* from Anza-Borrego Desert State Park were identified as probably *Platygonus pearcei* or *Platygonus bicalcaratus* (Murray, 2006b).

Remarks on Taxonomy

Overlap in the temporal ranges of species of *Platygonus* (Bell et al., 2004) suggests that evolution of the group may be more complex than a single evolving lineage. However, it is difficult to distinguish the Blancan and Irvingtonian species of *Platygonus* (Wright, 1995), so the overlap in temporal range could be an artifact of how species were identified.

Comments on HAFO Material (Figure 4.7)

The type material of *Platygonus pearcei* is from one of the few localities at HAFO other than the HHQ that contains in situ and articulated specimens. Partial skeletons of one adult and two young individuals of *Platygonus pearcei* were discovered about 4.5 km south of the HHQ (Gazin, 1938); unfortunately, precise location data is lacking.

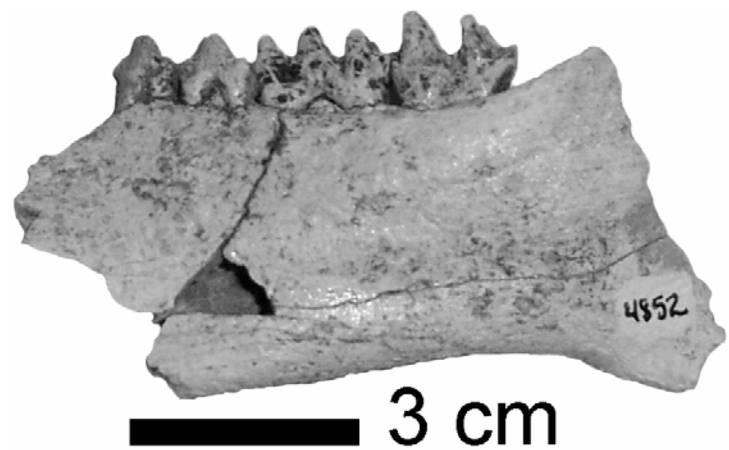


Figure 4.7. Left dentary of *Platygonus pearcei*, HAFO 4852, with dp2-4 and m1; labial view.

Antilocapridae Gray, 1866

Ceratomeryx Gazin, 1935a

Ceratomeryx prenticei Gazin, 1935a

Ceratomeryx prenticei n. sp. Gazin, 1935a: pp. 390-393, fig. 1.

Ceratomeryx prenticei Gazin. Gazin, 1936: p. 285, 288; Schultz, 1937: p. 85; Hibbard, 1958b: p. 22; Hibbard, 1941b: p. 304; Hibbard, 1941c: p. 87; Hibbard, 1972b: p. 129; Kurtén and Anderson, 1980: p. 319; Franz, 1981: p. 30; McDonald et al., 1996: pp. 32, 42, fig. 11B; Currie, 1998: p. 53, fig. 5B; Janis and Manning, 1998: p. 500.

Ceratomeryx furcifer Matthew. Czaplewski, 1987: p. 150.

Identification of HAFO Material

Ceratomeryx differs from all other antilocaprids in having two-tined horns with tines well separated and transversely flattened and with the anterior tine much larger than the posterior tine and directed slightly posteriorly (Gazin, 1935a; Janis and Manning, 1998). *Ceratomeryx* is monotypic, containing only *Ceratomeryx prenticei*; reference to "*Ceratomeryx furcifer*" by Czaplewski (1987) is an error because no such species exists.

Distribution

Ceratomeryx prenticei is known only from HAFO.

Remarks on Taxonomy

The HAFO antilocaprid was suggested to be most closely related to either *Tetrameryx* (Gazin, 1935a; Janis and Manning, 1998) or *Sphenophalos* (Kurtén and Anderson, 1980), but the horns of *Ceratomeryx* are not especially similar to those in either group.

Comments on HAFO Material

The horns of *Ceratomeryx* differ significantly from those of other antilocaprids, but other known elements are undiagnostic and are indistinguishable from several other antilocaprids. Few elements of *Ceratomeryx prenticei* are known, and only the holotype exhibits the unique morphology of this taxon. There is no evidence of more than a single species of antilocaprid at HAFO.

Cervidae Goldfuß, 1820

Odocoileus Rafinesque, 1832

Odocoileus sp.

Cervid sp. Gazin, 1936: pp. 285, 288; Schultz, 1937: p. 85; Hibbard, 1941c: p. 87; Hibbard, 1972b: p. 129.

Odocoileus sp. Gustafson, 1985a: p. 88, fig. 8; Morejohn and Dailey, 2004: p. 10; Wheatley and Ruez, 2006.

Cervidae. McDonald et al., 1996: p. 43; Currie, 1998: p. 53; Webb, 1998: p. 509.

Identification of HAFO Material

Odocoileus is a medium-sized deer with large dichotomously branching antlers (Webb, 1998) that form a continuous curving surface (sensu Gustafson, 1985a).

Distribution

There are numerous fossils of *Odocoileus* in the Pleistocene, but Pliocene records are relatively rare and are not identified typically to species (Webb, 1998; Wheatley and Ruez, 2006). Other Pliocene records of *Odocoileus* sp. in the Pacific Northwest include specimens from Taunton (Morgan and Morgan, 1995) and Three Mile East (Sankey, 2002).

Remarks on Taxonomy

A single Pliocene species of *Odocoileus*, *Odocoileus brachyodontus*, was recognized by Webb (1998) and Mead and Taylor (2004), but the diagnostic features were shown to be duplicated in modern samples of both *Odocoileus hemionus* and *O. virginianus* (Wheatley and Ruez, 2006).

Comments on HAFO Material

Cervid material was recovered early in the excavations at HAFO, but unfortunately species-level identification has remained elusive. An M3 from HAFO matches that tooth in the type specimen of *Odocoileus brachyodontus*, but based on the variation in *Bretzia* (Gustafson, 1978, 1985a; contra Hearst, 1999) and modern *Odocoileus* (Wheatley and Ruez, 2006), dentition cannot be reliably identified more specifically than Odocoileini. An antler allows for identification of the cervid from HAFO as *Odocoileus* sp., however, it does show slight differences when compared to both *Odocoileus hemionus* and *Odocoileus virginianus* (Gustafson, 1985a).

Camelidae Gray, 1821

Hemiauchenia Gervais and Ameghino, 1880

Hemiauchenia blancoensis (Meade, 1945)

Camelid, possibly *Procamelus* sp. or *Tanupolama* sp. Gazin, 1936: pp. 285, 288; Hibbard, 1941c: p. 87.

Procamelus? or *Tanupolama*?. J. Schultz, 1937: p. 85.

Tanupolama sp. Hibbard, 1972b: p. 129.

Hemiauchenia blancoensis or *Hemiauchenia macrocephala*. Franz, 1981: p. 29.

Hemiauchenia sp. McDonald et al., 1996: pp. 32, 42; Currie, 1998: p. 53; Honey et al., 1998: p. 454.

Identification of HAFO Material

This material is identified as a lamine based on the presence of anteroexternal stylids (lama buttresses) on the lower molars, recurved and laterally compressed canines, slender rostrum, procumbent mandibular symphyseal region, and fused metapodials; identification to *Hemiauchenia* is based on the absence of I1-2, presence of P2 and p2, reduced C1, less hypsodont cheekteeth than other lamines except *Palaeolama*, weakly expressed anteroexternal stylids on the lower molars, long and slender legs, and proximal phalanx with W-shaped suspensory ligament scar not extending onto shaft (Honey et al., 1998). Additional details separating *Hemiauchenia* and *Palaeolama* are discussed by Webb (1974b), Webb and Stehli (1995), and Ruez (2005). *Hemiauchenia blancoensis* is larger than all other species of *Hemiauchenia*, and further differs from *Hemiauchenia macrocephala* in having laterally compressed p4s and upper molars with more strongly developed styles (Webb, 1974b). Cheek tooth height of *Hemiauchenia blancoensis* is intermediate between the more brachydont *Hemiauchenia vera* and the more hypsodont *Hemiauchenia macrocephala* (Webb, 1974b).

Distribution

Hemiauchenia blancoensis is restricted to the Blancan and is known from Anita (Morgan and White, 2005), Blanco (Meade, 1945), Broadwater (Breyer, 1977), Cita Canyon (G. Schultz, 1977b; Hibbard, 1970), Keefe Canyon (Hibbard and Riggs, 1949), Gilliland (Hibbard and Dalquest, 1962, 1966), Los Lunas (Morgan and Lucas, 1999), Macasphalt Shell Pits (Morgan and Ridgway, 1987; Morgan and Hulbert, 1995; Morgan, 2005), Pearson Mesa (Morgan and White, 2005), Rancho Viejo (Jimenez-Hidalgo and Carranza-Casta eda [sic], 2002), Rexroad Locality 3 (Hibbard, 1970), San Simon (Morgan and White, 2005), Santa Fe River 1 (Morgan and Hulbert, 1995), Tonuco Mountain (Morgan et al., 1998), and UTEP 97 (Harris, 1993).

Lehigh Acres produced material reported as *Hemiauchenia blancoensis*? (Feranec, 2003), and *Hemiauchenia* cf. *Hemiauchenia blancoensis* occurs at Buckeye Creek (Kelly, 1994), Buckhorn (Tedford, 1981; Morgan et al., 1997), El Golfo (Shaw, 1981; Lindsay, 1984), Taunton (Morgan and Morgan, 1995), and White Rock (Eshelman, 1975).

Remarks on Taxonomy

Webb (1974b) considered *Hemiauchenia seymourensis* a valid species, but most subsequent authors have followed Breyer (1977) in considering it a junior synonym of *Hemiauchenia blancoensis* because purported diagnostic characters separating the two resulted from individual variation. This variation was later the basis for considering both *Hemiauchenia seymourensis* and *Hemiauchenia blancoensis* as conspecific with *Hemiauchenia macrocephala* (Dalquest and Schultz, 1992). This trend of combining species of *Hemiauchenia* was reversed with the identification of *Hemiauchenia seymourensis* from the Leisey Shell Pit, Bermont Formation, Florida (Webb and Stehli, 1995). The Leisey *Hemiauchenia*, however, does not fit the description of *Hemiauchenia seymourensis* as being "as large as *Hemiauchenia blancoensis*" (Webb, 1974b:201). Measurements of the lower dentition of *Hemiauchenia* from Leisey (Webb and Stehli, 1995:tab. 4) do not approach the size of topotypic material of *Hemiauchenia blancoensis* (personal observation; Breyer, 1977:tab. 2). The Leisey *Hemiauchenia* lower dentition is more similar to the smaller dimensions of the type of *Hemiauchenia macrocephala*, and in 15 of 19 specimens is actually smaller than the holotype. Other references to the Leisey fauna have recognized the *Hemiauchenia* as *Hemiauchenia macrocephala* (e.g., Morgan and Hulbert, 1995; Ruez, 2001; Meachen and Hallman, 2002; but see also Feranec, 2003).

Hemiauchenia blancoensis as used here includes the "*Hemiauchenia seymourensis*" from Gilliland (Webb, 1974b), but not the "*Hemiauchenia seymourensis*" from Leisey (Webb and Stehli, 1995). *Hemiauchenia blancoensis* is retained as distinct from *Hemiauchenia macrocephala* because of the substantial difference in size (Webb, 1974b; Breyer, 1977; Honey et al., 1998).

Comments on HAFO Material

Postcranial elements of *Hemiauchenia blancoensis* from HAFO are larger than those from Blanco, but the material from HAFO is limited.

Hemiauchenia gracilis Meachen, 2005

Identification of HAFO Material

Identification to *Hemiauchenia* follows that given above for *Hemiauchenia blancoensis*. This new species differs from other *Hemiauchenia* in being smaller and having more gracile limbs.

Distribution

The recently named *Hemiauchenia gracilis* was described based on material from De Soto Shell Pit, Inglis 1A, Inglis 1F, Santa Fe River 1, and Waccasassa River 9A (Meachen, 2005). At that time a specimen from 111 Ranch was suggested as also belonging to *Hemiauchenia gracilis*. Material from Anza-Borrego Desert State Park was said in the same paper both to represent an undescribed small species of *Hemiauchenia* (Webb, 2006:297) and also to be *Hemiauchenia gracilis* (Webb, 2006:fig. 17.10). Webb's manuscript was in preparation at the same time as Meachen's (2005) description of *Hemiauchenia gracilis*, and it appears that Webb (2006) was incompletely updated. Other records of a small *Hemiauchenia* are known from New Mexico at Arroyo de la Parida, Buckhorn, Cuchillo Negro Creek, Isleta, Mesas Mojinas, Tonuco Mountain, and Virden (Lucas and Morgan, 2001b; Morgan and Lucas, 2003), and Ranch Viejo (Jimenez-Hidalgo and Carranza-Castañeda, 2006). All records that may pertain to this small species of *Hemiauchenia* are Blancan in age, except for Hemphillian specimens from Mexico.

Comments on HAFO Material

A significant difference in size easily separates this small *Hemiauchenia* from *Hemiauchenia blancoensis*. Figure 4.8 shows the difference in one of the most abundant elements at HAFO for both species, the proximal phalanx.

Figure 4.8. Proximal phalanges of two species of *Hemiauchenia* from HAFO. *Hemiauchenia blancoensis*: A, IMNH 69003/34475; B, IMNH 70041/34481. *Hemiauchenia gracilis*: C, 70057/34479; D, 80011/5316.

Camelops Leidy, 1854

Camelops sp.

Camelid, possibly *Camelops arenarum* Hay. Gazin, 1936: p. 285, 288; Hibbard, 1941c: p. 87.

Camelops?. J. Schultz, 1937: p. 85.

Camelops sp. Hibbard, 1958b: p. 21; McDonald et al., 1996: pp. 32, 42; Currie, 1998: p. 53; Honey et al., 1998: p. 455; Thompson and White, 2004: p. 54.

Camelops sp. (large). Hibbard, 1972b: p. 129; Kurtén and Anderson, 1980: p.304.

Camelops kansanus [sic] or *Megatylopus*. Franz, 1981: p. 29 (in part?).

Identification of HAFO Material

This camelid material is referable to Lamini by the characters listed above for *Hemiauchenia blancoensis*. Assignment to *Camelops* is based on body size much larger than *Hemiauchenia*, robust and shortened metapodials, and proximal phalanx (Figure 4.9) with raised suspensory ligament scar that extends almost to the center of the diaphysis (Voorhies and Corner, 1986; Honey et al., 1998).

Distribution

Fossils referable to *Camelops* are known from a large number of late Cenozoic sites in North America (e.g., Honey et al., 1998). Pliocene records of *Camelops* are expecially abundant in Arizona (e.g., Johnson et al., 1975; Lindsay and Tessman, 1984; Galusha et al., 1984) and the central Great Plains (e.g., Hibbard,

Figure 4.9. Anterior view of a proximal phalanx of *Camelops*, HAFO 1038.

1970; Voorhies and Corner, 1986), but specimens are known as far south as central Mexico (Lindsay, 1984; Carranza-Castañeda et al., 1998) and as far north as South Dakota (Johnson and Milburn, 1984) and Idaho. In the Pliocene of Idaho, *Camelops* is known from Tyson Ranch (Sankey, 1991, 2002) and Birch Creek (Hearst, 1999)

Remarks on Taxonomy

Although *Camelops* is abundant in Pliocene deposits, most material from that epoch is not identified to species (Honey et al., 1998). *Camelops traviswhitei* and *Camelops hesternus* are the two species of *Camelops* recognized in the Pliocene (Honey et al., 1998).

Megatylopus Matthew and Cook, 1909

Megatylopus sp.

Megatylopus sp. Hibbard, 1972b: p. 129; Kurtén and Anderson, 1980: p. 302; McDonald et al., 1996: pp. 32, 42; Currie, 1998: p. 52; Honey et al., 1998: p. 456.

Titanotylopus sp. Conrad, 1980: pp. 156-157.

Camelops kansanus [sic] or *Megatylopus*. Franz, 1981: p. 29 (in part?).

Comments on HAFO Material

Although *Megatylopus* has appeared in several fauna lists of the HAFO Pliocene mammals, none of these studies described or otherwise discussed any specimens referable to that taxon. Continent-wide reviews of Megatylopus also have not included any material from HAFO (Harrison, 1985; Honey et al., 1998). I have not seen any specimens of *Megatylopus* from HAFO, however, study of this material is in progress elsewhere (pers. comm., M. Thompson, 2007).

Proboscidea Illiger, 1811

Mammutidae Hay, 1922

Mammut Blumenbach, 1799

Mammut americanum Kerr, 1792

Mastodont sp. Gazin, 1936: pp. 285, 288; J. Schultz, 1937: p. 85; Hibbard, 1941c: p. 87.

Mammut sp. Hibbard, 1972b: p. 129; Gustafson, 1978: p. 43.

Mammut americanum (Kerr). Kurtén and Anderson, 1980: p. 344; Franz, 1981: p. 30; McDonald et al., 1996: p. 43; Saunders, 1996: pp. 275, 278; Currie, 1998: p. 52; Lambert and Shoshani, 1998: p. 610.

Identification of HAFO Material

The HAFO proboscidean is referable to *Mammut* based on the zygodont and subhypsodont cheekteeth with transversely elongated cones, but lacking accessory conules (Lambert and Shoshani, 1998). *Mammut americanum* differs from *Mammut raki* in having a relatively wider and shorter m3 (Frick, 1933). I am unaware of any features that confidently distinguish *Mammut americanum* from the older *M. matthewi*, however, the latter was retained as a valid species by Saunders (1996) and Lambert and Shoshani (1998).

Distribution

Mammut americanum is known in the Pliocene at Fish Springs Flat (Kelly, 1994), White Bluffs (Gustafson, 1978), Santa Fe River 1 (Webb, 1974a), Saw Rock Canyon (as *Pliomastodon adamsi* in Hibbard, 1944; synonymized with *Mammut americanum* by Saunders, 1996), and Keefe Canyon (Hibbard and Riggs, 1949). *Mammut americanum* persisted until the late Pleistocene and was abundant and widespread in the Pleistocene (Lambert and Shoshani, 1998).

Remarks on Taxonomy

An early species of *Mammut*, *Mammut matthewi*, was described from the late Hemphillian Johnson Member of the Snake Creek Formation, Nebraska (Skinner et al., 1977). Frick (1933) described *Mammut raki* from a mandible collected from deposits most likely from the Palomas Formation (Lucas and Morgan, 1999), however, this species may not actually be distinct from *Mammut americanum* (Lucas, 1987).

Comments on HAFO Material (Figure 4.10)

The identity of the proboscidean stratigraphically higher in the Glenns Ferry Formation than HAFO is unclear. Material from Grand View was described as *Mammut* sp. (Shotwell, 1970), and subsequently as *Mammut americanum* (Kurtén and Anderson, 1980), whereas Conrad (1980) and Hearst (1999) only recognized *Stegomastodon*, and not *Mammut*, in the upper portion of the Glenns Ferry Formation.

Of the characteristic Blancan species first appearing in the Blancan and persisting into the Irvingtonian (after Bell et al., 2004) only *Mammut americanum* occurs at HAFO. *Mammut americanum* was also listed in Bell et al. (2004) as first occurring in late Blancan faunas that were previously recognized as early Irvingtonian. This is incorrect, because *Mammut americanum* is known from localities, including the Hagerman faunas, which significantly precede the latest Blancan (sensu Bell et al., 2004). The earliest *Mammut americanum* is from the early Blancan White Bluffs (Saunders, 1996; Lambert and Shoshani, 1998). *Mammut* sp. is also known from pre-Blancan sites (Hibbard et al., 1965), including abundant material in the Clarendonian and Hemphillian (Lambert and Shoshani, 1998).

Figure 4.10. Partial tooth of *Mammut americanum*, HAFO 979.

DISCUSSION

Although particular specimens from HAFO have greatly contributed to our knowledge of Pliocene mammals, this is the first attempt to evaluate the status of every mammalian species at HAFO. The result is a faunal list different from that used by all previous workers. *Hemiauchenia gracilis* and *Baiomys minimus* are here reported for the first time from HAFO, and the presence of *Miracinonyx inexpectatus* is supported. I was unable to identify some other taxa previously reported from HAFO, including *Megatylopus* and a tremarctine bear. The report of *Neotragoceros* from HAFO (White and Morgan, 2005) is a typographical error (pers. comm., R. White, 2006). Other changes to the faunal list provided in Table 4.1 reflect updated taxonomy.

Collection of fossils at HAFO continues, and there is always the possibility of adding additional taxa to the Pliocene fauna of the area. During the portion of the Blancan represented at HAFO, *Bassariscus casei* occurs in California, Kansas, and Texas, and possibly in Washington (Morgan and Morgan, 1995), but is unknown in Idaho. The much more widespread *Nannippus peninsulatus* spans nearly the entire Blancan (Bell et al., 2004), but also does not occur at HAFO. In this case, however, the location of HAFO may preclude recovery of this otherwise abundant taxon; I am not aware of any specimens of *N. peninsulatus* north of Meade County, Kansas. Some other common Blancan taxa not occurring at HAFO are represented by taxonomically and/or ecologically similar species. Instead of *Dipoides rexroadensis*, *Borophagus diversidens*, *Stegomastodon mirificus*, and *Platygonus bicalcaratus*, HAFO contains *Procastoroides intermedius*, *Borophagus hilli*, *Mammut americanum*, and *Platygonus pearcei* respectively. Likewise, the widespread *Ogmodontomys* is not present at HAFO, but the closely related *Cosomys primus* and *Ophiomys taylori* are.

The continued field work by the National Park Service at HAFO results in discovery of additional specimens every year and is accompanied by careful documention of the locality data for these discoveries. Such work may reveal additional taxa in the mammalian fauna from the Glenns Ferry Formation at HAFO and will certainly create new opportunities for more detailed analyses in the future.

CHAPTER 5. STRATIGRAPHIC CHANGES IN THE CARNIVORAN ASSEMBLAGE FROM HAGERMAN FOSSIL BEDS NATIONAL MONUMENT, IDAHO

ABSTRACT

At least 16 carnivoran taxa occur in the Pliocene Glenns Ferry Formation at Hagerman Fossil Beds National Monument (HAFO), Idaho. This assemblage was examined for stratigraphic changes in species distribution, specimen abundance, and species diversity. Three relatively common mustelids, *Trigonictis cookii*, *Trigonictis macrodon*, and *Mustela rexroadensis*, occur at most stratigraphic levels, but are absent during an interval coinciding with the coolest time segment at HAFO. It is within this gap that two less-common mustelids, *Ferinestrix vorax* and *Buisnictis breviramus*, first appear at HAFO; they persist up-section with the more common mustelids listed above. Specimens of *Borophagus hilli* are restricted to the warm intervals at HAFO, irrespective of the relative abundance of surface water. The other canid at HAFO, *Canis lepophagus*, is more abundant during the dry intervals at HAFO, regardless of the estimated paleotemperature. Most remarkable is the recovery of many taxa impacted by abrupt climate change, although a notable change

is the much higher relative abundance of carnivoran species following a return to warm temperatures.

INTRODUCTION

Hagerman Fossil Beds National Monument (HAFO) in southern Idaho (Figure 5.1) is internationally significant because it is one of the richest sources of Pliocene vertebrates. Hundreds of localities within the exposed beds of the Glenns Ferry Formation have produced many thousands of fossil mammals housed at museums across the United States (Chapter 4). These localities range in age from about 4.2 to 3.1 Ma (Chapter 2). This is the first in a series of chapters that document the stratigraphic distribution of fossil mammals at HAFO. Comparisons are here made with the estimated paleoclimate during the Pliocene represented in the Glenns Ferry Formation; additional analyses will follow.

There are at least 54 species of mammals at HAFO, including 16 species of carnivorans (Chapter 4). Eight species of carnivorans were named on holotypes from HAFO; of these, six are still valid. Publication on these specimens began in the 1930s (Gazin, 1933b, 1934, 1937), but comprehensive description of the carnivorans from HAFO was completed much later (Bjork, 1970). The taxonomy of these species is reviewed elsewhere with a discussion on their geographic distribution (Chapter 4).

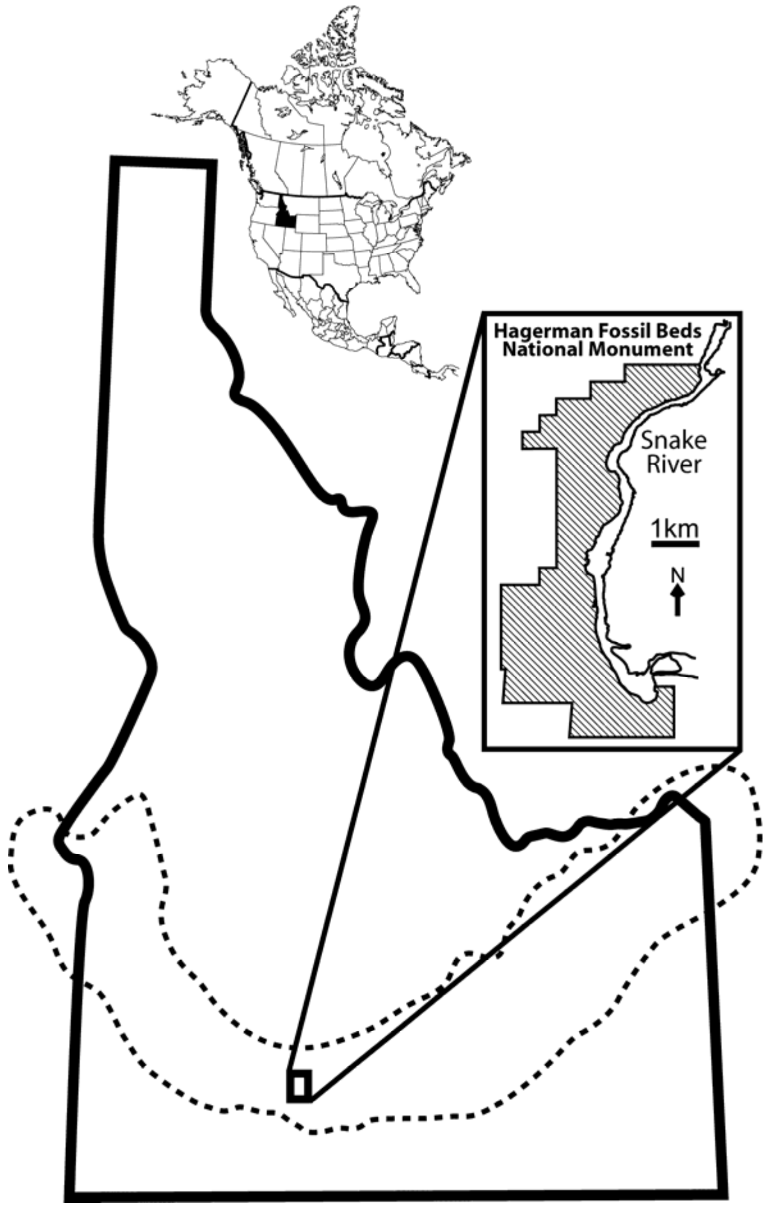


Figure 5.1. Location of Hagerman Fossil Beds National Monument within Idaho. The dotted line outlines the Snake River Plain-Yellowstone Plateau (sensu Leeman, 1982), but excludes the Owyhee Plateau in southwestern Idaho. The inset map shows the boundaries of HAFO to the west of the Snake River.

MATERIALS AND METHODS

In spite of the species-level diversity, the number of specimens referable to carnivorans is low; only 361 fossils were recognized during the preparation of this manuscript. Only specimens with well-established locality data were included in this study. Additionally, only specimens that could be identified to species, or as *Taxidea* sp. or *Homotherium* sp. were used. The 256 specimens used here are listed in Appendix C.

Although minimum number of individuals (MNI) commonly preferred in analysis of abundance in a fauna (e.g., Lyman, 1994), it is not an empirical observational unit like the number of identifiable specimens (NISP). The MNI must be calculated from the NISP, and the method involved can include various criteria (Klein and Cruz-Uribe, 1984). In the case of a single locality with abundant fossils, comparisons of MNI instead of NISP can give significantly different results. However, at HAFO there are hundreds of localities, so the MNI would have to be calculated for each locality because it is unlikely that different localities will contain specimens from the same individual. Because the ratio of localities to specimens is so high, about two-to-one, and no localities are especially abundant with carnivorans, the MNI and NISP of carnivorans at HAFO are similar. Bjork (1970) examined 196 carnivoran fossils, but calculated an MNI of 173. Use of NISP instead of MNI has little impact on the results.

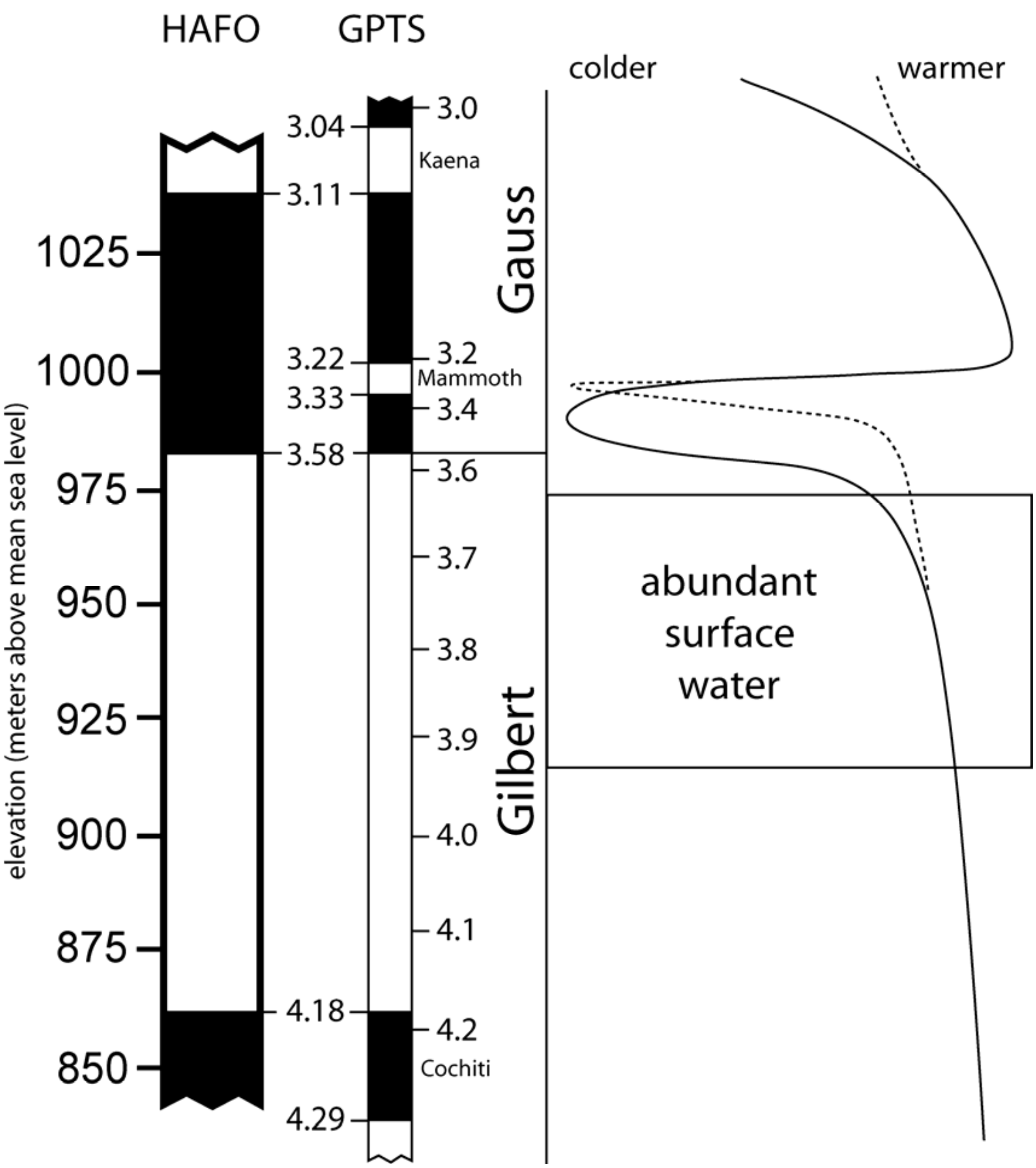
Paleoecological interpretations for HAFO (Figure 5.2) follow Chapter 3. Stratigraphic distribution of specimens is based on placement on the Hagerman Horse Quarry (HHQ) datum (sensu Chapter 2) of the collecting localities from which they were recovered. This facilitates comparison of sites across HAFO. Specimen and species abundances were plotted at 1-m intervals with a sliding window of 20 m for the stratigraphic span encompassing the majority of localities at HAFO: 900 to 1005 m on the HHQ datum, or about 4.0 to 3.2 Ma. By using a sliding window some detail may be lost, but the pattern will more accurately reflect overall trends and not be as subject to distorting spikes from particularly fossiliferous localities. Further, the sliding window acknowledges that there is difficulty in placing some localities stratigraphically.

Institutional abbreviations: HAFO, Hagerman Fossil Beds National Monument; IMNH, Idaho Museum of Natural History; UMMP, University of Michigan Museum of Paleontology; USNM, United States National Museum.

RESULTS

Three mustelids, *Trigonictis cookii*, *Trigonictis macrodon*, and *Satherium piscinarium* have stratigraphic ranges of more than 100 m at HAFO; a fourth, *Mustela rexroadensis*, spans almost 90 m (Figure 5.3). The ranges for three of these long-persisting taxa, *Trigonictis cookii*, *Mustela rexroadensis*, and *Trigonictis macrodon*, contain large gaps coinciding with the transition from an interval of

Figure 5.2. Pliocene paleoecological interpretations at HAFO. The temperature trend is adjusted to the chronology of deposits at HAFO (Chapter 2). The solid line indicates the temperature pattern exhibited by data generated from microfossil abundance; the dashed line illustrates where the isotopic data deviate (Chapter 3). Note that although the elevations are at a constant interval, the scale changes on the GPTS (after Berggren et al., 1995). Dates are in Ma.


HAFO
GPTS
colder
warmer
3.04
3.0
Kaena
3.11
Gauss
1025
3.22
3.2
1000
Mammoth
3.33
3.4
elevation (meters above mean sea level)
3.58
3.6
975
3.7
950
abundant
surface
water
3.8
925
3.9
Gilbert
900
4.0
875
4.1
4.18
4.2
850
Cochiti
4.29

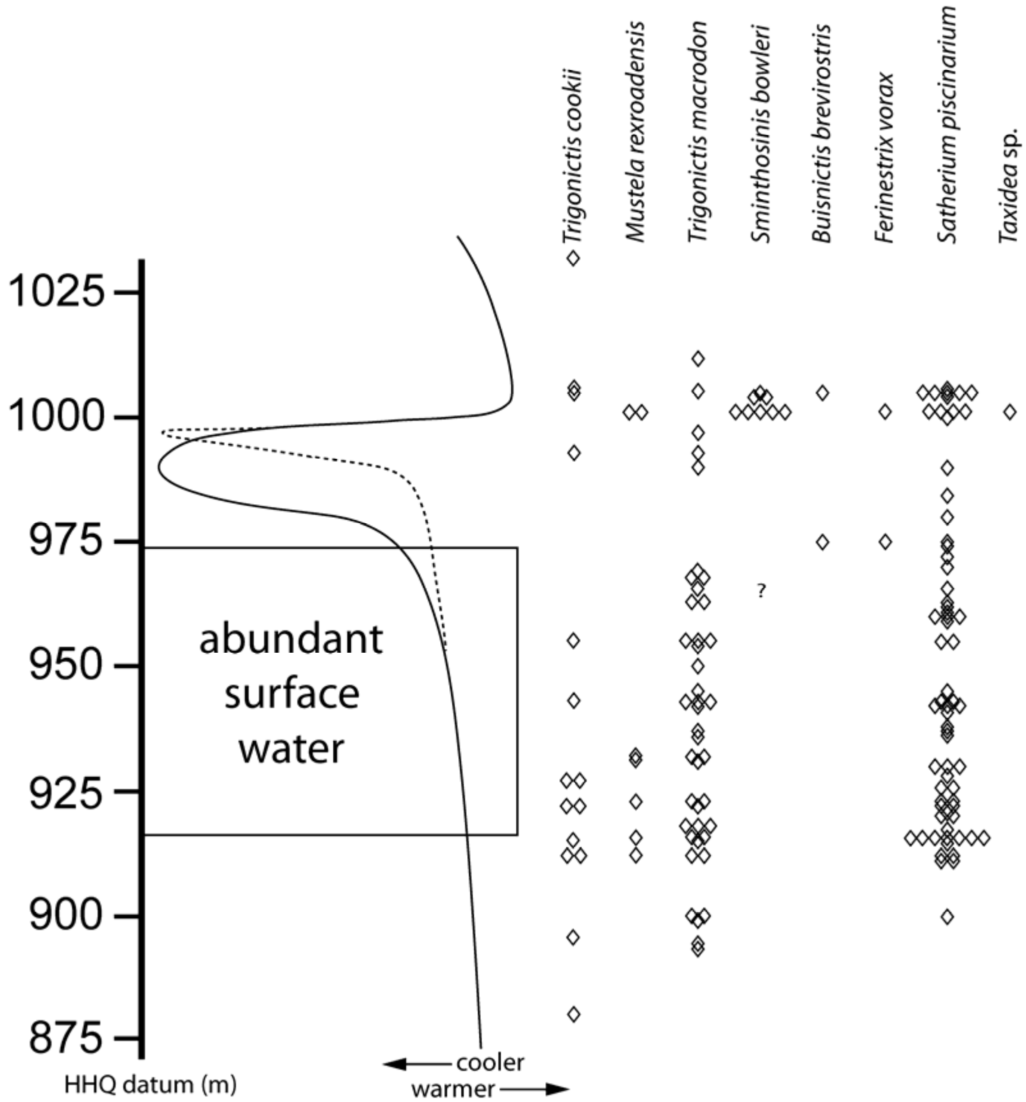


Figure 5.3. Distribution of mustelids at HAFO. Stratigraphic levels and paleoecologic data follow Figure 5.2. Each specimen is indicated with a diamond. The question mark under *Sminthosinis bowleri* indicates a specimen referred to that species by Bjork (1970), but here considered an indeterminate mustelid.

abundant surface water to one lacking surface water. That interval also is marked by dramatic cooling. The most abundant mustelid, *Satherium piscinarium*, does not exhibit such a significant gap, but the number of specimens of this species is reduced within that interval. It is within that interval that two other mustelids, *Buisnictis breviramus* and *Ferinestrix vorax*, first appear at HAFO.

Sminthosinis bowleri and *Taxidea* sp. first appear at the end of an abrupt warming at HAFO. Another specimen of *Sminthosinis bowleri* from about 35 m lower in the Glenns Ferry Formation was identified previously (Bjork, 1970), but this edentulous partial maxilla (UMMP 51681) is here considered undiagnostic to the species level because it is also similar in size and morphology to *Trigonictis cookii*. That specimen does not have any characters allowing for referral to either *Sminthosinis bowleri* or *Trigonictis cookii*.

Two large felids, *Megantereon hesperus* and *Homotherium* sp., are known from only two specimens with precise stratigraphic data; the single fossil representing *Miracinonyx inexpectatus* (USNM 12613) also lacks specific locality data. Two small felids, *Puma lacustris* and *Lynx rexroadensis*, are known from HAFO, but they are extremely similar in skeletal morphology. Most elements of these species can not be distinguished, and unfortunately the ones that have diagnostic characters do not have associated stratigraphic data. Therefore, these two cats are plotted together in Figure 5.4.

The large carnivorans (canids, ursids, felids) known from multiple specimens with stratigraphic data all have a long temporal range at HAFO. *Canis lepophagus*

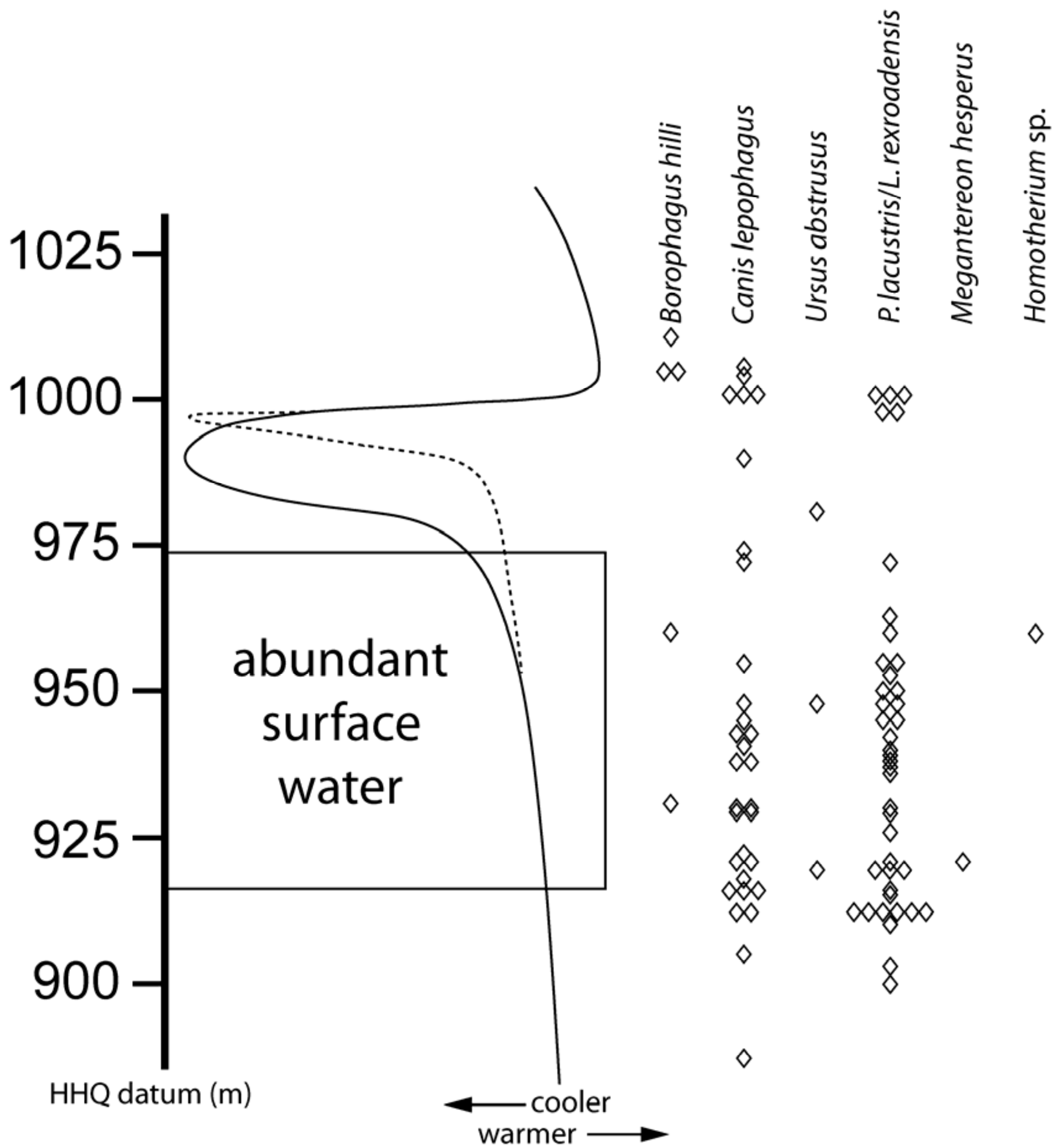


Figure 5.4. Distribution of large carnivorans (canids, ursids, and felids) at HAFO. Stratigraphic levels and paleoecologic data follow Figure 5.2. Each specimen is indicated with a diamond.

and *Puma lacustris*/*Lynx rexroadensis* have ranges of more than 100 m. Even rare species such as *Borophagus hilli*, known from only five fossils with precise field data, and *Ursus abstrusus*, known from only three specimens, have stratigraphic distributions of 80 and 62 m respectively.

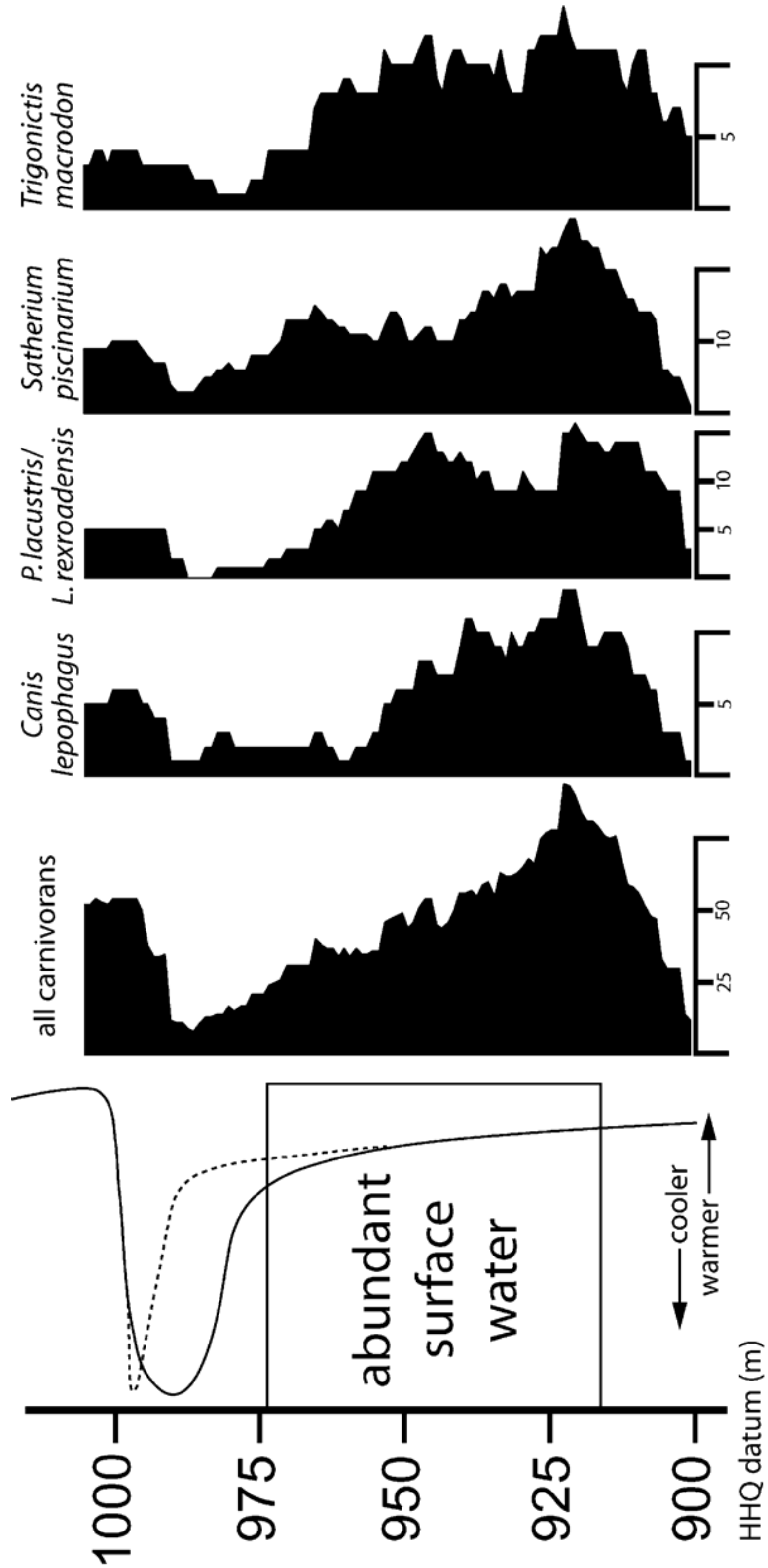
As in the case of some mustelids, two large carnivorans have gaps in their record that correspond to the end of abundant surface water and the beginning of pronounced cooling. There is a 26-m gap in the distribution of *Puma lacustris*/*Lynx rexroadensis.* A 45-m gap occurs in the range of the specimens of *Borophagus hilli*, but as mentioned above, that species is known from few fossils at HAFO. The range of *Canis lepophagus* does not include this significant gap, but localities within the cool interval only produced a single specimen.

The records of *Ursus abstrusus* occur in intervals both with and without abundant surface water, but all are known prior to the abrupt cooling event at HAFO. The specimens of *Megantereon hesperus* and *Homotherium* sp. occur during warm periods of abundant surface water.

The specimen abundance of the four most abundant taxa were examined and compared to the pattern of all carnivorans combined (Figure 5.5). Overall, the pattern for each species is similar to that for all carnivorans combined. This pattern, in turn, corresponds closely to the temperature trend at HAFO.

The specimen abundances for *Canis lepophagus* and *Puma lacustris*/*Lynx rexroadensis* decrease during the interval of slow climatic cooling. The patterns for *Satherium piscinarium* and *Trigonictis macrodon* show a delayed response, more

Figure 5.5. Specimen abundance of the four most abundant carnivoran species at HAFO, compared to data for all carnivorans and paleoecological interpretations. Specimen abundances were plotted at 1-m intervals with a sliding window of 20 m for the stratigraphic span encompassing the majority of localities at HAFO: 900 to 1005 m on the HHQ datum, or about 4.0 to 3.2 Ma.


all carnivorans
25
50
Canis lepophagus
5
P. lacustris/ L. rexroadensis
5
10
Satherium piscinarium
10
Trigonictis macrodon
5
abundant surface water
cooler
warmer
1000
975
950
925
900
HHQ datum (m)

closely matching the end of abundant surface water and onset of rapid temperature decrease. The abundance of *Puma lacustris*/*Lynx rexroadensis* is also decreased low in the stratigraphic section, near the bottom of the interval of abundant surface water.

The number of carnivoran species is relatively constant throughout most of the HAFO section, until the very top of the section (Figure 5.6). The pattern is similar, but more pronounced, when the number of carnivoran species is plotted as a proportion of all mammalian species. Both the absolute and relative abundance of carnivoran species have a positive correlation with the estimated temperature trend.

CONCLUSIONS

Beginning at about the 975-m stratigraphic level there is a faunal change at HAFO that coincides with the end of abundant surface water and a decrease in temperature. Three small mustelids, *Trigonictis cookii*, *Trigonictis macrodon*, and *Mustela rexroadensis*, are replaced by two new mustelids making their first appearance at HAFO. Mustelids reach their peak diversity at the warm, dry interval around 1000 m, whereas the diversity of large carnivorans is highest lower in the section, during an interval of abundant surface water.

Among the abundant carnivorans, the specimen abundance of *Canis lepophagus* begins a sharp decline with an increasing rate of cooling at 950 m; the distribution of this species is seemingly unaffected by the presence or absence of abundant surface water. Likewise, *Puma lacustris*/*Lynx rexroadensis* shows

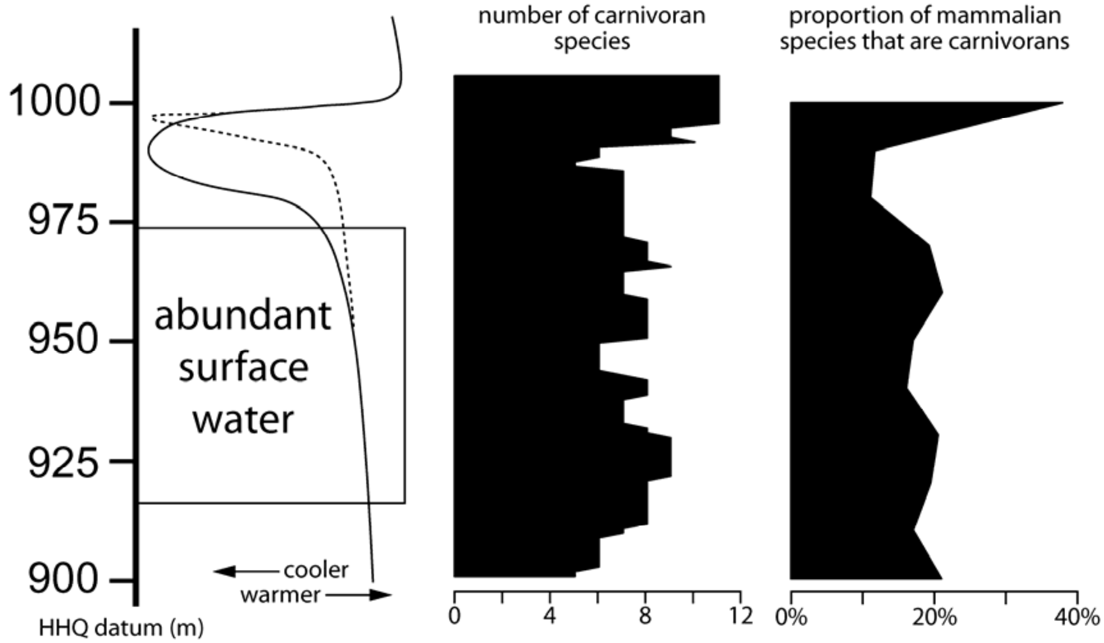


Figure 5.6. Species abundance at HAFO. Carnivoran species abundances were plotted at 1-m intervals with a sliding window of 20 m for the stratigraphic span encompassing the majority of localities at HAFO: 900 to 1005 m on the HHQ datum, or about 4.0 to 3.2 Ma. The relative abundance of carnivorans was plotted at 10-m intervals with the same 20-m sliding window.

reducing abundance of specimens before the end of the wet interval, and additionally has reduced numbers of specimens low in the section with abundant surface water. The abundance of *Trigonictis macrodon* does not decrease markedly until the end of the wet interval, where it actually increases through the continued cooling. The distribution of *Trigonictis macrodon* is here suggested as more dependent on the presence of surface water/moisture than temperature. The abundance of *Satherium piscinarium* appears linked to both temperature and surface moisture. The number of specimens decreases at the end of the wet intervel, as in *Trigonictis macrodon*, but continues to decrease, matching the temperature curve.

Correlation of specimen and species abundance with estimated temperature at HAFO is not the result of a lack of fossiliferous localities in the cool interval (Chapter 2). In modern environments warmer temperatures and wetter environments are correlated with increased carnivoran species diversity and higher numbers of individuals (Waide et al., 1999); some Quaternary faunas also seem to follow this trend (e.g., Dayan, 1994). Species richness in the carnivoran assemblage from HAFO is relatively constant through intervals of varying temperature and levels of aridity, until the sharp increase in temperature near the top of the section where the assemblage becomes more speciose. Study of Pliocene and Pleistocene carnivorans from east Africa documents the highest species diversity during an interval from 3.3 to 3.0 Ma (Werdelin and Lewis, 2005); that range corresponds to the age of the sediments containing the spike of carnivoran richness at HAFO.

Although the productivity of localities throughout HAFO will vary, calculating the relative abundance of carnivoran species as a proportion of all mammalian species adjusts for this difference. The lowest proportion of carnivorans occurred in the dry cool interval, and the highest occurred with the rapid return to warm temperatures. Analysis of Pleistocene mammalian faunas from Italy also showed decreased predator/prey ratios with cooler temperatures (Palombo et al., 2005), however, unlike HAFO the ratios in the Italian faunas result from increase herbivore richness during cold times (Mussi and Palombo, 2005). In contrast to those studies, the proportion of carnivorans in the mammalian fauna of Hayonim Cave in Israel is at both the highest and the lowest during cold intervals (Dayan, 1994). This disparity of results suggests that the correlation of temperature and relative abundance of carnivorans at HAFO may not be the result of impacts on carnivorans, but on other aspects of the faunas.

The changes documented here for HAFO primarily occur in association with the end of abundant surface water and onset of rapid cooling. Even though this interval persisted for about 300 ky until the return of warm temperatures, the carnivoran assemblage proved resilient, at least in part. At least five species were present early at HAFO, disappeared during the rapid cooling, and reappeared afterwards. Specimen abundance also rebounded with the return to warmer temperatures. Three large carnivorans did not reappear after the rapid cooling, but they are known from only a few total specimens.

The carnivoran assemblage at HAFO did differ following the interval of rapid change. In particular the mustelid diversity greatly increased. For the earliest ~600 ky, there were only four mustelid species represented at HAFO; once the temperature had warmed again, eight species of mustelids occur. This increase is not merely a result of increased overall mammalian diversity at HAFO, because the relative abundance of carnivoran species is double that of earlier times at HAFO. Unfortunately, the distribution of localities does not allow the determination of whether these ecological changes persisted long-term or were a brief response to the rapid warming. There are few deposits of Glenns Ferry Formation at HAFO that are stratigraphically higher than the rapid warming event.

CHAPTER 6. STRATIGRAPHIC CHANGES IN THE INSECTIVORAN ASSEMBLAGE FROM HAGERMAN FOSSIL BEDS NATIONAL MONUMENT, IDAHO

ABSTRACT

The stratigraphic distributions of the six species of insectivorans at Hagerman Fossil Beds National Monument (HAFO), Idaho, span 111 m, but there is a 25 m gap in this range. This gap coincides with the end of abundant surface water and a rapid cooling event. Only half of the insectivoran species reappear after a return to warm temperatures. Those that do not reappear may have distributions more controlled by moisture than temperature. Morphological trends in *Paracryptotis gidleyi* indicate a slight shortening of molar lengths coinciding with slow cooling. That this change is connected to temperature is further suggested by the longer molar lengths with the return to warm temperatures at HAFO.

INTRODUCTION

Hagerman Fossil Beds National Monument (HAFO) in southern Idaho (Figure 6.1) is internationally significant because it is one of the richest sources of Pliocene vertebrates (McDonald et al., 1996). Hundreds of localities within the exposed beds of the Glenns Ferry Formation have yielded many thousands of fossil mammals housed at museums across the United States (Chapter 4). These localities range in age from about 4.2 to 3.1 Ma (Chapter 2). This chapter is one in a series documenting the stratigraphic distribution of fossil mammals at HAFO and comparing them to the estimated paleoclimate during the portion of the Pliocene represented.

There are at least 54 species of mammals at HAFO, including six species of insectivorans (Chapter 4). The holotypes of five species of insectivorans, all still valid, are from HAFO. Two of these insectivorans, *Sorex hagermanensis* and *Scapanus hagermanensis*, are known only from fossils from HAFO. Shrews were long known to occur in the deposits at HAFO (Gazin, 1933a), but were not studied closely until almost four decades later (Hibbard and Bjork, 1971; Hutchison, 1987). The taxonomy of these species is reviewed elsewhere with a discussion on their geographic distribution (Chapter 4).

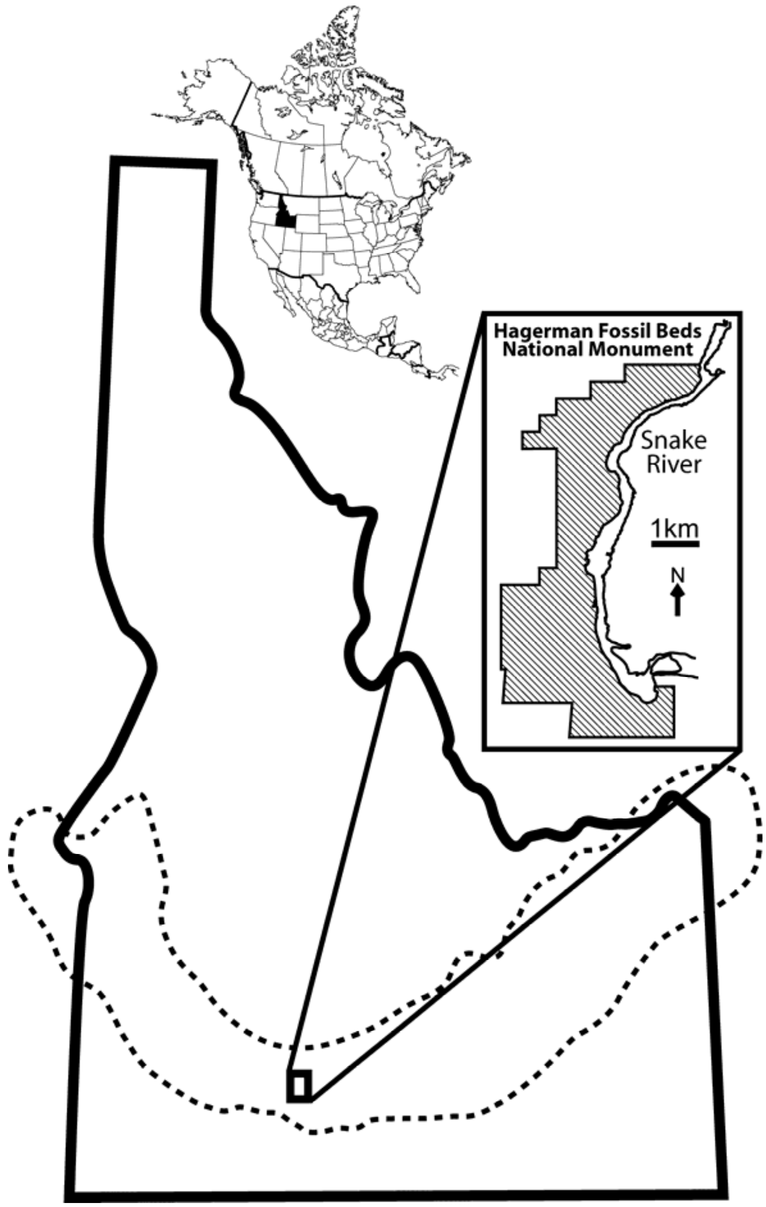


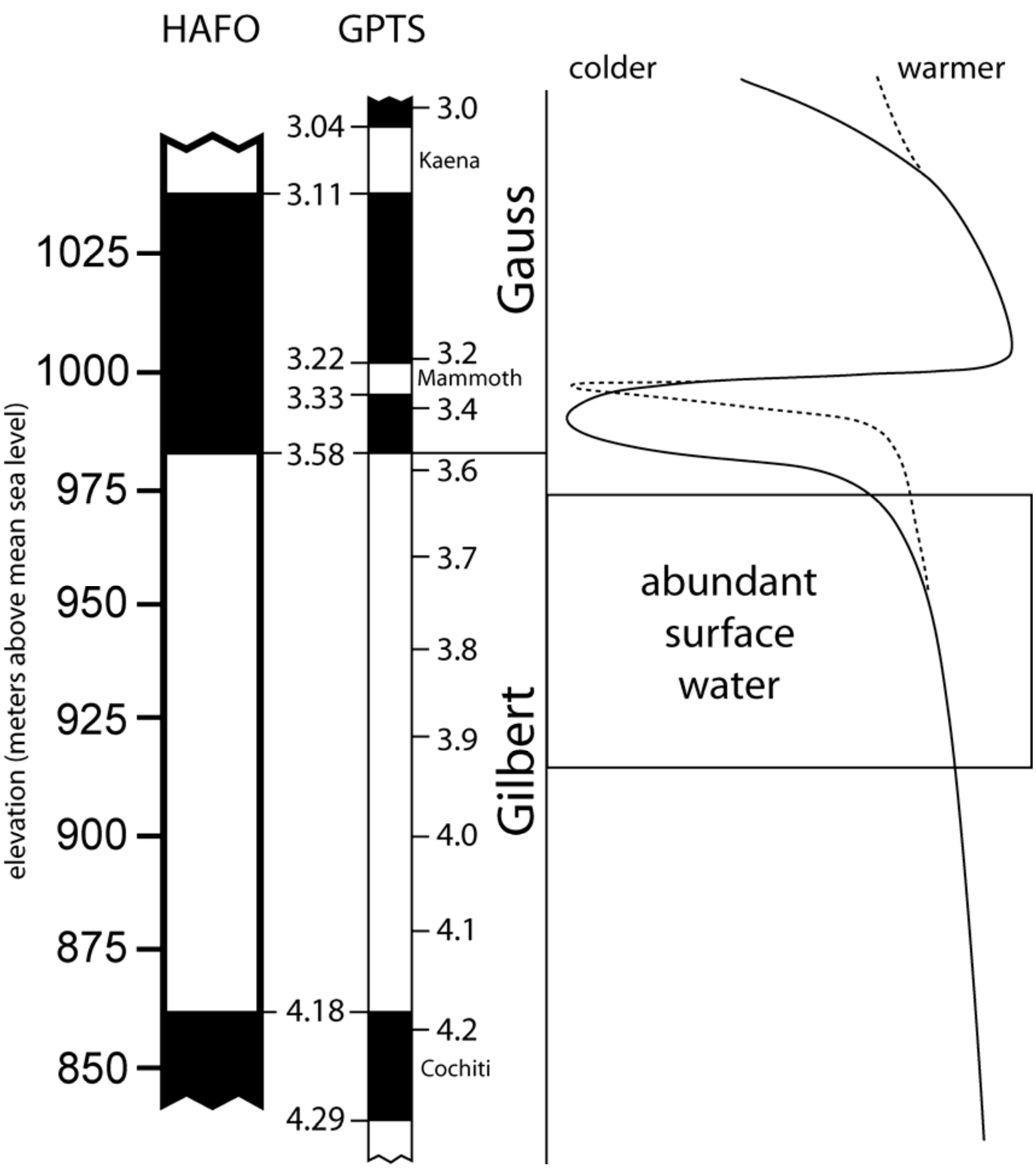
Figure 6.1. Location of Hagerman Fossil Beds National Monument within Idaho. The dotted line outlines the Snake River Plain-Yellowstone Plateau (sensu Leeman, 1982), but excludes the Owyhee Plateau in southwestern Idaho. The inset map shows the boundaries of HAFO to the west of the Snake River.

MATERIALS AND METHODS

In addition to insectivoran material previously recorded (Gazin, 1933a; Hibbard and Bjork, 1971; Hutchison, 1987), 89 more recently collected specimens (Appendix D) were included in this analysis. The greatest length and width of the molars was measured to the nearest 0.01 mm with dial calipers following the method of Selänne (2003). Institutional abbreviations: HAFO, Hagerman Fossil Beds National Monument; IMNH, Idaho Museum of Natural History; UMMP, University of Michigan Museum of Paleontology; USNM, United States National Museum.

Paleoecological interpretations for HAFO (Figure 6.2) follow Chapter 3. To facilitate comparison of sites across HAFO, stratigraphic distribution is based on placement of the locality on the Hagerman Horse Quarry (HHQ) datum (sensu Chapter 2). Molar lengths for *Paracryptotis gidleyi* were plotted in 5-m increments with a sliding window of 20 m for all intervals with at least three measurable specimens. By using a sliding window some detail may be lost, but the pattern will more accurately reflect overall trends and not be as subject to distorting spikes from particularly fossiliferous localities. Further, the sliding window acknowledges that there is difficulty in accurately placing some localities stratigraphically.

Figure 6.2. Pliocene paleoecology at HAFO. The temperature trend is adjusted to the chronology of the deposits at HAFO (Chapter 2). The solid line indicates the temperature pattern exhibited by data generated from microfossil abundance; the dashed line illustrates where the isotopic data deviate (Chapter 3). Note that although the elevations are in constant increments, the scale changes on the global polarity time scale (GPTS; after Berggren et al., 1995). Dates are in Ma.


HAFO
GPTS
colder
warmer
3.0
3.04
Kaena
3.11
Gauss
1025
1000
3.22
3.2
Mammoth
3.33
3.4
3.58
3.6
975
3.7
950
abundant surface water
3.8
925
3.9
Gilbert
elevation (meters above mean sea level)
900
4.0
4.1
875
4.18
4.2
850
Cochiti
4.29

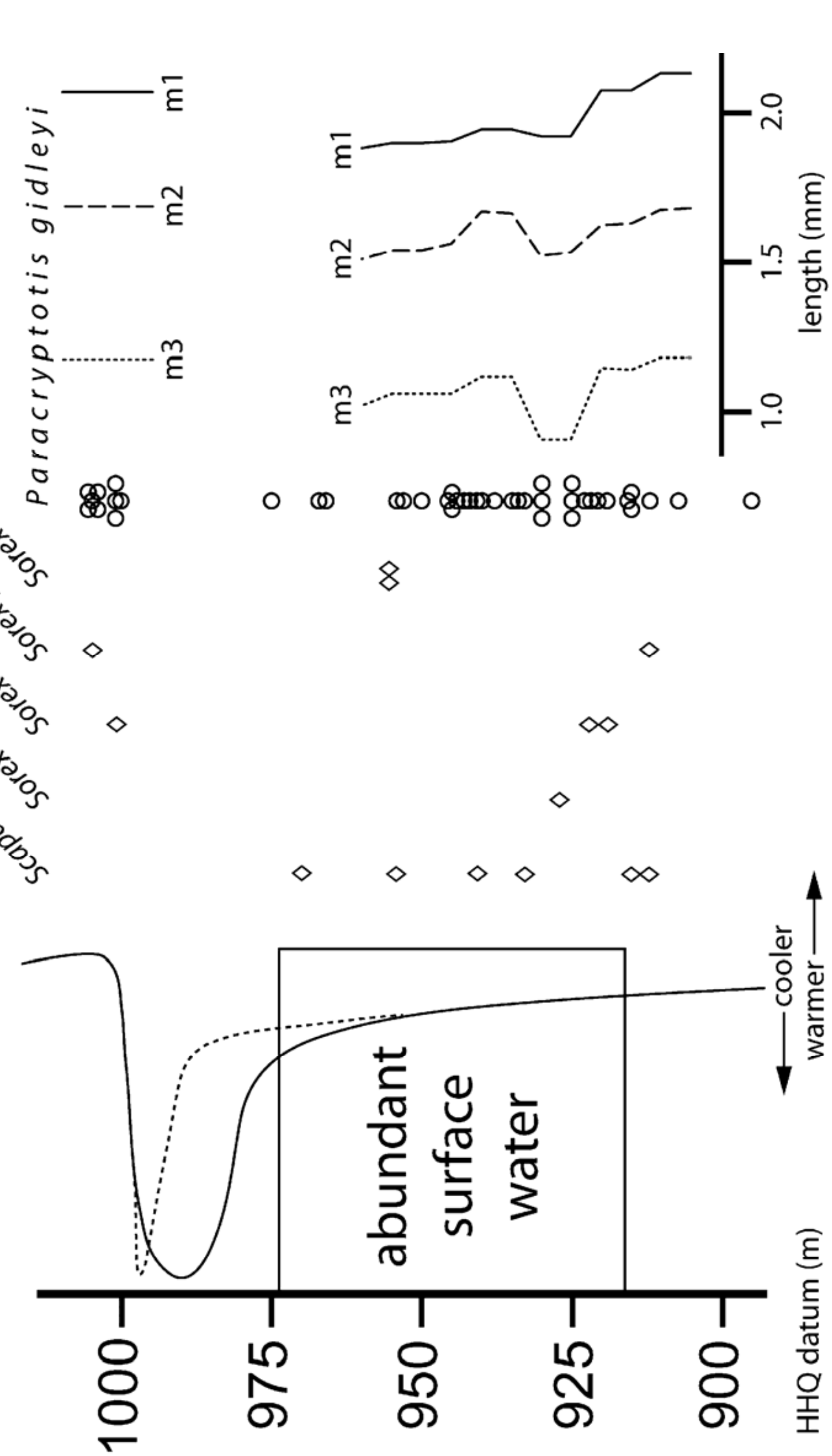
RESULTS

The single talpid from HAFO, *Scapanus hagermanensis*, has a stratigraphic range of 58 m (Figure 6.3), coinciding almost exactly with the interval of abundant surface water. Specimens of all species of *Sorex* are rare at HAFO. *Sorex hagermanensis* and *Sorex* cf. *Sorex rexroadensis* only occur in the warm interval with abundant surface water, but *Sorex meltoni* is widespread, occurring both in warm periods with and without abundant surface water, and *Sorex powersi* only occurs during warm dry intervals.

Paracryptotis gidleyi is by far the most abundant insectivoran at HAFO. The number of localities with *Paracryptotis gidleyi* rather than the number of specimens is plotted to simplify Figure 6.3. Localities with this soricid have a stratigraphic range of 111 m, but there is a significant gap coinciding with the cool interval at HAFO that occurs after the end of the period of abundant surface water.

Because of the abundance of specimens of *Paracryptotis gidleyi*, stratigraphic changes in the dimensions of the lower molars can be examined (Figure 6.3). In the lower portion of the Glenns Ferry Formation at HAFO, there is a slight trend toward decreasing tooth lengths upsection. This trend is interrupted most notably in the m3 lengths from 925-930 m on the HHQ datum. With the return to warm temperatures high in the section at HAFO, the longer molar lengths are revisited.

Figure 6.3. Distribution of insectivorans at HAFO. Stratigraphic levels and paleoecological data follow Figure 6.2. Each specimen is indicated with a diamond. For *Paracryptotis gidleyi*, localities are plotted instead and are marked by circles.


1000
975
950
925
900
HHQ datum (m)
abundant surface water
cooler
warmer
Scapanus hagermanensis
Sorex hagermanensis
Sorex meltoni
Sorex powersi
Sorex cf. S. rexroadensis
Paracryptotis gidleyi
m3
m2
m1
1.0
1.5
2.0
length (mm)

DISCUSSION

The gap in the stratigraphic distribution of insectivorans at HAFO corresponds to the end of abundant surface water and the onset of rapid cooling. With the return to warm temperatures at HAFO, three of the five soricids (*Sorex meltoni*, *Sorex powersi*, and *Paracryptotis gidleyi*) reappear, suggesting that their distribution is controlled, in this case, by changes in temperature and not the presence of abundant surface water. In the extreme case, the return to a warm interval at HAFO is marked by the reappearance of *Sorex powersi* after a hiatus of ~750,000 years. This demonstrates a remarkable ability of this assemblage to overcome the impacts of long-term climate change.

The resilience of the insectivoran assemblage at HAFO is demonstrated not only by the return of some soricid taxa following rapid environmental change, but also by the morphological trends. Molar lengths of *Paracryptotis gidleyi* shorten during the slow decrease in temperature, but after the return to a warm interval the molar lengths are again long. Alternatively, the reduced molar lengths could be correlated with the presence of abundant surface water. The lengths of the m3s vary more, both in absolute and relative terms, than the other lower molars. The m3 length was used previously as an important character in species-level systematics of fossil and modern soricines (Repenning, 1967), but it is unclear to what degree intraspecific variation was observed and whether it would affect proposed relationships.

Determining whether morphological change is ecophenotypic variation or genetic evolution is extremely difficult in the fossil record (Benton and Pearson, 2001). The strongest documentation of ecophenotypic variation requires molecular data from both recent and fossil organisms (e.g., Hadly et al., 1998; Hewitt, 2004). Because molar lengths of *Paracryptotis gidleyi* at HAFO mirror the trend in temperature, this is likely an example of ecophenotypic variation. This trend of smaller molars, and therefore presumedly smaller body mass, with reduced temperatures conflicts with the well-known Bergmann's rule which states that populations in colder areas tend to be larger than populations of the same species that live in warmer climates (Mayr, 1963). However, most of the species of modern soricines which have been examined in light of Bergmann's rule actually exhibit smaller body mass in colder areas (Mezhzherin, 1964; Braun and Kennedy, 1983; Ochocińska and Taylor, 2003; Yom-Tov and Yom-Tov, 2005; contra Huggins and Kennedy, 1989). Bergmann's rule holds true for most species of mammals, and most that do not, exhibit no significant variation in body mass due to environmental temperature (Ashton et al., 2000). Modern Soricinae follow the inverse of Bergmann's rule, and, based on *Paracryptotis gidleyi* at HAFO, this group has done so since the Pliocene. Unfortunately, the other insectivorans at HAFO are not sufficiently abundant to examine for morphological responses to climate change.

In contrast to the above discussion on faunal resilience, there are some notable changes in the insectivoran assemblage following the cool period at HAFO. The talpid, *Scapanus hagermanensis*, and two soricids, *Sorex hagermanensis* and

Sorex cf. *Sorex rexroadensis*, do not reappear with the return to warm temperatures. It is unclear if this implies that the distribution of these taxa is controlled by surface moisture, if they were unable to return to the altered HAFO ecosystem, or if the taxa became extinct. No new insectivorans arrived in the HAFO fauna high in the stratigraphic section to replace these taxa.

CONCLUSIONS

The stratigraphic distribution of fossil insectivorans at HAFO seems to be controlled by a combination of temperature and surface moisture, but it is unclear which of the climatic factors, if either, is the driving force. *Scapanus hagermanensis* has a distribution that closely matches the interval of abundant surface water. However, the highest occurrence of *Scapanus hagermanensis* is also near the rapid decrease in temperature. That species does not reappear at HAFO after the return to warm temperatures, but it could be extinct rather than just extirpated. There are no records of *Scapanus hagermanensis* outside of HAFO to help clarify the situation.

The distribution of the four species of *Sorex* at HAFO appears to be tied to warm conditions, possibly with *Sorex* cf. *Sorex rexroadensis* ecologically replacing the other three near the middle of the stratigraphic section. The paucity of specimens of *Sorex*, precludes any more definitive statements, however, the distribution of the abundant *Paracryptotis gidleyi* is more clearly connected to temperature. The change in lower molar lengths of *Paracryptotis gidleyi* matches changes in both surface moisture and temperature, but based on modern body-size patterns of modern soricines, the morphometric shift at HAFO is more likely connected to temperatures.

CHAPTER 7. STRATIGRAPHIC CHANGES IN THE LEPORID ASSEMBLAGE FROM HAGERMAN FOSSIL BEDS NATIONAL MONUMENT, IDAHO

ABSTRACT

The fossil leporid assemblage at Hagerman Fossil Beds National Monument (HAFO) is comprised of three extinct species that span about 100 m of exposed Glenns Ferry Formation deposits. During this nearly one million-year interval there is evidence for a pronounced cooling period and subsequent warmth. Response of the leporids to these climatic events is reflected in their diversity, abundance, and dimensions of the lower third premolar (p3). None of the three leporids are present during the coolest interval at HAFO, but all reappear after a long hiatus. This reappearance coincides with a return to warm conditions at HAFO, and is additionally marked by a change in the relative abundance of the leporid taxa. All three species exhibit a longer p3 after the hiatus, which suggests that individuals returning to the HAFO area had a larger body size.

INTRODUCTION

Hagerman Fossil Beds National Monument (HAFO) in southern Idaho (Figure 7.1) is internationally significant because it is one of the richest sources of Pliocene vertebrates (McDonald et al., 1996). Many thousands of fossil mammals from the hundreds of localities within the exposed beds of the Glenns Ferry Formation are housed at museums across the United States (Chapter 4). These localities range in age from about 4.2 to 3.1 Ma (Chapter 2). This manuscript is one in a series in which I examine the stratigraphic distribution of fossil mammals at HAFO and makes comparisons of distribution data to the estimated paleoclimate.

There are at least 54 species of mammals at HAFO, including three species of leporids (Chapter 4). Early study of the mammals from HAFO resulted in the naming of two species of leporids, *Hypolagus limnetus* and *Alilepus vagus* (Gazin, 1934a). Subsequently, *H. limnetus* was judged to be a junior synonym of *Hypolagus edensis*, and material from HAFO was used to erect the new species *Hypolagus gidleyi* (White, 1987). The taxonomy of these species is reviewed elsewhere with a discussion on their geographic distribution (Chapter 4). The deposits at HAFO are especially important for the study of fossil leporids because it is one of the few places globally that contain associated cranial and postcranial elements (Campbell, 1969). Unfortunately, even at HAFO most leporid fossils are recovered as isolated elements.

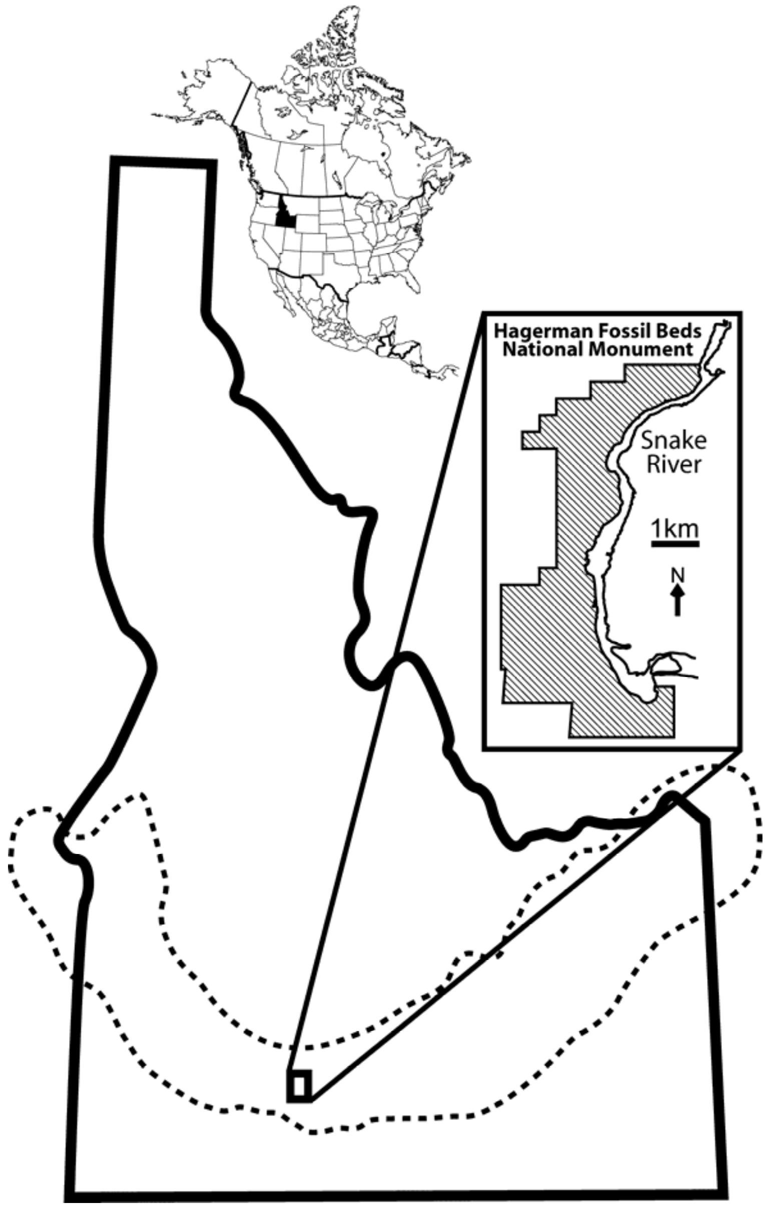


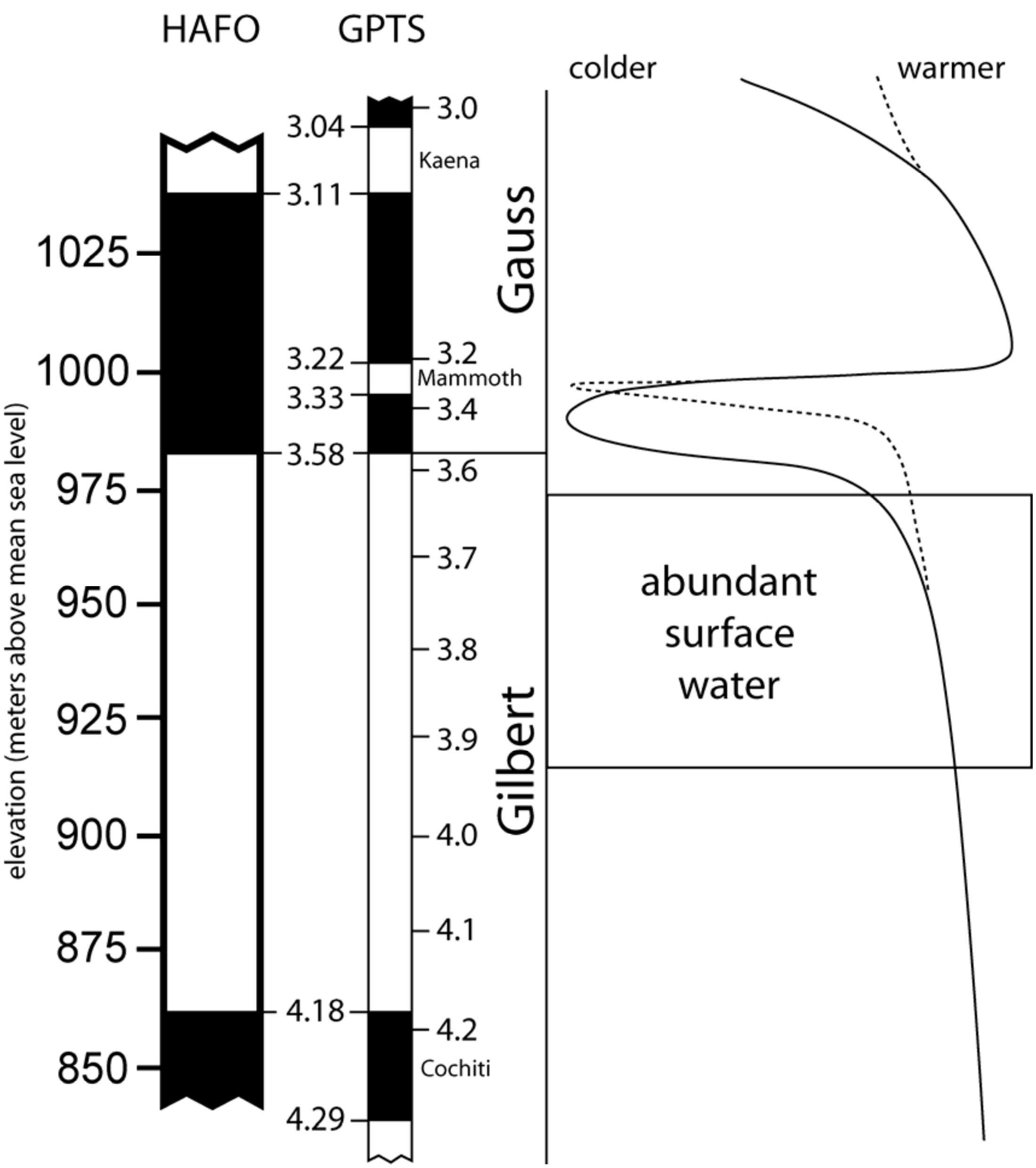
Figure 7.1. Location of Hagerman Fossil Beds National Monument within Idaho. The dotted line outlines the Snake River Plain-Yellowstone Plateau (sensu Leeman, 1982), but excludes the Owyhee Plateau in southwestern Idaho. The inset map shows the boundaries of HAFO to the west of the Snake River.

MATERIALS AND METHODS

In addition to leporid material previously recorded (Gazin, 1934a; Campbell, 1969; Hibbard, 1969; White, 1987, 1991), 498 more recently collected specimens (Appendix F) were included in this analysis. Institutional abbreviations: HAFO, Hagerman Fossil Beds National Monument; IMNH, Idaho Museum of Natural History; UMMP, University of Michigan Museum of Paleontology; USNM, United States National Museum. Not all fossils have associated locality data; specimens with problematic provenience were not included in this analysis. Additionally, many elements can not be diagnosed to the species level; these were excluded from species-level analyses and discussion. Some leporid specimens were catalogued by lot (Appendix F); the actual number of specimens is used in this chapter unless the material was collected in articulation. Measurement of the third lower premolars (Appendix G) followed the methodology of White (1987).

Specimen abundance was plotted at 1-m intervals with a sliding window of 20 m for the stratigraphic span encompassing the majority of localities at HAFO: 900 to 1005 m on the Hagerman Horse Quarry (HHQ) datum, or about 4.0 to 3.2 Ma. By using a sliding window some detail may be lost, but the pattern will more accurately reflect overall trends and not be as subject to distorting spikes from particularly fossiliferous localities. Further, the sliding window acknowledges that there is difficulty in placing some localities stratigraphically.

Figure 7.2. Pliocene paleoecology at HAFO. The temperature trend is adjusted to the chronology of deposits at HAFO (Chapter 2). The solid line indicates the temperature pattern exhibited by data generated from microfossil abundance; the dashed line illustrates where the isotopic data deviate (Chapter 3). Note that although the elevations are at a constant interval, the scale changes on the GPTS (after Berggren et al., 1995). Dates are in Ma.



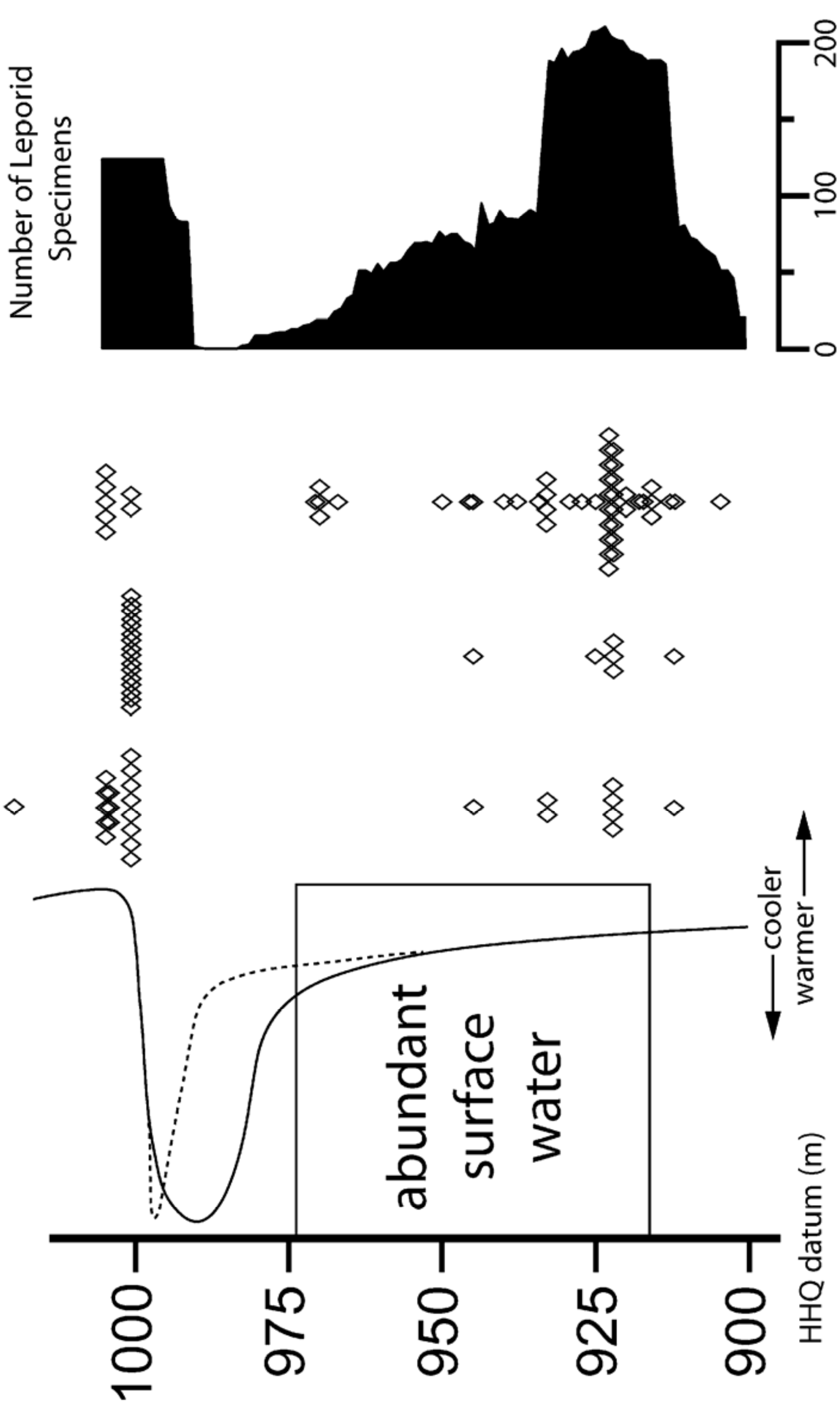
HAFO
GPTS
colder
warmer
3.04
3.0
Kaena
3.11
1025
Gauss
3.22
3.2
1000
Mammoth
3.33
3.4
3.58
975
3.6
3.7
950
abundant
surface
water
3.8
925
3.9
Gilbert
900
4.0
elevation (meters above mean sea level)
875
4.1
4.18
4.2
850
Cochiti
4.29

Paleoecological interpretations for HAFO (Figure 7.2) follow Chapter 3. Stratigraphic distribution of specimens is based on position on the HHQ datum (sensu Chapter 2) of the localities from which they were recorded. This facilitates comparison of sites across HAFO.

RESULTS

Alilepus vagus, *Hypolagus edensis*, and *Hypolagus gidleyi* each have long stratigraphic ranges within the Glenns Ferry Formation at HAFO (108 m, 89 m, and 101 m respectively; Figure 7.3). All three species first appear below the interval of abundant surface water and have their youngest occurrences near the top of the Glenns Ferry Formation at HAFO, after the return to warm temperatures. Low in the Glenns Ferry Formation, *Hypolagus gidleyi* is more than twice as abundant as the other two leporids combined. Stratigraphically higher in the section, both *Alilepus vagus* and *Hypolagus edensis* become numerically dominant and are each represented by more than twice the number of specimens as is *Hypolagus gidleyi*. All three leporids have a large gap in their stratigraphic distribution at HAFO. Both *Alilepus vagus* and *Hypolagus edensis* are absent at HAFO between 945 m and 1001 m on the HHQ datum, a duration of about 0.5 Ma. Specimens of *Hypolagus gidleyi* are rare during that interval with only five fossils, and none occur between 971 m and 1001 m. Because most postcranial elements examined are not assigned to a particular species, Figure 7.3 also shows the distribution of all specimens identified

Figure 7.3. Distribution of leporids at HAFO. Stratigraphic levels and paleoecological data follow Figure 7.2. Each specimen is indicated with a diamond. Number of specimens is plotted in 1-m increments as a sliding 20-m window.



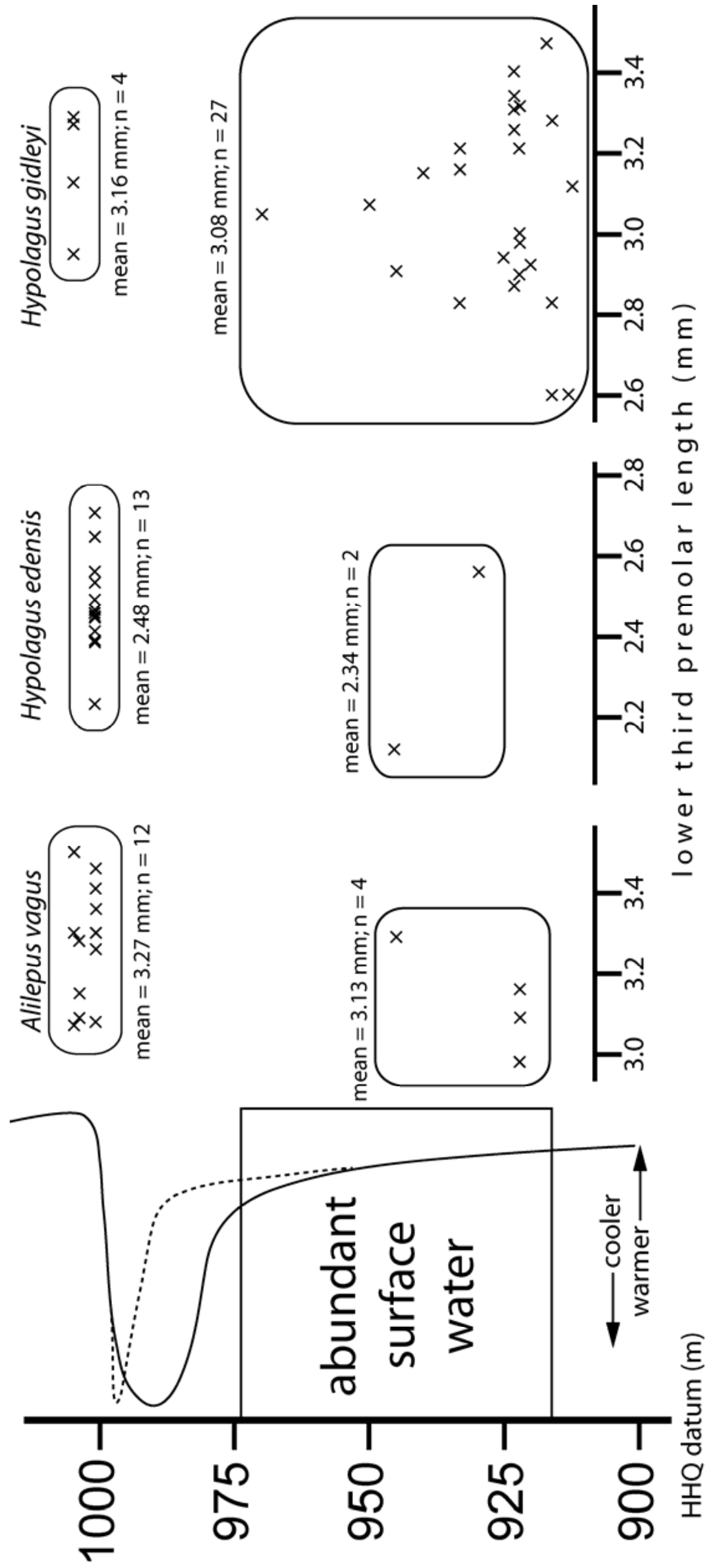
Alilepus vagus
Hypolagus edensis
Hypolagus gidleyi
Number of Leporid Specimens
0
100
200
abundant surface water
cooler
warmer
1000
975
950
925
900
HHQ datum (m)

taxonomically to Leporidae or to any lower taxonomic level. During the coldest interval at HAFO there is a complete absence of leporid fossils, not just an absence of specimens identified at the species level.

Documentation of morphometric change of the HAFO leporids with climate must be considered more tenuous because of the relatively few specimens referred to *Alilepus vagus* and *Hypolagus edensis* stratigraphically below the hiatus and *Hypolagus gidleyi* above the hiatus. When each species is divided into two groups (before and after the coolest interval), all three leporids have longer p3s after their reappearance at HAFO (Fig. 7.4). *Alilepus vagus*, *Hypolagus edensis*, and *Hypolagus gidleyi* exhibit increases of 4.5%, 6.0%, and 3.6 % respectively. None of these changes are significant, however, at 95% confidence levels using a two-tailed heteroscedastic t-test; P-values for *Alilepus vagus*, *Hypolagus edensis*, and *Hypolagus gidleyi* are 0.119, 0.643, and 0.433.

Tooth-length is among the most commonly used ways to estimate body size for extinct mammals (Damuth and MacFadden, 1990). Because the p3 of fossil leporids at HAFO is the element most confidently assigned to species, this tooth can be used as a proxy for body size of these extinct species. Dimensions of isolated teeth were shown to accurately predict the body size of the European rabbit *Oryctolagus cuniculus* (Calzada et al., 2003). Using the equation generated for the p3 and the average of the tooth dimensions given in Appendix G, the most common leporid at HAFO, *Hypolagus gidleyi*, is estimated at 1236 g before the stratigraphic hiatus and 1801 g afterwards. The equations of Calzada et al. (2003) were generated

Figure 7.4. Lower third premolar lengths of leporids from HAFO plotted against paleoclimatic interpretation.


Alilepus vagus
mean = 3.27 mm; n = 12
mean = 3.13 mm; n = 4
Hypolagus edensis
mean = 2.48 mm; n = 13
mean = 2.34 mm; n = 2
Hypolagus gidleyi
mean = 3.16 mm; n = 4
mean = 3.08 mm; n = 27
lower third premolar length (mm)
abundant surface water
cooler
warmer
HHQ datum (m)
1000
975
950
925
900

with individuals from a single population, so these estimates for *Hypolagus gidleyi* may certainly be incorrect. However, given the conservative nature of leporid morphology (both extant and fossils), the estimates are useful in illustrating how small changes in tooth dimensions may indicate large changes in body size.

DISCUSSION AND CONCLUSIONS

Leporid diversity and abundance declined to zero with the transition into the interval of cooler temperature. The resilience of the HAFO leporids is marked by the reappearance of all three species despite a lengthy hiatus. The relative abundances did change after the stratigraphic gap; *Hypolagus gidleyi* was the most abundant species before the cool interval and the least common afterwards. The abundance of all leporid specimens closely matches the temperature pattern (more abundant during times of warmer temperatures); this is also seen in studies of modern leporids (Andersen, 1952; Meriggi and Alieri, 1989; Nyenhuis, 1995; contra Smith et al., 2005).

All three of the leporids showed an increased body size with their reappearance at HAFO. It is unclear, however, whether this increase can be attributed to climate change. Studies of modern leporids in North America differ in showing correlation of larger body size with cooler average temperatures (Orr, 1940; Baker et al., 1978), showing no correlation (McNab, 1971), or only showing correlation within particular regions (Olcott and Barry, 2000). Alternatively, leporid body size may be better tied to rates of precipitation (Kronfeld and Shkolnik, 1996) or complex interactions of multiple climatic variables (Nagorsen, 1985). Given the large degree of intraspecific variation in body size of modern North American leporids (e.g., Nelson, 1909), the increase in body size of the HAFO leporids may possibly not be attributed to climate change.

CHAPTER 8. PALEOECOLOGICAL INTERPRETATIONS FROM MODERN ECOREGIONS: MAMMALIAN SPECIES DIVERSITY

"In examining things present, we have data from which to reason with regard to what has been; and, from what has actually been, we have data for concluding with regard to that which is to happen hereafter." (Hutton, 1788:217)

ABSTRACT

Correlations between taxonomic diversity of modern mammals and climatic variables were established using datasets generated from ecoregion maps. Predictive equations from the statistically significant correlations were used to estimate temperature and precipitation values for the Blancan (Pliocene) mammals in the Glenns Ferry Formation of Hagerman Fossil Beds National Monument, Idaho. The estimated climatic variables were then compared to independent assessments. Temperature patterns based on fossil mammals matched external evidence, however, precipitation estimates differed greatly. The ability of these predictive equations to produce reliable estimates apprears to be more dependent on the diversity of the

particular group of mammals being examined than on the correlation coefficients of the equations.

INTRODUCTION

Approaches to reconstructing paleoecology should, when possible, be documented in the modern biota. A biological extension of the geological axiom ‘the present is the key to the past’ implies that rigorous examination of modern environments can estimate paleoecological conditions. Failure of a proposed model within this current, relatively well-known, slice of evolutionary time should preclude its application to past environmental reconstruction. In reality, paleoecological models are rarely tested rigorously in modern ecosystems before they are applied to fossil ecosystems.

Even when based on modern observations, methods of reconstructing paleonenvironments using fossil mammals vary greatly in their approach, and, in some cases, interpretations may be based on as little as a single species in a paleofauna. Interpretations based on the presence of a single fossil species are problematic because climatic restrictions of a species can change over time, the species may be extinct, there may be a taphonomic bias for or against presenvation, or the occurrence may be an aberration. Therefore, preference should be given to methods of paleoenvironmental reconstruction that use multiple species delimited at higher grouping levels, either taxonomic clades or ecologic grades. This relies on more basic fauna-climate connections and reduces the impact of any single species.

Using relative abundances of taxa within a vertebrate fossil assemblage, as done for amphibians and reptiles (Meylan, 1982, 1995) avoids reliance on only one, or a few, species. Although Meylan used a quantitative analysis to give a qualitative interpretation of paleoecology, his method could be modified to produce quantitative estimates. Unfortunately, this method is hampered by uncertainties and variances in life-spans, fecundity rates, and home range of extinct taxa.

The rigorous quantification of climatic parameters and species diversity in select groups of rodents served as the model for the approach used in this chapter. Previous authors established correlations between the diversity of arvicolines, murines, and sigmodontines with temperature and/or precipitation in modern biotas, and applied this correlation to fossil faunas (Montuire, 1996; Michaux et al., 1997; Montuire et al., 1997; Aguilar et al., 1999; Legendre et al., 2005). The equations generated from those studies provide quantitative estimates of climatic values. In this chapter I extend the work done on those groups of rodents to all terrestrial mammals in the United States and Canada. I generated predictive equations with the species-level diversity of numerous arrangements of phylogenetic clades and ecological grades. In this manner, quantitative estimates can be made based on many different groupings of mammals. Species-level diversity was chosen to avoid the problems mentioned above regarding the use of relative abundances. Only the more speciose groups were chosen for analysis to avoid making large differences in ecological interpretations based on only one or a few species.

The previous works correlating diversity of arvicolines, murines, and sigmodontines with climate (Montuire, 1996; Michaux et al., 1997; Montuire et al., 1997; Aguilar et al., 1999; Legendre et al., 2005) used numerous modern faunas to establish the relationships. However, the modern localities were not selected systematically. That is, there was no attempt to avoid including multiple localities within a larger homogenous region, or to explicitly include localities to encompass as much ecological disparity as possible. Therefore the correlation statistics generated from those datasets could have inflated values not related to natural processes. In order to avoid those issues, I chose to base my selection of modern localities based on the terrestrial ecoregions of North America (sensu Ricketts et al., 1999). These ecoregions were delineated based on overall similarities in species diversity and environmental conditions. By selecting modern localities based on ecoregion maps, I was able to ensure maximum variation was included in my dataset, and I avoided auto-correlation that would result from choosing different numbers of localities from different ecoregions.

Once correlations were established between the modern faunas and climatic values, I then applied the results to the relatively continuous fossiliferous strata at Hagerman Fossil Beds National Monument (HAFO), Idaho. The abundant mammalian fossils at HAFO within the Pliocene Glenns Ferry Formation are internationally significant for the data they yield on life during the Blancan land mammal age (McDonald et al., 1996) and provide an excellent testing ground for application of the modern correlations to paleoecological trends.

MATERIALS AND METHODS

Faunal lists were compiled for two localities within each of the ecoregions (sensu Ricketts et al., 1999) of the United States and Canada. Preference was given to localities having better studied mammalian faunas and more complete climate data. Localities were as far apart from ecoregion boundaries as possible, but keeping the two localities within each ecoregion as far apart as possible in order to encompass the greatest possible climatic variation. Choice of localities was restricted by the presence of climate recording stations. References used to generate these individual faunal lists are given in Appendix H.

Mammalian taxonomy used here follows Baker et al. (2003), with a few exceptions. *Brachylagus idahoensis* is more appropriately called *Sylvilagus idahoensis* following Orr (1940) and the presence of the "*Brachylagus*" occlusal pattern in neotenic individuals of *Sylvilagus* (personal observation). I follow Nowak (2002; contra Wilson et al., 2000, 2003) in recognizing *Canis lycaon* as a subspecies of *Canis lupus*. The spelling *Herpailurus yagouaroundi* is used instead of *Herpailurus yaguarondi* because of the earlier use of the former (Geoffroy Saint-Hilaire, 1803; not B. G. E. Lacépède in Azara, 1809).

The faunal lists were produced using many published resources (Appendix H) and attempt to represent the mammalian assemblage of the localities prior to European colonization. Faunal lists include taxa recently extirpated, most notably species such as *Antilocapra americana* (Miller and Kellogg, 1955; Hall and Kelson, 1959), *Bos bison* (Miller and Kellogg, 1955; Hall and Kelson, 1959), *Canis lupus* (Nowak, 2002), *Canis rufus* (Nowak, 2002), *Cervus elephus* (Whitaker and Hamilton, 1998), *Erethizon dorsatum* (Hall and Kelson, 1959), *Gulo gulo* (Hash, 1987; Banci, 1994), *Lepardus pardalis* (Oliveira, 1994), *Leopardus wiedii* (Goldman, 1943), *Lontra canadensis* (Whitaker and Hamilton, 1998), *Lynx canadensis* (Koehler and Aubry, 1994), *Lynx rufus* (Peterson and Downing, 1952), *Martes americana* (Buskirk and Ruggiero, 1994), *Martes pennanti* (Powell and Zielinski, 1994), *Mustela frenata* (Hall, 1951), *Mustela nigripes* (Hall and Kelson, 1959), *Panthera onca* (Brown, 1983), *Puma concolor* (Young and Goldman, 1946; Hall and Kelson, 1959), *Rangifer tarandus* (Spalding, 2000; Courtois et al., 2004), and *Ursus americanus* (Pelton et al., 1994). The faunal lists exclude recent immigrants, such as *Canis latrans* (Whitaker and Hamilton, 1998; Gompper, 2002), *Dasypus novemcinctus* (McBee and Baker, 1982), *Didelphis virginiana* (Hamilton, 1958), and human-mediated introductions.

Climate data was taken from the United States National Climatic Data Center of the National Oceanographic and Atmospheric Administration (NCDC, 2002) and the Canadian Department of the Environment (National Climate Archive, 2004). Preference was given to localities with data meeting the completeness criteria outlined by the World Meteorological Organization (WMO) for 30 year intervals to reduce the effects of year to year variation (WMO, 1989). Use of the climate data from 1970-2000 was chosen because of the consistency of the data both within and between each country. Specific climate station data are presented in Appendix I. Due to the sparse number of climate data stations in a few localities, notably northern Canada, climatic values were taken from the nearest available data station; these instances are detailed in Appendix I. Four climatic parameters were gathered for each locality: mean-annual maximum-daily temperature, mean-annual mean-daily temperature, mean-annual minimum-daily temperature, and mean annual precipitation. Other factors, particularly those indicative of seasonality may also prove useful in future studies using ecoregions. Although such data was not available for all ecoregions and therefore not used in this chapter, regional studies may benefit from incorporation of seasonality.

Each analysis was done four times, each with a slightly different collection of localities. Even though Ricketts et al. (2000) included Hawaii and Puerto Rico in their discussion of ecoregions of the United States, I excluded them from all analyses because of their extreme distance from the North American mainland. The Great Basin Montane Forests ecoregion was excluded from all analyses because of its very fragmented and heterogenous nature, especially true of the mammalian assemblage, and because of the difficultly in determining accurate faunal and climatic data in the very small regions. A separate analysis excluded all islands from consideration, including fragmented continental ecoregions with a total area of less than 12,000 km.

This was done on the a priori assumption that islands would likely have anomalous faunas due to the physical barriers. Each dataset (with islands and without islands) was analyzed again with the zero values excluded. That is, when the species diversity within a particular group was zero for a particular locality, that locality was omitted from the analysis. This was done because although it may be invalid to make conclusions based on the absence of data, the absence of species may have climatic causes.

Pearson correlation coefficients were calculated for each dataset of taxonomic abundance and climate; t-tests were used to determine levels of significance of the correlation. A linear least square regression was used to generate a regression line that can be used to estimate climatic values based on taxonomic abundance (Figures 8.1, 8.2). The groupings of species that best fit the environmental data were then used to estimate temperature and precipitation patterns based on the species diversity of mammals through the Glenns Ferry Formation at HAFO (Appendix J).

Paleoclimatic estimates using the equation generated from the diversity of modern artiodactyls were made in two ways. First, just the HAFO artiodactyls were used. Because artiodactyls are the only large herbivorous mammals in most modern ecoregions of the United State and Canada, the second approach considered the modern artiodactyl dataset to represent all large herbivorous mammals, which in the Pliocene of HAFO included Artiodactyla, Perissodactyla, Xenarthra, and Proboscidea.

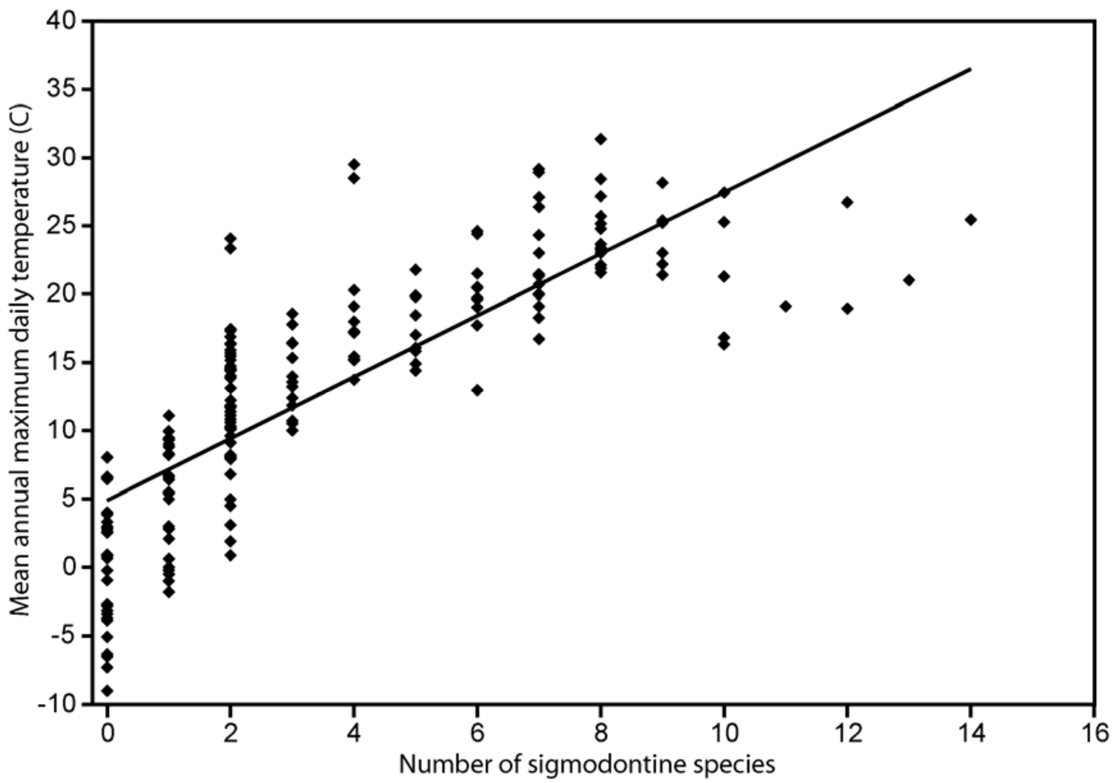


Figure 8.1. Scatter plot of number of sigmodontine species and mean-annual maximum-daily temperature. This plot is of the most inclusive dataset, excluding only the ecoregions in Hawaii, Puerto Rico, and the Great Basin Montane Forests.

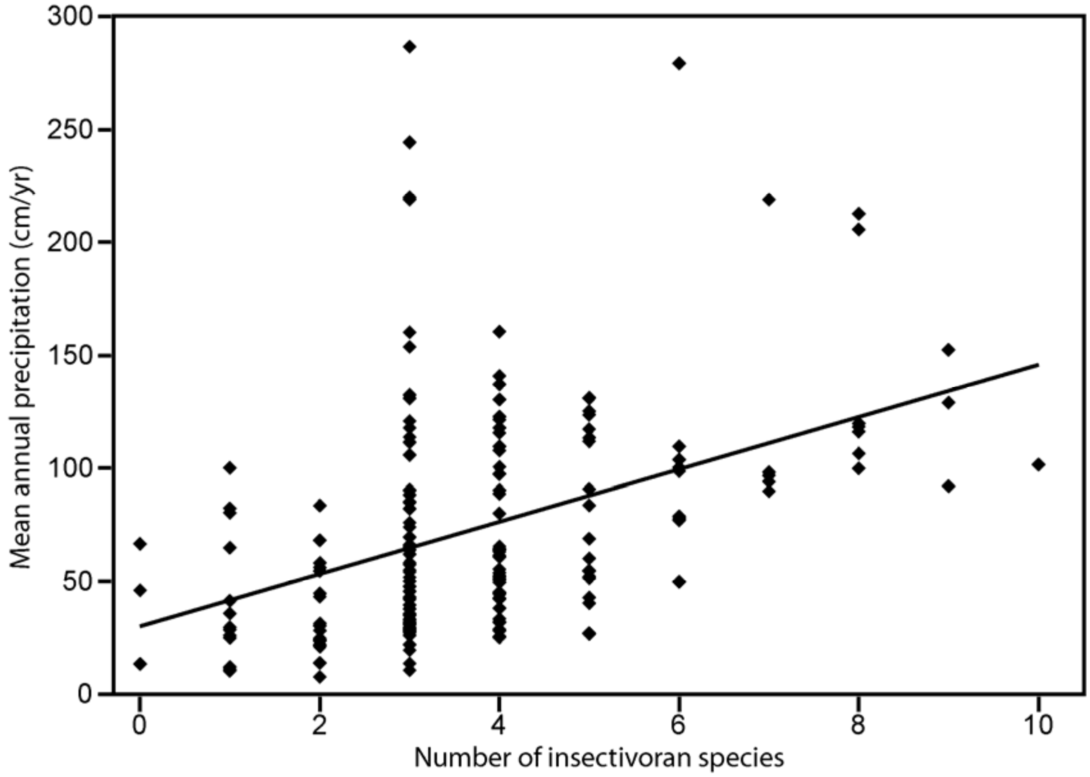


Figure 8.2. Scatter plot of number of insectivoran species and mean annual precipitation. This plot is of the most inclusive dataset, excluding only the ecoregions in Hawaii, Puerto Rico, and the Great Basin Montane Forests.

RESULTS

The analyses found statistically significant correlations between most groups of mammals and temperature, but correlations with temperature were much rarer and weaker (Tables 8.1-8.4). Table 8.5 gives the equation with the best correlation for each group of mammals. In most groups, there was not one dataset that produced the best correlations for all four climatic variables. The only consistency was that datasets with islands included always yielded better correlations than the datasets that omitted islands when precipitation is examined.

Table 8.6 shows the best groups to use to estimate each climatic variable. Chiropterans were the second best group to use for temperature estimates. However, bats are not commonly preserved as fossils, and none are known from the Glenns Ferry Formation at HAFO. The total number of mammals was also highly correlated with temperature, but this is also difficult to apply to the fossil record because it includes bats.

Some of the better correlations were used to estimate paleoenvironmental values within the Glenns Ferry Formation at HAFO, and the results were mixed. Sigmodontinae and Arvicolinae were the two groups present at HAFO with the highest correlations with temperature in modern ecoregions. However, the estimated temperature values for each do not resemble one another, nor does either match the reconstruction derived in Chapter 3 from non-mammalian data (Figure 8.3). More speciose groups, even those that include both the Arvicolinae and Sigmodontinae, do

Table 8.1a. Predictive equations for climatic parameters given the number of species in various groups of mammals. All ecoregions (sensu Ricketts, 1999) in the United States and Canada were included except for those in Hawaii, Puerto Rico, and Great Basin Montane Forests. Zero values for species diversity were included. The equation presented for each correlation is a least squares regression line. Pearson correlation coefficient values (ρ) are significant at alpha levels of 0.05 (*), 0.01 (**), and 0.001 (***) when indicated by asterisk(s) within the table; tests of significance were done with a two-tailed homoscedastic t-test with 216 degrees of freedom. Maximum temperature is the mean-annual maximum-daily temperature (°C); mean temperature is the mean-annual mean-daily temperature (°C). Non-volant group includes all terrestrial mammals except bats; the small mammal group includes Insectivora, Lagomorpha, and Rodentia; the large mammal group includes Carnivora and Artiodactyla.

	Maximum Temperature		Mean Temperature	
Taxon/Group	equation	ρ	equation	ρ
all terrestrial mammals	0.402n - 4.918	0.631***	0.324n - 7.314	0.546***
Insectivora	1.222n + 8.066	0.239***	1.122n + 2.664	0.236***
Chiroptera	1.466n + 3.272	0.744***	1.271n - 1.276	0.693***
Lagomorpha	4.198n + 3.924	0.461***	3.274n + 0.009	0.387***
Rodentia	0.808n + 0.231	0.533***	0.617n - 2.675	0.438***
Sciuridae	1.369n + 6.867	0.345***	0.942n + 2.798	0.255***

	Maximum Temperature		Mean Temperature	
Taxon/Group	equation	ρ	equation	ρ
Arvicolinae	-1.773n + 19.423	-0.425***	-1.792n + 13.756	-0.462***
Sigmodontinae	2.300n + 4.492	0.772***	2.031n - 0.349	0.734***
Carnivora	1.044n - 1.152	0.373***	0.804n - 3.824	0.309***
Mustelida	0.439n + 9.587	0.091	0.141n + 5.634	0.032
Artiodactyla	-0.042n + 12.351	-0.008	-0.448n + 7.838	-0.086
non-volant	0.415n - 2.922	0.504***	0.318n - 5.131	0.415***
small	0.669n - 1.290	0.548***	0.523n - 4.080	0.460***
large	0.548n + 3.538	0.269***	0.367n + 0.663	0.194**

Table 8.1b. Predictive equations for climatic parameters given the number of species in various groups of mammals. All ecoregions (sensu Ricketts, 1999) in the United States and Canada were included except for those in Hawaii, Puerto Rico, and Great Basin Montane Forests. Zero values for species diversity were included. The equation presented for each correlation is a least squares regression line. Pearson correlation coefficient values (ρ) are significant at alpha levels of 0.05 (*), 0.01 (**), and 0.001 (***) when indicated by asterisk(s) within the table; tests of significance were done with a two-tailed homoscedastic t-test and 216 degrees of freedom. Minimum temperature is the mean-annual minimum-daily temperature (°C); precipitation is the mean annual precipitation (cm). The non-volant group includes all terrestrial mammals except bats; the small mammal group includes Insectivora, Lagomorpha, and Rodentia; the large mammal group includes Carnivora and Artiodactyla.

	Minimum Temperature		Precipitation	
Taxon/Group	equation	ρ	equation	ρ
all terrestrial mammals	0.248n - 9.875	0.436***	-0.511n + 99.72	-0.145*
Insectivora	1.027n - 2.813	0.226***	7.846n + 51.24	0.279***
Chiroptera	1.083n - 5.928	0.616***	-0.419n + 80.51	-0.039
Lagomorpha	2.382n - 4.028	0.293***	-9.371n + 96.47	-0.187**
Rodentia	0.432n - 5.729	0.320***	-1.661n + 102.58	-0.198**
Sciuridae	0.528n - 1.384	0.149*	-1.730n + 84.72	-0.079

	Minimum Temperature		Precipitation	
Taxon/Group	equation	ρ	equation	ρ
Arvicolinae	-1.811n + 8.034	-0.487***	-3.856n + 93.60	-0.168*
Sigmodontinae	1.773n - 5.279	0.668***	-0.429n + 79.39	-0.026
Carnivora	0.568n - 6.590	0.227***	-2.448n + 109.31	-0.158*
Mustelida	-0.147x + 1.563	-0.035	-2.619n + 93.69	-0.099
Artiodactyla	-0.840n +3.225	-0.168*	-12.003n + 114.29	-0.389***
non-volant	0.224n - 7.501	0.305***	-0.779n + 106.38	-0.171*
small	0.381n - 7.025	0.350***	-0.794n + 94.00	-0.118
large	0.190n - 2.328	0.104	-2.891n + 123.74	-0.257***

Table 8.2a. Predictive equations for climatic parameters given the number of species in various groups of mammals. All ecoregions (sensu Ricketts, 1999) in the United States and Canada were included except for those in Hawaii, Puerto Rico, and Great Basin Montane Forests. Zero values for species diversity were omitted. The equation presented for each correlation is a least squares regression line. Pearson correlation coefficient values (ρ) are significant at alpha levels of 0.05 (*), 0.01 (**), and 0.001 (***) when indicated by asterisk(s) within the table; tests of significance were done with a two-tailed homoscedastic t-test. Degrees of freedom (df) are listed parenthetically after each taxon/group. Maximum temperature is the mean-annual maximum-daily temperature (°C); mean temperature is the mean-annual mean-daily temperature (°C). The large mammal group includes Carnivora and Artiodactyla. Taxa/groups present in all included ecoregions are not included here because the data are already presented in Table 8.1.

	Maximum Temperature		Mean Temperature	
Taxon/Group	equation	ρ	equation	ρ
Insectivora (df = 199)	0.334n + 12.074	0.065	0.364n + 6.087	0.075
Chiroptera (df = 180)	1.124n + 6.782	0.677***	0.964n + 1.873	0.608***
Lagomorpha (df = 210)	4.511n + 3.117	0.473***	3.619n - 0.880	0.407***
Sciuridae (df = 191)	0.584n + 11.190	0.142*	0.221n + 6.765	0.057
Arvicolinae (df = 206)	-1.503n + 17.951	-0.352***	-1.575n + 12.575	-0.396***
Sigmodontinae (df = 171)	1.767n + 8.039	0.736***	1.562n + 2.781	0.681***

	Maximum Temperature		Mean Temperature	
Taxon/Group	equation	ρ	equation	ρ
Carnivora (df = 214)	1.138n - 2.452	0.381***	0.896n - 5.088	0.322***
Mustelida (df = 214)	0.411n + 9.775	0.082	0.128n + 5.723	0.028
Artiodactyla (df = 215)	-0.063n + 12.437	-0.010	-0.461n + 7.892	-0.088
large (df = 215)	0.562n + 3.306	0.269***	0.381n + 0.425	0.196**

Table 8.2b. Predictive equations for climatic parameters given the number of species in various groups of mammals. All ecoregions (sensu Ricketts, 1999) in the United States and Canada were included except for those in Hawaii, Puerto Rico, and Great Basin Montane Forests. Zero values for species diversity were omitted. The equation presented for each correlation is a least squares regression line. Pearson correlation coefficient values (ρ) are significant at alpha levels of 0.05 (*), 0.01 (**), and 0.001 (***) when indicated by asterisk(s) within the table; tests of significance were done with a two-tailed homoscedastic t-test. Degrees of freedom (df) are listed parenthetically after each taxon/group. Minimum temperature is the mean-annual minimum-daily temperature (°C); precipitation is the mean annual precipitation (cm). The large mammal group includes Carnivora and Artiodactyla. Taxa/groups present in all included ecoregions are not included here because the data are already presented in Table 8.1.

	Minimum Temperature		Precipitation	
Taxon/Group	equation	ρ	equation	ρ
Insectivora (df = 199)	0.412n - 0.038	0.086	8.890n + 46.53	0.284***
Chiroptera (df = 180)	0.801n - 3.044	0.510***	-1.858n + 95.26	-0.161*
Lagomorpha (df = 210)	2.760n – 5.002	0.324***	-5.171n + 85.65	-0.104
Sciuridae (df = 191)	-0.102n + 2.088	-0.026	-1.049n + 80.97	-0.042
Arvicolinae (df = 206)	-1.648n + 7.141	-0.431***	-5.032n + 100.02	-0.206**
Sigmodontinae (df = 171)	1.354n - 2.490	0.594***	-1.950n + 89.53	-0.122

	Minimum Temperature		Precipitation	
Taxon/Group	equation	ρ	equation	ρ
Carnivora (df = 214)	0.655n - 7.794	0.246***	-2.087n + 104.34	-0.128
Mustelida (df = 214)	-0.147n + 1.566	-0.033	-1.924n + 89.02	-0.070
Artiodactyla (df = 215)	-0.848n + 3.255	-0.169*	-11.887n + 113.82	-0.383***
large (df = 215)	0.202n - 2.544	0.109	-2.838n + 122.82	-0.247***

Table 8.3a. Predictive equations for climatic parameters given the number of species in various groups of mammals. All ecoregions (sensu Ricketts, 1999) in the United States and Canada were included except for those in Hawaii, Puerto Rico, Great Basin Montane Forests, the small and fragmented ecoregions (South Florida Rocklands, Madrean Sky Islands Montane Forests, Atlantic Coastal Pine Barrens, Florida Sand Pine Scrub), and islands. The excluded continental ecoregions each have total areas of less than 12,000 km^2. Zero values for species diversity were included. The equation presented for each correlation is a least squares regression line. Pearson correlation coefficient values (ρ) are significant at alpha levels of 0.05 (*), 0.01 (**), and 0.001 (***) when indicated by asterisk(s) within the table; tests of significance were done with a two-tailed homoscedastic t-test with 186 degrees of freedom. Maximum temperature is the mean-annual maximum-daily temperature (°C); mean temperature is the mean-annual mean-daily temperature (°C). The non-volant group includes all terrestrial mammals except bats; the small mammal group includes Insectivora, Lagomorpha, and Rodentia; the large mammal group includes Carnivora and Artiodactyla.

	Maximum Temperature		Mean Temperature	
Taxon/Group	equation	R^2	equation	R^2
all terrestrial mammals	0.456n - 7.902	0.619***	0.374n - 10.171	0.543***
Insectivora	0.418n + 11.444	0.084	0.503n + 5.117	0.108
Chiroptera	1.456n + 3.438	0.778***	1.291n - 1.492	0.737***

	Maximum Temperature		Mean Temperature	
Taxon/Group	equation	R^2	equation	R^2
Lagomorpha	3.698n + 5.329	0.438***	2.897n + 0.979	0.366***
Rodentia	0.833n - 0.507	0.481***	0.632n - 3.247	0.389***
Sciuridae	0.897n + 9.100	0.229**	0.530n + 4.686	0.144*
Arvicolinae	-2.528n + 24.201	-0.648***	-2.428n + 17.745	-0.664***
Sigmodontinae	2.259n + 4.865	0.803***	2.037n - 0.346	0.773***
Carnivora	0.727n + 3.126	0.228**	0.553n - 0.522	0.185*
Mustelida	-0.631n + 17.070	-0.125	-0.783n + 12.040	-0.166*
Artiodactyla	-0.666n + 15.180	-0.128	-0.937n + 10.053	-0.193*
non-volant	0.413n - 3.239	0.419***	0.313n - 5.297	0.339***
small	0.697n - 2.330	0.491***	0.546n – 5.020	0.411***
large	0.226n + 9.191	0.102	0.094n + 5.396	0.046

Table 8.3b. Predictive equations for climatic parameters given the number of species in various groups of mammals. All ecoregions (sensu Ricketts, 1999) in the United States and Canada were included except for those in Hawaii, Puerto Rico, Great Basin Montane Forests, the small and fragmented ecoregions (South Florida Rocklands, Madrean Sky Islands Montane Forests, Atlantic Coastal Pine Barrens, Florida Sand Pine Scrub), and islands. The excluded continental ecoregions each have total areas of less than 12,000 km^2. Zero values for species diversity were included. The equation presented for each correlation is a least squares regression line. Pearson correlation coefficient values (ρ) are significant at alpha levels of 0.05 (*), 0.01 (**), and 0.001 (***) when indicated by asterisk(s) within the table; tests of significance were done with a two-tailed homoscedastic t-test with 186 degrees of freedom. Minimum temperature is the mean-annual minimum-daily temperature (°C); precipitation is the mean annual precipitation (cm). The non-volant group includes all terrestrial mammals except bats; the small mammal group includes Insectivora, Lagomorpha, and Rodentia; the large mammal group includes Carnivora and Artiodactyla.

	Minimum Temperature		Precipitation	
Taxon/Group	equation	ρ	equation	ρ
all terrestrial mammals	0.299n - 12.813	0.447***	-0.269n + 85.47	-0.066
Insectivora	0.606n - 1.345	0.134	11.564n + 30.12	0.419***
Chiroptera	1.138n - 6.567	0.668***	0.210n + 71.73	0.020

	Minimum Temperature		Precipitation	
Taxon/Group	equation	ρ	equation	ρ
Lagomorpha	2.139n - 3.531	0.279***	-6.189n + 85.95	-0.132
Rodentia	0.446n - 6.315	0.282***	-1.297n + 94.13	-0.135
Sciuridae	0.189n + 0.086	0.053	0.164n + 72.40	0.008
Arvicolinae	-2.323n + 11.199	-0.654***	-2.731n + 85.21	-0.126
Sigmodontinae	1.828n - 5.677	0.714***	0.527n + 71.21	0.033
Carnivora	0.391n - 4.406	0.135	-1.810n + 97.70	-0.102
Mustelida	-0.910n + 6.775	-0.198*	-1.475n + 82.63	-0.053
Artiodactyla	-1.187n + 4.788	-0.251***	-10.515n + 107.51	-0.365***
non-volant	0.221n - 7.763	0.246***	-0.542n + 94.39	-0.099
small	0.408n - 8.073	0.316***	-0.104n + 75.41	-0.014
large	-0.028n + 1.369	-0.014	-2.754n + 119.54	-0.226**

Table 8.4a. Predictive equations for climatic parameters given the number of species in various groups of mammals. Ecoregions (sensu Ricketts, 1999) included are the same as Table 8.3. Zero values for species diversity were omitted. The equation presented for each correlation is a least squares regression line. Pearson correlation coefficient values (ρ) are significant at alpha levels of 0.05 (*), 0.01 (**), and 0.001 (***) when indicated by asterisk(s) within the table; tests of significance were done with a two-tailed homoscedastic t-test. Degrees of freedom (df) are listed parenthetically after each taxon/group. Maximum temperature is the mean-annual maximum-daily temperature (°C); mean temperature is the mean-annual mean-daily temperature (°C). Taxa/groups present in all included ecoregions are not included here because the data are already presented in Table 8.3.

	Maximum Temperature		Mean Temperature	
Taxon/Group	equation	ρ	equation	ρ
Insectivora (df = 183)	0.455n + 11.275	0.089	0.531n + 4.988	0.111
Chiroptera (df = 163)	1.204n + 5.984	0.697***	1.072n + 0.721	0.646***
Sciuridae (df = 181)	0.677n + 10.325	0.169*	0.325n + 5.822	0.086
Arvicolinae (df = 178)	-2.420n + 23.593	-0.600***	-2.334n + 17.213	-0.619***
Sigmodontinae (df = 158)	1.891n + 7.240	0.763***	1.706n + 1.786	0.723***

Table 8.4b. Predictive equations for climatic parameters given the number of species in various groups of mammals. Ecoregions (sensu Ricketts, 1999) included are the same as Table 8.3. Zero values for species diversity were omitted. The equation presented for each correlation is a least squares regression line. Pearson correlation coefficient values (ρ) are significant at alpha levels of 0.05 (*), 0.01 (**), and 0.001 (***) when indicated by asterisk(s) within the table; tests of significance were done with a two-tailed homoscedastic t-test. Degrees of freedom (df) are listed parenthetically after each taxon/group. Minimum temperature is the mean-annual minimum-daily temperature (°C); precipitation is the mean annual precipitation (cm). Taxa/groups present in all included ecoregions are not included here because the data are already presented in Table 8.3.

	Minimum Temp (C)		Precipitation (cm)	
Taxon/Group	equation	R^2	equation	R^2
Insectivora (df = 183)	0.625n - 1.425	-0.134	11.799n + 29.03	0.415***
Chiroptera (df = 163)	0.935n - 4.515	-0.567***	-0.460n + 78.51	0.042
Sciuridae (df = 181)	0.012n + 1.077	0.003	0.588n + 70.04	0.026
Arvicolinae (df = 178)	-2.239n + 10.736	0.611***	-3.524n + 89.68	0.151*
Sigmodontinae (df = 158)	1.516n - 3.656	-0.653***	-0.749n + 79.45	0.049

Table 8.5. Summary of best correlation statistics for each group of mammals. IZ, islands and zero species diversity values included (Table 8.1); INZ, islands included, zero species diversity values omitted (Table 8.2); NIZ, islands omitted, zero species diversity values included (Table 8.3); NINZ, islands and zero species diversity values omitted (Table 8.4). Max. Temp., mean-annual maximum-daily temperature (°C); Mean Temp., mean-annual mean-daily temperature (°C); Min. Temp., mean-annual minimum-daily temperature (°C); Precip., mean annual precipitation (cm). The non-volant group includes all terrestrial mammals except bats; the small mammal group includes Insectivora, Lagomorpha, and Rodentia; the large mammal group includes Carnivora and Artiodactyla.

Taxon/Group	Max. Temp.	Mean Temp.	Min. Temp.	Precip.
Total	IZ/INZ	IZ/INZ	NIZ/NINZ	IZ/INZ[1]
Insectivora	IZ	IZ	IZ	NIZ
Chiroptera	NIZ	NIZ	NIZ	INZ[2]
Lagomorpha	INZ	IZ	INZ	IZ[3]
Rodentia	IZ/INZ	IZ/INZ	IZ/INZ	IZ/INZ[3]
Sciuridae	IZ	IZ	IZ	IZ[1]
Arvicolinae	NIZ	NIZ	NIZ	INZ[3]
Sigmodontinae	NIZ	NIZ	NIZ	INZ
Carnivora	INZ	INZ	INZ	IZ[2]
Mustelida	NIZ/NINZ[1]	NIZ/NINZ[2]	NIZ/NINZ[3]	IZ[1]

Artiodactyla	NIZ/NINZ[1]	NIZ/NINZ[2]	NIZ/NINZ	IZ
non-volant	IZ/INZ	IZ/INZ	IZ/INZ	IZ/INZ[2]
small	IZ/INZ	IZ/INZ	IZ/INZ	IZ/INZ[1]
large	IZ[4]	INZ	INZ[1]	IZ

[1] no equation significant at 0.05 or better

[2] no equation significant at 0.01 or better

[3] no equation significant at 0.001

[4] differs from INZ at fourth decimal place, which is not shown in Tables 8.1 and 8.2.

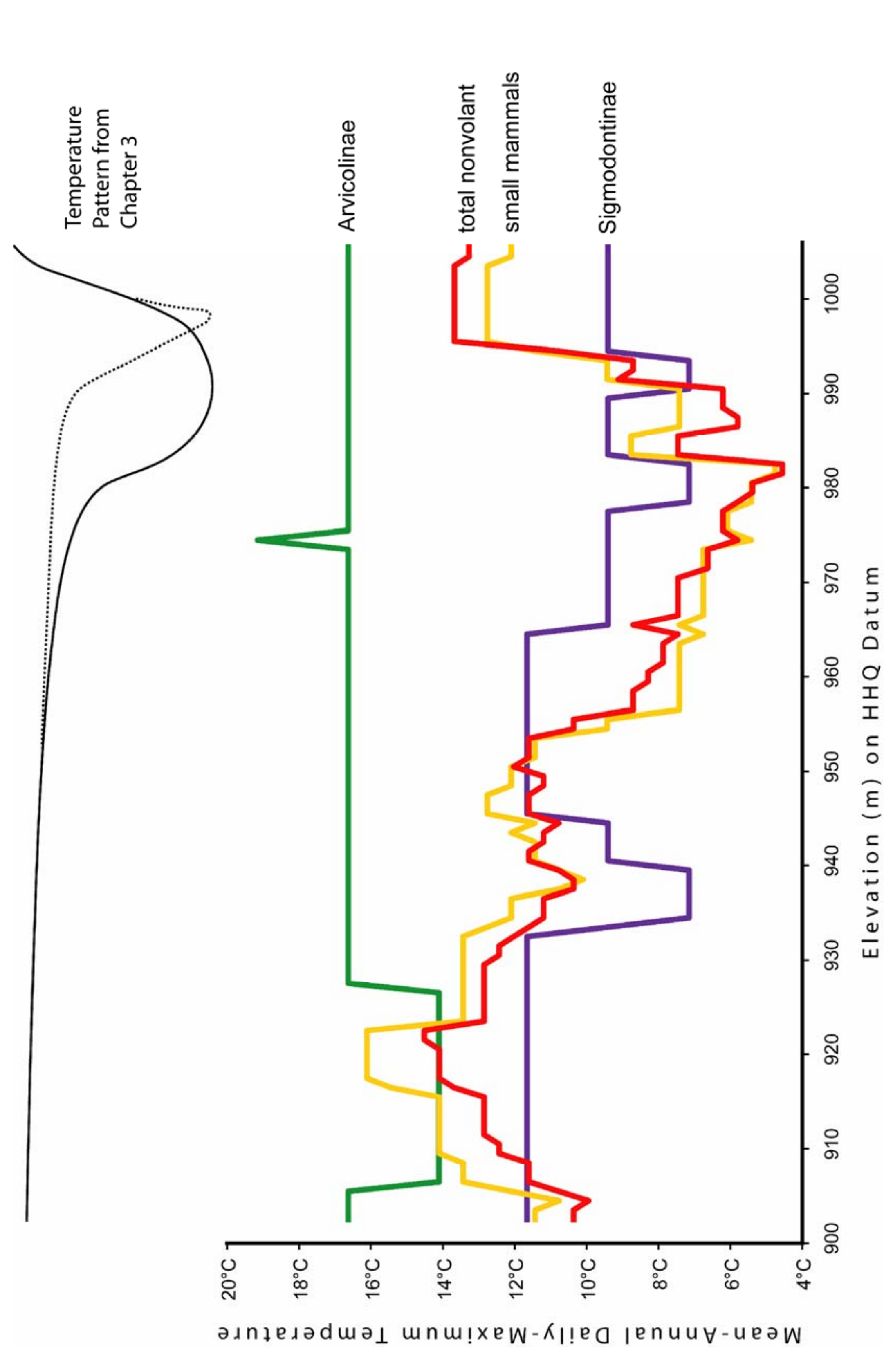
Table 8.6. Best predictors of each climate value. Only the best equation for each taxon/group as indicated in Tables 8.1-8.4 is considered. Unless noted, all correlations are significant at 0.001.

Maximum Temperature	Mean Temperature	Minimum Temperature	Precipitation
Sigmodontinae (NIZ)	Sigmodontinae (NIZ)	Sigmodontinae (NIZ)	Insectivora (NIZ)
Chiroptera (NIZ)	Chiroptera (NIZ)	Chiroptera (NIZ)	Artiodactyla (IZ)
Arvicolinae (NIZ)	Arvicolinae (NIZ)	Arvicolinae (NIZ)	large (IZ)
total (IZ/INZ)	total (IZ/INZ)	total (NIZ/NINZ)	Arvicolinae (INZ)[1]
small (IZ/INZ)	small (IZ/INZ)	small (IZ/INZ)	Rodentia (IZ/INZ)[1]
Rodentia (IZ/INZ)	Rodentia (IZ/INZ)	Rodentia (IZ/INZ)	Lagomorpha (IZ/INZ)[1]
non-volant (IZ/INZ)	non-volant (IZ/INZ)	non-volant (IZ/INZ)	non-volant (IZ/INZ)[2]

[1] significant at 0.01, but not 0.001

[2] significant at 0.05, but not 0.01

Figure 8.3. Temperature pattern determined in Chapter 3 for the Glenns Ferry Formation at HAFO compared to the mean-annual maximum-daily temperature estimated from the correlations determined using modern ecoregions. The HAFO mammalian assemblage is grouped in 20 m sliding windows. The modern mean-annual daily-maximum temperature at Hagerman is 19.9°C.



Temperature Pattern from Chapter 3
Arvicolinae
total nonvolant small mammals
Sigmodontinae
Mean-Annual Daily-Maximum Temperature
20°C
18°C
16°C
14°C
12°C
10°C
8°C
6°C
4°C
900
910
920
930
940
950
960
970
980
990
1000
Elevation (m) on HHQ Datum

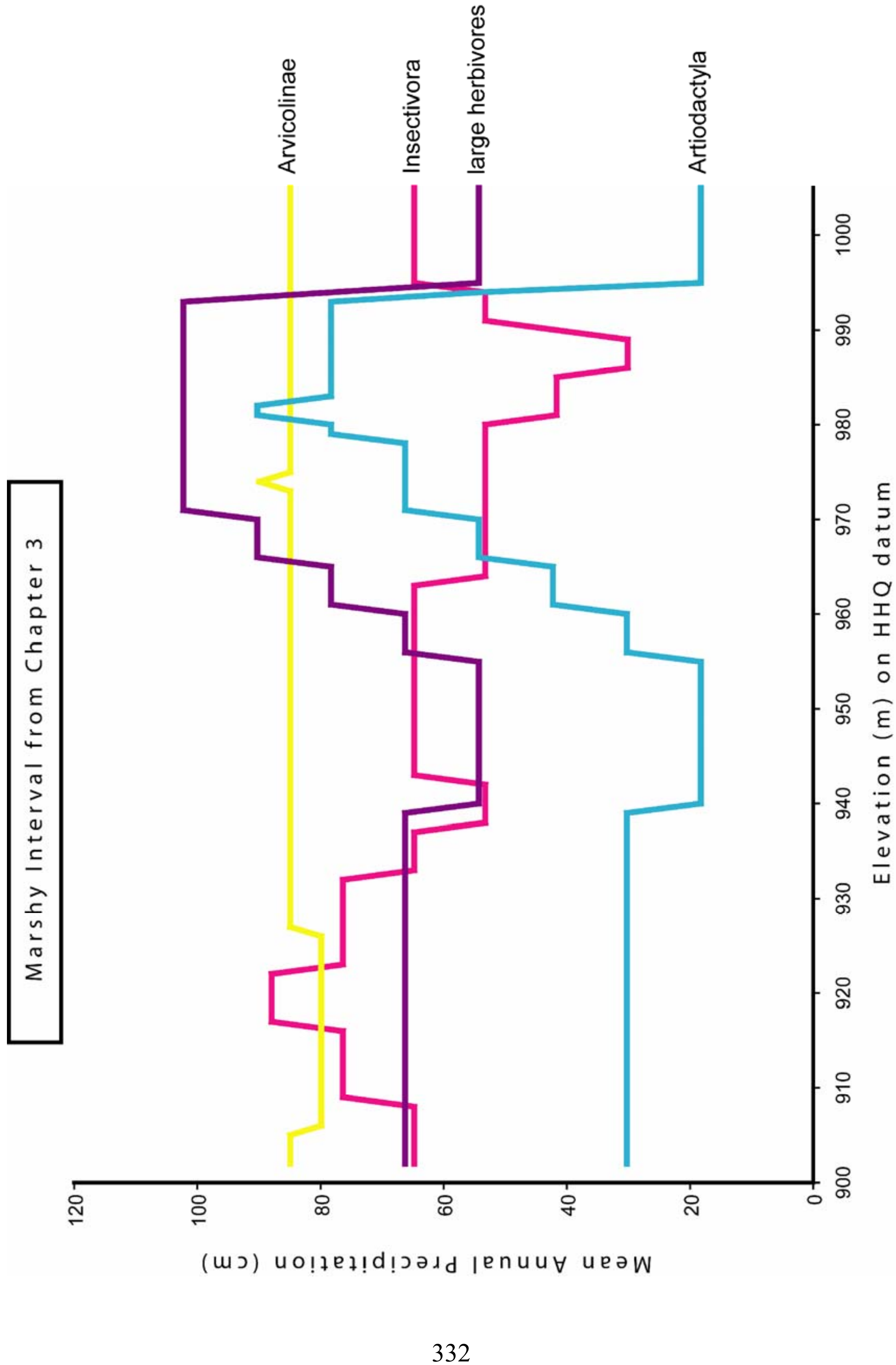
show patterns similar to that from Chapter 3. All equations suggest that all time regresented in the Glenns Ferry Formation of HAFO had cooler temperatures than today (mean-annual daily-maximum temperature of 19.9°C).

Figure 8.4 displays the estimates for yearly precipitation during the time of the Glenns Ferry Formation at HAFO. Insectivora has the highest degree of correlation in the modern ecoregions, and is the only group that indicates higher precipitation rates during the marshy interval (as determined in Chapter 3). The precipitation curve for Arvicolinae is essentially static for the duration of the Glenns Ferry Formation at HAFO. Two curves were plotted using the Artiodactyla correlation derived from modern ecoregions: one using just the HAFO artiodactyls and the other using all large herbivores at HAFO (Artiodactyla, Perissodactyla, Xenarthra, Proboscidea). Both curves suggested the wettest time at HAFO occurred after the marshy interval documented in Chapter 3. Wetter conditions in the Pliocene than today for HAFO are suggested by all equations based on modern ecoregions except for the Artiodactyla equation when only HAFO artiodactyls are used.

DISCUSSION

Most of the groups of extant mammals examined were determined to have a statistically significant correlation to modern climatic values when examined in light of modern ecoregions. In spite of this, estimates of values for the Pliocene Glenns

Figure 8.4. The marshy interval based on Chapter 3 for the Glenns Ferry Formation at HAFO compared to the mean annual precipitation estimated from the correlations determined using modern ecoregions. The HAFO mammalian assemblage is grouped in 20 m sliding windows. The modern mean annual precipitation at Hagerman is 24.8 cm/yr.

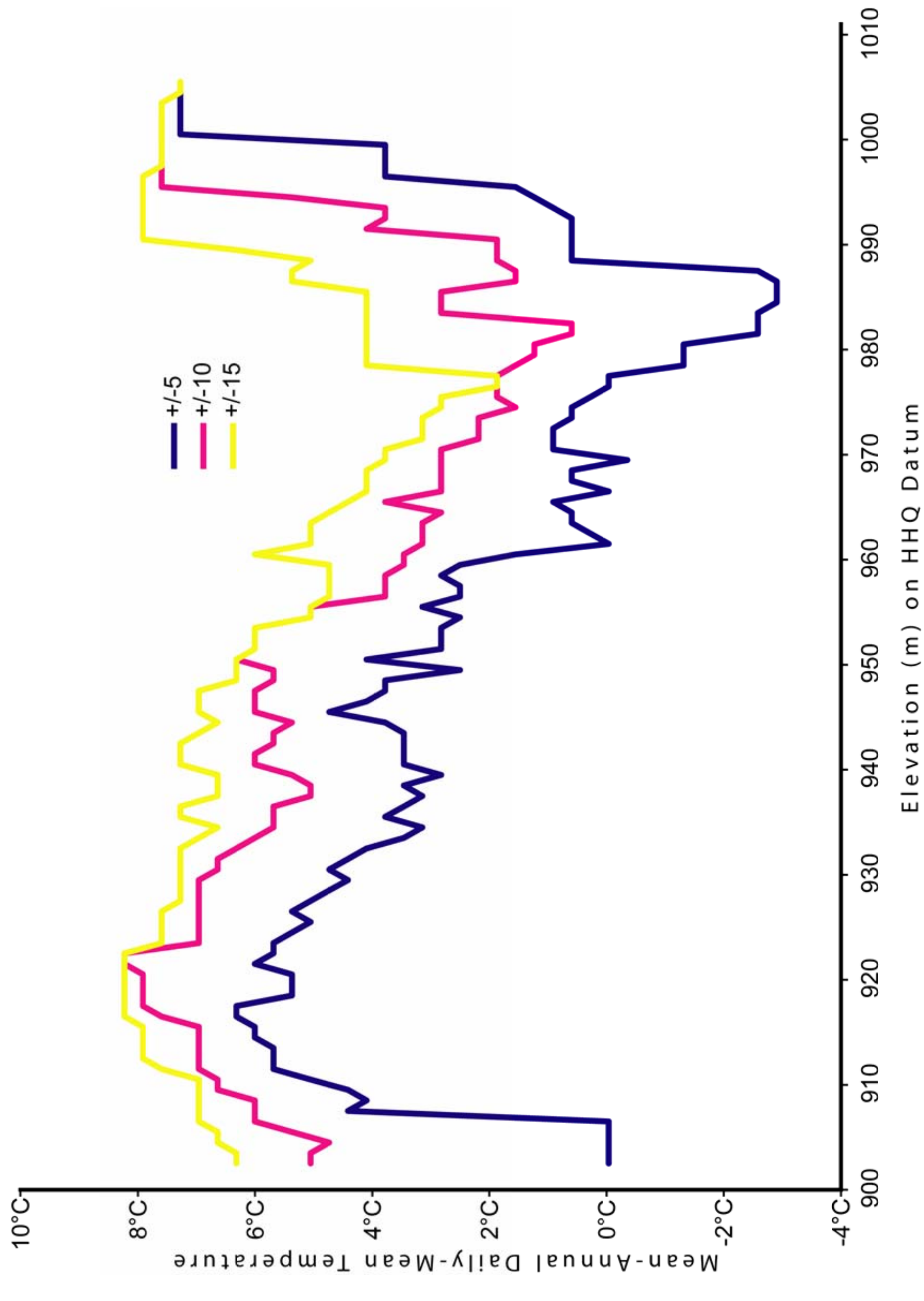

Marshy Interval from Chapter 3
Arvicolinae
Insectivora
large herbivores
Artiodactyla
Mean Annual Precipitation (cm)
0
20
40
60
80
100
120
Elevation (m) on HHQ datum
900
910
920
930
940
950
960
970
980
990
1000

Ferry Formation at HAFO based on equations derived from modern correlations produced variable results. The two groups (Arvicolinae and Sigmodontinae) represented at HAFO that have the most significant correlations in modern ecoregions do not match each other in values or patterns, nor do they match the temperature pattern determined in Chapter 3. Larger, more inclusive groups, however, did produce patterns similar to that seen in Chapter 3. In estimating precipitation, Arvicolinae again failed to match the patterns of other groups; moreover, it failed to exhibit much variation at all. In spite of the high levels of correlation, the relatively low numbers of species of Arvicolinae and Sigmodontinae at HAFO preclude their use by themselves in paleoenvironmental reconstruction. Larger groups that included both Arvicolinae and Sigmodontinae were better able to estimate the expected patterns. This suggests that the reconstruction of paleoenviroments should not necessarily use the best predictive equations based on modern ecoregions, but should use equations based on speciose groups well represented in the fossil assemblage. The use of Arvicolinae or Sigmodontinae alone for estimation of paleotemperatures may be appropriate in some faunas, however, this should be examined in concert with estimates from other groups, especially more inclusive ones.

The general failure of precipitation estimates based on modern ecoregions to match other data might not be a fault of the methodology used in this chapter. Instead, the marshy interval suggested in Chapter 3 might not represent increased precipitation rates in the HAFO area, but may rather reflect increased precipitation in another area(s) that drained into the HAFO region. Additionally, there may be other physical factors that maintained an abundance of surface water in the marshy interval that are not related to precipitation.

The offset of the temperature pattern generated in Chapter 3 compared to those predicted using equations from modern ecoregions is not a result of imprecise stratigraphic placement of fossiliferous localites, because that would affect all temperature curves similarly. Instead, this seems to be related to taphonomic factors. Figures 8.3 and 8.4 were generated using a sliding 20 m stratigraphic window. As shown in Figure 8.5, the size of the sliding window has a significant impact on both the estimated values, and the overall pattern derived. In particular, overall values are greater with a larger sliding window when the correlation is positive, as shown in Figure 8.5, and the amount of variation is reduced. Values are lower with large sliding windows when the correlation is negative. Maximum values when the correlation is positive, and minimum values when the correlation is negative, do not exhibit as much of a change with varying window size; these particular extremes are less affected by time averaging in the ecoregion models. Additionally, the placement of climatic peaks is altered. With each increase in size of the sliding window, the cool peak is indicated as occurring earlier within the Glenns Ferry Formation. Smaller sliding windows more accurately place the cool peak toward the top of the stratigraphic section, however, the chance of missing an included species is increased.

Figure 8.5. Mean-annual daily-mean temperature based on the equation for all non-volant mammals. The values were determined with a sliding window of 10 m (blue), 20 m (magenta), and 30 m (yellow). For comparison, the modern value for Hagerman, Idaho, is 10.9°C.



Mean-Annual Daily-Mean Temperature
10°C
8°C
6°C
4°C
2°C
0°C
-2°C
-4°C
900
910
920
930
940
950
960
970
980
990
1000
1010
Elevation (m) on HHQ Datum
+/-5
+/-10
+/-15

At HAFO, some degree of time-averaging is necessary since few individual localities at HAFO can be said to have a large proportion of the mammalian fauna present at that particular time. Additionally, several taxa at HAFO are only known from a few specimens, making them likely to be missed with smaller sampling windows. In spite of this, I have not used a range-through approach, which considers a taxon present at a horizon if it occurs both higher and lower stratigraphically (Boltovskoy, 1988), in documentation of the distribution of fossil mammals at HAFO. A range-through approach would exclude the possibility of extirpation, which could result from the rapid climate changes recorded at HAFO.

Building a dataset of modern biotas using distribution maps may include in a fauna a species that has not been found at that exact locality. Distribution maps of modern mammals are created based on multiple occurrences and inherently contain undrawn and/or unknown patches where the species does not occur. However, this patchiness typically results from the low detection probability of a species and not necessarily the absence of a species that is present in ecologically similar surrounding areas (Burnham and Overton, 1978, 1979; Boulinier et al., 1998; Nichols et al., 1998a, b; Cam et al., 2000; MacKenzie et al., 2004). Moreover, because local species assemblages are the products of both local and regional processes (e.g., Gaston and Blackburn, 2000; He et al., 2005; Shurin and Srivastava, 2005), local species-level diversity will approximate regional diversity (Cornell and Lawton, 1992). Modern species with low detection probabilities also have higher extinction probabilities (Alpizar-Jara, 2004), however, modern extirpations were excluded from the generation of the datasets in this chapter.

Allochthonous fossil faunas are similar to modern faunas generated from biogeographic distribution maps in that both represent regional diversity patterns, even when one particular fossil or modern locality is examined. In the case of HAFO, taxa may have been transported distances much greater than a kilometer by either physical means, such as fluvial transport, or biological vectors, such as carnivores.

Correlative models that estimate climatic parameters, such as the ones in this chapter, are limited in that they presuppose species are in equilibrium with the ecosystem. The correlation of diversity and environmental parameters seen today and in the past does not necessarily represent ideal connections, not do they necessarily display all the possible variation. Additionally, most correlative models do not account for physical barriers to dispersal (Pearson and Dawson, 2003). However, ecoregions already account for these barriers, so the models in this chapter avoid that obstacle. Alternative methods that use climate envelopes are subject to the same limitations, but additionally do not include interspecific interactions (Davis et al., 1998a, b; Lawton, 2000). This failing not only excludes a possible source of variation, but can even yield erroneous results such that Woodward and Beerling suggested that “such models should now become extinct” (1997:418). That same conclusion was reached in a study of late Quaternary mammals in North America based on the Gleasonian change in distributions: "Models for future change must rely increasingly on individual species and their requirements" (Graham et al., 1996).

Because the diversity-climate correlations documented in this chapter were determined on data built using modern ecoregions, I was able to include a maximum amount of variation and avoid auto-correlation. A different approach was taken in another analysis of North American mammal species density and environmental factors (Badgley and Fox, 2000); faunal lists were compiled by dividing the continent into equal-area quadrats and using a single set of climate values for each quadrat. Although predictive equations as produced in this chapter were not provided by Badgley and Fox, such equations could presumably be generated from their dataset. That method avoids arbitrary locality choices, but is limited in that it, like all correlative models, assumes that the more abundant and/or widespread assemblages today are the more stable ones. Additionally, the size of the quadrat can include multiple small areas of high endemism and large range of climate values. This can significantly inflate the species diversity in the faunal lists and dissociate the connectivity between the fauna and climate. The equal-area quadrats will also sample the larger ecoregions more often than the smaller ones. Although I consider this a criticism because it produces auto-correlations, it could conceivably be considered an attribute that could improve my ecoregion-based models. If the larger ecoregions represent the more likely or more stable species assemblages, they could be weighted by measures of their geographic area. I have not taken that approach here because ecoregions acknowledge the physical barriers that can preclude the formation of the 'ideal' fauna for a particular set of climatic conditions.

Ultimately, the applicability of these correlations based on modern ecoregions need to be examined in more densely fossiliferous deposits, particularly those in the late Pleistocene and Holocene, when the faunal similarities to today are more likely to be stronger. The faunal lists produced in this chapter to examine species diversity in light of modern ecoregions could be adapted to examine the strength of other models of paleoecology using fossil mammals. Such critical evaluation should be done before application to fossil assemblages, but could also be done a posteriori to appraise previously used models and the interpretations based on them.

APPENDIX A. LOCALITIES WITHIN AND NEAR HAFO, WITH ELEVATIONS ON THE HHQ DATUM

Precise locality information may be obtained by qualified persons from Hagerman Fossil Beds National Monument (HAFO). Collection of fossil vertebrates at HAFO is ongoing and new localities are being discovered. The list of sites below represents all the sites known to the author as of 2 April 2002.

Abbreviations

HAFO, Hagerman Fossil Beds National Monument locality number; IMNH, Idaho Museum of Natural History locality number; UM Ida, University of Michigan Museum of Paleontology Idaho locality number; USGS, United States Geological Survey; Prec., precision of the elevation given; HHQD, elevation of site correlated to the Hagerman Horse Quarry Datum. Locality types: A, anthill fossil locality; B, blowout fossil locality; F, locality is in the faulted area in the southern part of the monument (shaded area of Figure 2.10); I, in situ fossil locality; O, obliterated locality (most commonly caused by landslides); S, surface float; U, unknown locality type or uncertain elevation on the HHQD. Letters in the IMNH column are collections reported by Cunningham (1984). An asterisk after the HAFO locality number indicates the site is not with the monument boundaries.

HAFO	IMNH	UM Ida	USGS	Prec. (m)	HHQD (m)	type
1	31001		20987	2	1005	I
2				4	996	I
3	65006		20765	2	912	A, B
4	67002	1-64		1	916	A, B
5	69003		19216	2	1004	B
6	69007, 106	2-65		1	F	B
7	69008, 105	1a-65		1	1001	B
8	70016			1	966	A, S
9	70017			2	945	A
10	70018			3	970	B
11	70019			15	1022	U, O
12	70020			2	926	A
13	70021			7	931	A
14	70022			2	938	B
15	70023			5	891	U
16	70024			4	F	S
17*	70025			4	962	U
18				5	1005	I
19	70027		19207	3	905	S

HAFO	IMNH	UM Ida	USGS	Prec. (m)	HHQD (m)	type
20	70028	2-64		1	930	A
21	70029	3-64		3	921	B
22	70030	6-64		4	890	U, O
23	70031	17-64		3	911	B
24	70032	18-64		1	907	A
25	70033	23-64		2	915	A, B, S
26	70034	31-64		3	919	U, O
27	70035	44-64		1	929	A
28	70036	51-64		3	943	B
29	70037	52-64		3	943	B
30	70038	66-64		5	924	U
31	70039	70-64	19193	2	956	U, O
32	70040	77-64		4	979	U
33	70041	98-64		3	916	A
34	70042	3-65		5	954	B
35	70043	7-65		2	900	U
36	70044	11-65		2	908	S
37	70045	21-65		1	911	A
38	70046	23-65		2	925	A
39	70047	22-65		3	925	A, S
40	70048	25-65		4	937	U, O
41	70049	27-65		4	912	A, B, S

HAFO	IMNH	UM Ida	USGS	Prec. (m)	HHQD (m)	type
42	70050	31-65		2	925	A
43	70051	38-65		2	925	A
44	70052	43-65	21053	5	934	A
45	70053	45-65		10	F	U
46	70054	53-65		2	945	B
47	70055	60-65		3	945	A, B
48	70056	61-65		5	962	B
49	70057	66-65		1	960	A, B
50	70058	68-65		1	955	B
51	70059	70-65		20	972	B
52	70060	81-65		3	974	U, O
53	70061	86-65		2	1000	U
54*	70062	91-65		2	961	B
55*	70063	93-65		3	966	U
56*	70064	94-65		3	968	U
57	70065	57-64		2	945	U, O
58	70066			5	925	B
59	70067			1	913	A
60	70068	20-65		4	913	I, A, S
61				5	962	B
62*	71010				F	U
63	74022	1-65		3	1001	B

HAFO	IMNH	UM Ida	USGS	Prec. (m)	HHQD (m)	type
64				10	938	A
65	77001			1	1000	B
66	80001			4	970	U
67	80002			1	950	B
68	80005, 112		20769	1	923	A, B, S
69	80011			2	1034	B
70				5	925	B
71				5	957	A
72				5	960	S
73				5	961	A
74				5	982	S
75	81002	29-66		1	942	A, S
76	81004		21018	2	920	I, B
77				5	930	B
78	83012				U	U
79	83013			5	937	U
80	83018		20765	1	925	S
81	83021	32-64		4	928	U, O
82	83022			5	1021	U, O
83	83023			5	1047	S
84	83024			2	947	U, O
85	83025			4	960	S

HAFO	IMNH	UM Ida	USGS	Prec. (m)	HHQD (m)	type
86	83026			6	952	U, O
87	83027			5	896	U, O
88	83028	16-64		2	913	S
89	83029			5	887-905	S, O
90	83030			1	929	I, B
91	84004			3	892	U
92	84007			3	895	S
93	84010			3	897	U
94	85003				U	U
95	85004			5	904	U
96				5	920	A
97				5	925	U
98	85029			3	F	U
99				5	960	B
100		4-64		5	963	A, O
101		5-64		2	926	B
102		7-64		5	890	U, O
103		8-64		3	893	U, O
104		10-64			900	U
105	70073	14-64		2	902	S
106		15-64			890	U
107		19-64		2	912	S

HAFO	IMNH	UM Ida	USGS	Prec. (m)	HHQD (m)	type
108		20-64		2	910	B
109		21-64		2	905	I
110		22-64		3	907	S
111		24-64		3	900	U
112		25-64		4	917	S
113		26-64		4	930	B, O
114		28-66		2	924	A
115		29-64		2	927	U, O
116		30-64		8	915	S
117		33-64		4	918	U
118*		34-64		3	1030	U
119		35-64		4	923	A
120		36-64		3	920	A
121		37-64		3	927U	U
122		38-64		3	925	U
123		39-64		3	932	S
124		40-64		6	916	A, S
125		42-64		3	920	B
126		43-64		1	983	U, O
127		45-64		3	991	U, O
128	80019	46-64		4	937	U, O
129		47-64		4	934	A

HAFO	IMNH	UM Ida	USGS	Prec. (m)	HHQD (m)	type
130		48-64		3	930	U, O
131		49-64		4	935	U, O
132		50-64		5	923	A
133		53-64		4	937	U, O
134	489	54-64		2	940	A
135		55-64		8	934	U, O
136		56-64		4	943	U, O
137		58-64		2	942	B
138		59-64		3	910	U
139		60-64			U	U
140		61-64		4	941	U, O
141		62-64		4	945	U, O
142		63-64		3	945	S
143		64-64		4	938	A
144		65-64		3	949	B
145		67-64		5	921	S
146	80016	68-64		4	940	U, O
147		69-64		3	952	B
148		71-64			U	U
149		72-64			968	U
150		73-64		5	970	U
151		74-64		3	934	A

HAFO	IMNH	UM Ida	USGS	Prec. (m)	HHQD (m)	type
152		75-64	19215	1	972	B
153		76-64		4	975	U, O
154		78-64			U	U
155		79-64		3	988	U, O
156		80-64		4	966	S
157		81-64		5	998	U, O
158		82-64		2	1013	B
159		83-64			U	U
160		84-64		4	913	U
161		85-64		3	920	U
162		87-64		3	990	U
163		88-64			U	U
164		89-64		3	945	U
165		90-64		3	926	U
166		91-64		3	945	U
167		92-64		3	965	U
168		93-64		3	936	U
169		94-64		3	924	U
170		95-64		3	936	U
171		97-64			U	U
172		99-64		3	900	U
173		100-64		3	900	U

HAFO	IMNH	UM Ida	USGS	Prec. (m)	HHQD (m)	type
174		104-64			U	U
175	80018	4-65		2	967	A
176		5-65		2	892	B
177		6-65		2	894	B
178		8-65		2	898	U, O
179		9-65		3	885	U
180		10-65		3	899	U
181		12-65		2	920	A, B
182		13-65		3	912	U
183		14-65		7	912	S
184		15-65		3	905	U, O
185		16-65		5	945	U
186		17-65		4	935	B
187		18-65		5	914	U
188		19-65		5	887	U
189		24-65		4	932	A
190		26-65		8	907	U
191		28-65		1	920	B
192		29-65		2	918	S
193		30-65		2	926	B
194		32-65		4	926	U
195		33-65			U	U

HAFO	IMNH	UM Ida	USGS	Prec. (m)	HHQD (m)	type
196		34-65		3	925	U
197	85006	35-65		2	933	A
198		36-65		3	927	U
199		37-65			U	U
200		39-65		4	935	U
201		40-65		3	925	U
202		41-65		3	945	U
203		42-65		3	936	U, O
204	70052	43-65	21053	5	934	A
205		44-65	21023	3	928	U
206		46-65	D1715	4	930	U
207	80015	47-65		3	959	A
208		48-65		2	941	B
209		49-65		2	942	B
210		51-65		3	960	U
211*		52-65			U	U
212		54-65			U	U
213		55-65		5	945	A
214		56-65		5	938	B
215		57-65		3	937	U, O
216		58-65		1	952	S
217		59-65		5	945	U

HAFO	IMNH	UM Ida	USGS	Prec. (m)	HHQD (m)	type
218	70055	60-65		3	953	A, B
219		62-65		3	955	A
220		63-65		3	955	B
221		64-65			U	U
222		65-65		10	962	U, O
223		69-65		2	950	S
224*		72-65			U	U
225		73-65		3	966	S
226		74-65		3	960	U
227*		75-65			U	U
228*		76-65			U	U
229		77-65		1	972	A, B
230		78-65		4	964	U
231*		79-65		5	981	U
232		80-65		5	978	U
233		82-65		10	999	A, B
234*		83-65			U	U
235		84-65		2	984	B
236	80017	85-65		1	990	A
237	70061	86-65		2	1000	U
238		88-65		2	998	U, O
239		89-65		5	989	B

HAFO	IMNH	UM Ida	USGS	Prec. (m)	HHQD (m)	type
240		90-65		2	1004	A
241		92-65		7	982	U
242*		95-65		3	1001	B
243		96-65		3	1012	B
244		97-65		1	1019	B, S
245		98-65		4	1020	U
246		99-65		2	1032	A
247*		100-65			U	U
248*		101-65			U	U
249		102-65			U	U
250		103-65		3	955	U
251		104-65		3	895	U
252		105-65			U	U
253		106-65			U	U
254		107-65			U	U
255		108-65			U	U
256		109-65		3	975	S
257*		110-65			U	U
258		111-65		3	942	U
259		112-65			U	U
260		113-65			U	U
261		114-65		3	997	U

HAFO	IMNH	UM Ida	USGS	Prec. (m)	HHQD (m)	type
262		115-65		3	990	U
263		116-65			U	U
264		117-65			U	U
265		118-65			U	U
266		119-65			U	U
267		120-65		3	990	U
268		121-65			U	U
269		122-65			U	U
270		123-65		3	932	U
271		124-65		6	926	U
272		125-65			U	U
273		126-65		4	949	U
274		127-65		3	948	U
275		128-65		2	957	B
276		129-65		3	931	U
277		130-65		3	926	U
278		131-65			U	U
279		132-65			U	U
280		133-65			U	U
281		134-65		2	947	U, O
282		135-65			U	U
283		136-65			U	U

HAFO	IMNH	UM Ida	USGS	Prec. (m)	HHQD (m)	type
284		137-65		3	940	U
285		138-65		3	943	U
286		139-65			U	U
287		143-65			U	U
288*		144-65			F	U
289		145-65		3	984	U
290		146-65			U	U
291*		1-66			F	U
292*		2-66			U	U
293*		3-66			U	U
294*		4-66			U	U
295		5-66		3	945	U
296		6-66		3	950	U
297		8-66		3	925	U
298		9-66			U	U
299		10-66		3	970	U
300*		11-66			F	U
301		12-66		2	949	A
302		13-66		2	892	U, O
303		14-66		2	884	U, O
304		15-66		2	892	U, O
305		16-66		2	893	U, O

HAFO	IMNH	UM Ida	USGS	Prec. (m)	HHQD (m)	type
306		17-66		3	950	U
307		18-66		5	950	A
308		19-66		5	930	U
309		21-66		4	941	U
310		22-66		4	915	U
311		23-66		4	944	U
312		25-66		3	963	U
313		26-66		4	920	U
314		27-66		2	919	S
315		28-66		2	924	A
316		29-66		4	936	U
317		30-66		5	901	U
318		31-66		3	880	U
319		32-66		5	886	U
320		33-66		5	861	U
321		34-66		5	997	U
322		35-66		5	970	U
323*		36-66		3	985	U
324		37-66		6	960	U
325		38-66		3	1000	U
326*		39-66		5	975	U
327		40-66		3	990	U

HAFO	IMNH	UM Ida	USGS	Prec. (m)	HHQD (m)	type
328		41-66			U	U
329		1-67			U	U
330		2-67		3	1006	U
331		3-67		3	1006	U
332		4-67			F	U
333		5-67			U	U
334		6-67			U	U
335*		7-67			U	U
336*		8-67			U	U
337*		9-67			U	U
338*		10-67			U	U
339		12-67		3	969	U
340			20126	4	961	S
341			21022	3	980	U, O
342			19224	5	953	S
343			19213	3	945	I
344			19219	2	975	B
345			19221	2	948	S, O
346			19220	2	955	U
347			19223	3	968	U, O
348			D1126		U	U
349			D1698	4	948	U

HAFO	IMNH	UM Ida	USGS	Prec. (m)	HHQD (m)	type
350			D6125	7	882	B
351			19194	3	929	S
352			19195	4	945	S
353			19209	3	959	U, O
354			19212	3	980	U
355			19217	2	950	A
356			19222	4	968	A
357			19225		U	U
358			19226	1	917	A
359			20410	3	975	S
360			20413	2	892	S
361			20414	2	890	A
362				6	953	A
363				6	944	U, O
364			21014	3	959	U, O
365			21021	3	916	U
366			21025	12	920	U
367	85005		21038	3	922	B
368			21046	4	953	B
369	E			2	940	B
370	F			3	909	A
371				6	906	B

HAFO	IMNH	UM Ida	USGS	Prec. (m)	HHQD (m)	type
372	H			8	917	A
373	I				U	U
374	J			2	881	U
375	K			5	922	U
376	H'			4	968	S
377	P'			3	F	S
378	Q'			3	F	B
379				3	956	A
380				1	918	A
381				2	945	B
382				3	919	B
383				3	919	A
384				3	923	A
385				3	957	A
386				4	904	A
387	U'			4	892	B
388				3	941	A
389				3	954	A
390				2	948	B
391				2	932	A
392				1	932	A
393				3	945	A

HAFO	IMNH	UM Ida	USGS	Prec. (m)	HHQD (m)	type
394				2	956	A
395				4	900	A
396				2	962	A
397					U	A, B
398				4	960	A, B
399				2	958	A
400				3	957	A
401				2	950	A
402				4	946	A
403				4	960	A, B
404				4	964	A
405				3	957	B
406				3	967	A
407				3	926	A
408				5	976	A
409				5	971	A
410				5	971	A
411				2	924	A
412				1	928	A, B
413				3	952	A
414				5	935	A
415				4	970	A

HAFO	IMNH	UM Ida	USGS	Prec. (m)	HHQD (m)	type
416				4	930	A
417				5	978	A
418				3	957	A
419				5	960	B
420				3	967	B
421				2	975	B
422				4	930	A
423				3	893	A
424				1	927	S
425				4	897	A
426				5	949	A
427				2	956	B
428				1	945	B
429				5	925	A
430				4	902	A
431				5	975	A
432				5	950	A
433				3	926	A
434				3	926	A, B
435				3	947	B
436				5	920	B
437				3	907	A

HAFO	IMNH	UM Ida	USGS	Prec. (m)	HHQD (m)	type
438				5	916	A
439				4	917	B
440				4	910	B
441				4	917	A
442				5	956	A
443				3	938	B
444				3	924	A
445				5	963	B
446				1	939	B
447				1	950	B
448				2	915	I
449				3	943	A
450				1	1005	B
451				5	1007	B
452				4	941	A
453				4	941	A
454				1	944	A, B
455				2	942	A
456				4	964	S
457				5	958	A
458				1	1016	A
459				1	967	B

HAFO	IMNH	UM Ida	USGS	Prec. (m)	HHQD (m)	type
460				3	897	A
461				3	933	A, B
462				1	956	B
463				3	957	B
464				6	936	A
465				2	892	A
466				5	917	A
467				7	932	A
468				5	F	A
469				5	928	A, B
470				4	934	A
471				4	926	B
472			23013	4	967	U
473				3	942	A, S
474				4	940	B
475				4	945	B
476				4	936	B
477				5	929	A
478				2	935	A
479				3	935	A
480				2	935	A
481				2	937	B

HAFO	IMNH	UM Ida	USGS	Prec. (m)	HHQD (m)	type
482				1	926	B
483				1	899	B
484				7	950	B
485				4	950	A, B
486				4	932	A
487				7	926	A
488				1	F	A
489				2	922	I
490				7	945	A
491				5	963	A
492				5	963	A
493				2	909	A
494				1	912	A
495				1	924	A
496				5	931	B
497				3	932	I
498				3	976	A
499				3	983	A
500				2	985	A
501				3	943	B
502				3	943	A, B
503				1	943	B

HAFO	IMNH	UM Ida	USGS	Prec. (m)	HHQD (m)	type
504				5	971	B
505				1	934	A
506				2	999	I
507				5	942	A
508				4	918	B
509				4	1016	S
510				2	923	I
511				3	928	A
512				6	940	A
513				3	955	A
514				2	955	I
515				4	955	A
516				3	938	B
517				4	940	B
518				3	900	B
519				4	952	A
520				5	943	A
521				3	943	B
522				3	F	A
523				2	F	I
524				1	F	A
525				2	F	A

HAFO	IMNH	UM Ida	USGS	Prec. (m)	HHQD (m)	type
526				4	F	B
527				3	F	B
528				2	1005	A
529				2	1002	A
530				1	957	A
531				3	910	A
532				5	914	B
533				4	F	A
534				4	901	A
535				7	909	A
536				3	903	A
537				4	902	A
538				1	893	A
539				2	914	B
540				3	867	A
541					F	U
542				1	920	I
543				3	909	A
544				3	932	B
545				3	920	I
546				3	1014	I
547				3	1023	I

HAFO	IMNH	UM Ida	USGS	Prec. (m)	HHQD (m)	type
548				4	1014	S
549				3	935	A
550				3	926	B
551		50-64		5	922	A
552				3	922	A
553				3	925	A
554		90-65		3	1003	A
555				3	895	B
556				4	949	B
557				3	927	A
558				8	963	B
559				3	917	S
560				4	940	B
561				2	946	S
562				2	925	A
563				1	904	I, S
564				3	928	A
565				2	F	B
566				6	F	S
567				4	912	A
568				4	952	B
569				3	950	I

HAFO	IMNH	UM Ida	USGS	Prec. (m)	HHQD (m)	type
570				3	937	I
571				4	949	S
572					U	U, O
573				5	944	U, O
		41-64			921	U
	85006, 108			4	929	U
	85005			4	924	U
	92217				U	U
	113			4	930	U
	182			2	917	U
	183			2	859	U
	184			3	939	U
	110			2	F	U
	109			2	F	U
	111			2	F	U
	468			2	F	U
	185			4	951-956	U
	186			4	966-985	U
	181			2	993	U
	622			3	913	U
	621			3	905	U
	263			2	875	U

HAFO	IMNH	UM Ida	USGS	Prec. (m)	HHQD (m)	type
	617			2	948	U
	618			3	948	U
	619			2	936	U
	620			2	933	U
	85032			4	916	U
			19210	4	965	U
			19208	4	933	U
		11-67		3	974	U

APPENDIX B. LOCALITIES OTHER THAN HAFO DISCUSSED IN TEXT: SORTED ALPHABETICALLY BY SITE NAME

References are listed at the end of the text for Chapter 4. Individual localities within the Blanco fauna, Anza-Borrego Desert State Park, San Timeteo Formation, and Temecula Arkose are not identified; see the references given for more precise locality data. The Palmetto Fauna includes specimens from multiple phosphate mines in Polk County, Florida. Grand View fauna (sensu Repenning et al., 1995) includes Jackass Butte, Birch Creek, Chattin Hill, Black Butte, Castle Butte, Ninefoot Rapids, Oreana, Poison Creek, Unnamed Butte, and Wild Horse Butte. Faunas in the Gila Conglomerate may actually belong to multiple, unnamed formations (Morgan et al., 1997).

Locality	Formation	State	Citations
111 Ranch	Gila Conglomerate	Arizona	Galusha et al., 1984; Tomida, 1987; Morgan and White, 2005
Angus		Nebraska	L. Martin, 1969
Anita		Arizona	Hay, 1921; Lindsay and Tessman, 1974; White, 1991; Morgan and White, 2005
Anza-Borrego Desert State Park	Palm Springs (other fossiliferous formations also occur within the park))	California	Downs and White, 1968; Remeika et al., 1995; Cassiliano, 1997; Jefferson, 2001; Jefferson and Lindsay, 2006
Arroyo de la Parida	Palomas	New Mexico	Morgan and Lucas, 2001b, 2003
Arroyo Pequeno		California	White, 1987
Ash Wash		California	Dorsey, 2002; Gensler, 2002
Axtel Ranch	Ogallala	Texas	Johnston, 1939; Wang et al., 1999
Bear Springs	St. David	Arizona	Tomida, 1987; Morgan and White, 2005
Beck Ranch	Ogallala	Texas	Dalquest, 1978; Zakrzewski, 1993
Benson (=Post Ranch)	St. David	Arizona	Gidley, 1922; Gazin, 1942; Tomida, 1987; Morgan and White, 2005
Bevins Pit 2	Ogallala	Texas	Ray et al., 1981; Anderson, 1984
Big Spring	Long Pine	Nebraska	White, 1991; Bever, 2005
Birch Creek	Glenns Ferry	Idaho	Hearst, 1999
Black Ranch (=Tehama)		California	VanderHoof, 1933; Nowak, 1979

Locality	Formation	State	Citations
Blanco	Blanco	Texas	Cope, 1893; Meade, 1945; Hibbard, 1972b; Dalquest, 1975; Schultz, 1977b
Blufftop	Ringold	Washington	Gustafson, 1985b; Morgan and Morgan, 1985
Booth Draw	Keim	Nebraska	Ray et al., 1981
Borchers	Crooked Creek	Kansas	Hibbard, 1941d; R. Martin et al., 2002b
Broadwater	Broadwater	Nebraska	Hibbard, 1972b; Breyer, 1977
Buckeye Creek	Sunrise Pass	Nevada	Kelly, 1994, 1997; Trexler et al., 2000
Buckhorn	Gila Conglomerate	New Mexico	Tedford, 1981; Morgan and Sealey, 1995; Morgan et al., 1997
Buis Ranch	Ogallala	Oklahoma	Hibbard, 1954a
Buttonwillow (=Crites No. 1 Well)	San Joaquin	California	Hesse, 1934; Wilson, 1937b; Repenning, 1987
California Wash	St. David	Arizona	Johnson et al., 1985; Mezzabotta, 1997
Castle Creek	Glenns Ferry (probably)	Idaho	Leidy, 1871
Cavetown		Maryland	Van Valkenburgh et al., 1990
Chalk Flat	Glenns Ferry	Idaho	Conrad, 1980
Chamita Formation faunas	Chamita	New Mexico	White, 1987
Christian Place Quarry	Ogallala	Texas	Johnston and Savage, 1955; Wang et al., 1999
Cita Canyon	Cita	Texas	Johnston, 1938; Johnston and Savage, 1955; Savage, 1960; Hirschfeld and Webb, 1968; Hibbard, 1972b; G. Schultz, 1977b; White, 1987

Locality	Formation	State	Citations
Clarkdale	Verde Formation	Arizona	Czaplewski, 1987; Morgan and White, 2005
Coffee Ranch	Ogallala	Texas	White, 1987; Schultz, 1990
Collins	Gila Conglomerate?	Arizona	Werdelin, 1985, Seymour, 1999
Comosi Wash		Arizona	Repenning, 1962; Lindsay and Tessman, 1974; Morgan and White, 2005
Conard Fissure		Arkansas	Brown, 1908; Graham, 1972; Van Valkenburgh et al., 1990
Coso Mountains	Coso	California	Wilson, 1932, 1937b; Hesse, 1934; Wang et al., 1999
County Club	Gila Conglomerate	Arizona	Tomida, 1987; Morgan and White, 2005; White and Morgan, 2005
Courtney Pit		Alberta	Burns and Young, 1988; Owen and Burns, 2006
Crypt Cave		Nevada	Orr, 1969
Cuchillo Negro Creek	Palomas	New Mexico	Lucas and Oakes, 1986; Wang et al., 1999; Morgan and Lucas, 2002
Cucumber	Glenns Ferry	Idaho	Repenning et al., 1995
Cumberland Cave		Maryland	Gidley and Gazin, 1933b, 1938; Van der Meulen, 1978; Van Valkenburgh et al., 1990
Curtis Ranch	St. David	Arizona	Gazin, 1942; Morgan and White, 2005
De Soto Shell Pit	Caloosahatchee	Florida	Webb and Wilkins, 1984; Morgan and Hulbert, 1995; Ruez, 2001

Locality	Formation	State	Citations
Deer Park (=Deer Park A; =Rexroad Locality 1)	Rexroad	Kansas	Hibbard, 1956; Zakrzewski, 1991, 1993; R. Martin et al., 2000, 2002a
Deer Park B	Rexroad	Kansas	R. Martin et al., 2000, 2002a
Del Valle		Calilfornia	White, 1987
Devils Nest Airstrip	Ash Hollow	Nebraska	Voorhies, 1990
Duncan	Gila Conglomerate	Arizona	Tomida, 1987; Mezzabotta, 1997; Seymour, 1999; Morgan and White, 2005
El Golfo		Sonora	Shaw, 1981; Lindsay, 1984
Elk Hills	Tulare	California	Woodring et al., 1932; White, 1987
Fish Spring Flat	unnamed	Nevada	Kelly, 1994
Flat Iron Butte (Grand View fauna)	Glenns Ferry	Idaho	Conrad, 1980; White, 1987; Repenning et al., 1995
Fort Green Mine	Bone Valley	Florida	Webb, 1973; Berta and Galiano, 1983
Fox Canyon (=Rexroad Locality 4)	Rexroad	Kansas	Hibbard, 1950, 1953a; Repenning, 1962; R. Martin et al., 2000
Froman Ferry sequence	Glenns Ferry	Idaho	Hay, 1927; Repenning et al., 1995
Gilliland	Seymour	Texas	Hibbard and Dalquest, 1962, 1966; Kurtén, 1976; Dalquest and Carpenter, 1988
Grand View	Glenns Ferry	Idaho	Conrad, 1980; White, 1987; Repenning et al., 1995
Haile 7C		Florida	Webb and Wilkins, 1984; Morgan and Hulbert, 1995

Locality	Formation	State	Citations
Haile 15A		Florida	Webb, 1974; Robertson, 1976; Morgan and Hulbert, 1995
Haile 21A		Florida	Morgan and Hulbert, 1995
Hamilton Cave		West Virginia	Repenning and Grady, 1988; Van Valkenburgh et al., 1990
Honey Creek	Ash Hollow	Nebraska	Voorhies, 1990
Hooker County		Nebraska	Ray et al., 1981
Horn's Ranch	Glenns Ferry	Idaho	Stirton, 1935
Hornet	Rexroad	Kansas	R. Martin et al., 2000
Hudspeth	Camp Rice	Texas	Strain, 1966
Inglis 1A		Florida	Webb and Wilkins, 1984; Morgan and Hulbert, 1995; Ruez, 2001
Inglis 1F		Florida	Meachen, 2005
Isleta	Arroyo Ojito	New Mexico	Morgan and Lucas, 2003
Jackass Butte	Glenns Ferry	Idaho	Hirschfeld and Webb, 1968; Shotwell, 1970
Java		South Dakota	R. Martin, 1989
Jones	Rexroad	Kansas	R. Martin et al., 2000
Keefe Canyon	Rexroad	Kansas	R. Martin et al., 2000
Kern River		California	Gazin, 1934a; Wilson, 1937a; White, 1987

Locality	Formation	State	Citations
Kettleman Hills Pecten Bed (=Kettleman Hills North Dome)	San Joaquin	California	Kellogg, 1911, Stirton, 1935; Woodring et al., 1940; Repenning, 2003
Kissimmee River		Florida	Webb and Wilkins, 1984; Morgan and Hulbert, 1995
Kuchta Sand Pit	Bon Homme Gravel	South Dakota	Johnson and Milburn, 1984; Pinsof, 1985; Heaton and McDonald, 1993
La Goleta		Michoacán	Repenning, 1962; Miller and Carranza, 1984; Carranza, 1992
Ladds Quarry		Georgia	Ray, 1967
Las Tunas	Salada	Baja California	Miller, 1980; White, 1988; Munthe, 1998; Wang et al., 1999
Layer Cake	Palm Springs	California	Downs and White, 1968
Lehigh Acres	Tamiami	Florida	Morgan and Hulbert, 1995; Feranec, 2003
Lemoyne Quarry	Ash Hollow	Nebraska	Bown, 1980; Leite, 1990
Lisco	Broadwater	Nebraska	Hibbard and Schultz, 1948; Voorhies and Corner, 1986
Little Valley	Chalk Butte	Oregon	Shotwell, 1967, 1970
Los Lunas	Arroyo Ojito	New Mexico	Tedford, 1981; Morgan and Lucas, 1999
Macasphalt Shell Pit (=APAC Shell Pit; =Newburn Pit; =Warren Brothers Pit)	Tamiami	Florida	Webb and Wilkins, 1984; Morgan and Ridgway, 1987; Morgan and Hulbert, 1995; Ruez, 2001
Mailbox	Ash Hollow	Nebraska	Voorhies, 1990
Mammut raki type locality	Palomas	New Mexico	Frick, 1933; Lucas and Morgan, 1999

Locality	Formation	State	Citations
McRae Wash	St. David	Arizona	Johnson et al., 1975
Mendevil Ranch	St. David	Arizona	Johnson et al., 1975
Medicine Hat		Alberta	Churcher, 1984
Mesa Mojinas	Arroyo Ojito	New Mexico	Morgan and Lucas, 2003
Miñaca Mesa		Chihuahua	Repenning, 1962; Lindsay, 1984
Mission Viejo		California	White, 1987
Mount Eden	Mount Eden	California	Frick, 1921, Seymour, 1999
Mountainview	Sierra Ladrones	New Mexico	Morgan and Lucas, 2003
Mullen		Nebraska	L. Martin, 1972; Kurtén, 1976
Murphy	Glenns Ferry	Idaho	Sankey, 1990
Natural Trap Cave		Wyoming	L. Martin et al., 1977; L. Martin and Gilbert, 1978; Gilbert and Martin, 1984
Ninefoot Rapids	Glenns Ferry	Idaho	Conrad, 1980; White, 1987; Repenning et al., 1995
Oreana	Glenns Ferry	Idaho	Conrad, 1980; White, 1987
Oshkosh	Ash Hollow	Nebraska	White, 1987; Voorhies, 1990
Otay Ranch (=Poggi Canyon)	San Diego	California	Wagner et al., 2000, 2001
Overton		Nevada	Kurtén, 1976; Werdelin, 1985 (both authors mistakenly said this locality was in Texas)
Palmetto Fauna	Bone Valley	Florida	Webb, 1973; Berta and Galiano, 1983; Morgan, 1994; Wang et al., 1999

Locality	Formation	State	Citations
Panaca Formation faunas	Panaca	Nevada	Mou, 1999; Lindsay et al., 2002
Payne Creek Mine	Bone Valley	Florida	Webb, 1973; Berta and Galiano, 1983
Pearson Mesa	Gila Conglomerate	New Mexico	Morgan and Lucas, 2003; Morgan and White, 2005; White and Morgan, 2005
phosphate beds near Charleston		South Carolina	Kurtén, 1976
Pinole Junction	Pinole Tuff	California	Frick, 1921; Stirton, 1939; White, 1987
Pipe Creek Sinkhole		Indiana	Farlow et al., 2001; R. Martin et al. 2002b
Pliohippus Draw	Snake Creek	Nebraska	Matthew, 1932; Stirton, 1935
Poggi Canyon (=Otay Ranch)	San Diego Formation	California	Wagner et al., 2000, 2001
Porcupine Cave		Colorado	Barnosky, 2004
Port Kennedy Cave		Pennsylvania	Daeschler et al., 1993; Van Valkenburgh et al., 1990
Proctor Pits		Texas	Hirschfeld and Webb, 1968
Railroad Canyon		Idaho (?)	White, 1987
Rancho Viejo (=Arrastracaball os)		Guanajuato	Miller and Carranza-Castañeda, 1984; Carranza-Castañeda and Miller, 1996; Jimenez-Hidalgo and Carranza-Casta eda [sic], 2002 ; Jimenez-Hidalgo and Carranza-Castañeda, 2006
Red Corral	Ogallala	Texas	Taylor, 1960; White, 1987
Red Light	Love	Texas	Akersten, 1970

Locality	Formation	State	Citations
Redington	Quiburis	Arizona	Jacobs, 1977; Lindsay et al., 1984; White, 1987
Rexroad Locality 1 (=Deer Park; = Deer Park A)	Rexroad	Kansas	Hibbard, 1956; Zakrzewski, 1991, 1993; R. Martin et al., 2000, 2002a
Rexroad Locality 2	Rexroad	Kansas	Hibbard, 1938, 1941a, 1970
Rexroad Locality 3	Rexroad	Kansas	Hibbard, 1941a, 1954b, 1970; Bjork, 1973; Wagner, 1976; R. Martin et al., 2000
Rexroad Locality 4 (=Fox Canyon)	Rexroad	Kansas	Hibbard, 1950, 1953a; Repenning, 1962; R. Martin et al., 2000
Ripley B	Rexroad	Kansas	R. Martin et al., 2000
Rome		Oregon	Repenning, 1967b
San Miguel de Allende		Guanajuato	Jimenez-Hildalgo and Carranza-Castañeda, 2006
San Simon Power Line	Gila Conglomerate	Arizona	Tomida, 1987
San Timoteo faunas	San Timoteo	California	Reynolds and Reeder, 1991; Albright, 1999
Sand Draw	Keim	Nebraska	Hibbard, 1972a, b
Sand Point	Glenns Ferry	Idaho	Conrad, 1980; White, 1987
Santa Fe River 1		Florida	Webb and Wilkins, 1984; Morgan and Hulbert, 1995
Santa Fe River 1A		Florida	Webb, 1976
Santa Fe River 1B		Florida	Webb, 1976
Santa Fe River 8A		Florida	Ray et al., 1981
Santee	Ash Hollow	Nebraska	Voorhies, 1990

Locality	Formation	State	Citations
Saratoga	Santa Clara	California	Adams, 1979; Adam et al., 1983; Van Valkenburg et al., 1990
Saw Rock Canyon	Rexroad	Kansas	Hibbard, 1949, 1953a, 1957, 1964; Hibbard and Bjork, 1971
Seneca		Nebraska	Martin and Schultz, 1985
Sinker Creek	Glenns Ferry (probably)	Idaho	Leidy, 1873
Smith Mill Run		North Carolina	Ray et al., 1981
Strathcona Fiord		Nunavut	Harington, 1996, 2001, 2003; Hutchison and Harington, 2002; Tedford and Harington, 2003
Taunton	Ringold	Washington	White, 1987; Morgan and Morgan, 1995; White and Morgan, 1995; McDonald, 1998
Temecula Arkose faunas	Temecula Arkose	California	Reynolds and Reynolds, 1993; Pajak et al., 1996
Three Mile East	Glenns Ferry and Bruneau	Idaho	Sankey, 2002
Thayne		Wyoming	Fejfar and Repenning, 1998
Tijeras Arroyo	Sierra Ladrones	New Mexico	Lucas et al., 1993; Repenning et al., 1995; Morgan and Lucas, 2000, 2001a
Tonuco Mountain	Camp Rice	New Mexico	Morgan et al., 1998; Morgan and Lucas, 2003
Trench Canyon		California	White, 1987
Trigonicits macrodon type locality	Brandywine (possibly)	Maryland	Cope, 1868; Ray et al., 1981

Locality	Formation	State	Citations
Truth or Consequences	Palomas	New Mexico	Repenning and May, 1996; Lucas and Morgan, 2001, 2003
Turlock Lake	Merhten	California	Wagner, 1976
Tyson Ranch	Glenns Ferry and Bruneau	Idaho	Sankey, 1991, 2002
Unwiley Coyote Site		South Dakota	Bjork, 1996, 1997
UTEP 97		New Mexico	Vanderhill, 1986; Harris, 1993
Vallecito Creek	Palm Springs	California	Downs and White, 1968
Virden	Gila Conglomerate	New Mexico	Tedford, 1981; Morgan and Lucas, 2003; Morgan and White, 2005
Waccasassa River		Florida	Webb, 1974a; Meachen, 2005
Washoe	Sunrise Pass	Nevada	Kelly, 1997; Trexler et al., 2000
Wendell Fox	Rexroad	Kansas	Hibbard and Bjork, 1971; Bjork, 1973
White Cone	Bidahochi	Arizona	Lindsay et al., 1984; L. Martin, 1998
White Bluffs	Ringold	Washington	Gustafson, 1978; Tedford and Martin, 2001
White Narrows Formation faunas	White Narrows	Nevada	Reynolds and Lindsay, 1999
White Rock	Belleville	Kansas	Eshelman, 1975
Wiens B	Rexroad	Kansas	R. Martin et al., 2000
Wikieup	Big Sandy	Arizona	MacFadden et al., 1979; Lindsay et al., 1984; L. Martin, 1998
Wild Horse Butte	Glenns Ferry	Idaho	Shotwell, 1967, 1970

Locality	Formation	State	Citations
Wolf Ranch	St. David	Arizona	Johnson et al., 1975; Harrison, 1978; Morgan and White, 2005
Wood Mountain	Wood Mountain	Saskatchewan	Storer, 1975, 1978
Yepómera (=Ricón)		Chihuahua	Wilson, 1949; Dalquest and Mooser, 1980; Lindsay, 1984; Lindsay and Jacobs, 1985

APPENDIX C. CARNIVORAN SPECIMEN LIST

Abbreviations: l, left; r, right; c, lower canine; C, upper canine; ; dP, decidous upper premolar i, lower incisor; I, upper incisor; m, lower molar; M, upper molar; Inst., Institution; Loc. No., HAFO locality number; Spec. No., specimen number. Specimens without locality data are not listed here and were not included in this study. Specimens without a HAFO locality number listed have locality data on file with the respective institution.

Inst.	Loc. No.	Spec. No.	Taxon	Element
HAFO		266	*Borophagus hilli*	dentary, l; with c1, p4-m1
HAFO	1	831	*Borophagus hilli*	second metacarpal, r; proximal half
IMNH	13	70021/34876	*Borophagus hilli*	phalanx, proximal
UMMP	49	54660	*Borophagus hilli*	C1, l
USNM	1	24931	*Borophagus hilli*	dP4, l
UMMP	256	55963	*Buisnictis breviramus*	p4-m1, r
UMMP	1	56026	*Buisnictis breviramus*	m1
HAFO		107	*Canis lepophagus*	p3, l
HAFO		109	*Canis lepophagus*	M2, r
HAFO	7	286	*Canis lepophagus*	second metatarsal, r
HAFO	7	1092	*Canis lepophagus*	frontals and parietals; fused
HAFO	109	3907	*Canis lepophagus*	phalanx, proximal
HAFO	145	4925	*Canis lepophagus*	dentary, r; with m2
HAFO	220	6379	*Canis lepophagus*	metacarpal
IMNH	4	67002/4937	*Canis lepophagus*	dentary, r; with m2
IMNH	4	67002/4938	*Canis lepophagus*	m1, l
IMNH	29	70037/6825	*Canis lepophagus*	metacarpal
IMNH	59	70037/6826	*Canis lepophagus*	dentary, r; with m1
IMNH	367	85005/9967	*Canis lepophagus*	entocuneiform
IMNH	79	83013/32930	*Canis lepophagus*	metacarpal
UMMP	343	45222	*Canis lepophagus*	dentary, l; with p3-4, twinned p2

Inst.	Loc. No.	Spec. No.	Taxon	Element
UMMP	4	49560	*Canis lepophagus*	fifth metacarpal, r
UMMP	20	50000	*Canis lepophagus*	M1, l
UMMP	20	50008	*Canis lepophagus*	p3, r
UMMP	117	50249	*Canis lepophagus*	m2, r
UMMP	3	50335	*Canis lepophagus*	calcaneum, r
UMMP	128	51052	*Canis lepophagus*	p3, r
UMMP	3	52280	*Canis lepophagus*	P4-M2, l
UMMP	5	52757	*Canis lepophagus*	m1, r; partial
UMMP	236	53452	*Canis lepophagus*	m2, l
UMMP	274	53519	*Canis lepophagus*	dentary, r; edentulous
UMMP	21	53817	*Canis lepophagus*	p4, l
UMMP	51	53910	*Canis lepophagus*	dentaries, r and l
UMMP	188	54995	*Canis lepophagus*	P4, r
UMMP	309	56282	*Canis lepophagus*	m2, r
UMMP		56401	*Canis lepophagus*	P4-M2
UMMP	7	56809	*Canis lepophagus*	p2, r
UMMP	331	57016	*Canis lepophagus*	M1, partial
UMMP	153	49941	*Ferinestrix vorax*	femur, l
UMMP	63	53343	*Ferinestrix vorax*	dentary, r; with p4-m2
HAFO	49	4973	*Homotherium* sp.	metapodial, distal half
UMMP	21	56815	*Megantereon hesperus*	p4, r
HAFO	68	154	*Mustela rexroadensis*	dentary, r; with m1

Inst.	Loc. No.	Spec. No.	Taxon	Element
HAFO	7	6459	*Mustela rexroadensis*	humerus, l; distal end
IMNH	13	70021/34873	*Mustela rexroadensis*	canine
UMMP	4	50089	*Mustela rexroadensis*	p4-m3, l
UMMP	270	54908	*Mustela rexroadensis*	m1, l
UMMP	2707	55950	*Mustela rexroadensis*	P4, l
USNM	73	21824	*Mustela rexroadensis*	p3-m3, l
HAFO		95	*P. lacustris/L. rexroadensis*	calcaneum, r
HAFO	274	274	*P. lacustris/L. rexroadensis*	pelvis fragment
HAFO	220	1200	*P. lacustris/L. rexroadensis*	radius, r; distal end
HAFO	7	2295	*P. lacustris/L. rexroadensis*	cuboid, r
HAFO	20	2524	*P. lacustris/L. rexroadensis*	MP
HAFO		4845	*P. lacustris/L. rexroadensis*	dentary, l; with c-m1
HAFO	390	4891	*P. lacustris/L. rexroadensis*	second metatarsal, l
HAFO	345	4923	*P. lacustris/L. rexroadensis*	calcaneum, r
HAFO		4928	*P. lacustris/L. rexroadensis*	calcaneum, l
HAFO	49	4972	*P. lacustris/L. rexroadensis*	calcaneum, l; partial
HAFO	314	5019	*P. lacustris/L. rexroadensis*	lumbar
HAFO	25	8563	*P. lacustris/L. rexroadensis*	second metatarsal, l; proximal end
IMNH	75	81002/34836	*P. lacustris/L. rexroadensis*	cervical
IMNH	47	70055/35165	*P. lacustris/L. rexroadensis*	tibia
IMNH	47	70055/35166	*P. lacustris/L. rexroadensis*	metacarpal
IMNH	7	69008/37840	*P. lacustris/L. rexroadensis*	femur

Inst.	Loc. No.	Spec. No.	Taxon	Element
IMNH		85032/38171	*P. lacustris/L. rexroadensis*	acetabulum
UMMP	19217	34128	*P. lacustris/L. rexroadensis*	P4, r
UMMP	143	48929	*P. lacustris/L. rexroadensis*	dentary, l; anterior portion, edentulous
UMMP	157	48950	*P. lacustris/L. rexroadensis*	p4-m1, r
UMMP	3	50160	*P. lacustris/L. rexroadensis*	ulna, r
UMMP	3	50161	*P. lacustris/L. rexroadensis*	ulna, r
UMMP	3	50194	*P. lacustris/L. rexroadensis*	tibia, r
UMMP		50199	*P. lacustris/L. rexroadensis*	ulnae, r and l
UMMP	108	50203	*P. lacustris/L. rexroadensis*	tibia (distal), calcaneum, astragalus, and cuboid, l; associated
UMMP	3	50227	*P. lacustris/L. rexroadensis*	2m1s, partial; p3
UMMP	104	50252	*P. lacustris/L. rexroadensis*	ulna, l; proximal end
UMMP	3	50336	*P. lacustris/L. rexroadensis*	ectocuneiform, l
UMMP	101	50595	*P. lacustris/L. rexroadensis*	third metacarpal, l
UMMP	218	53530	*P. lacustris/L. rexroadensis*	calcaneum, r
UMMP	100	53684	*P. lacustris/L. rexroadensis*	P4, r; partial
UMMP	220	53712	*P. lacustris/L. rexroadensis*	third and fourth metatarsal, r
UMMP	284	53738	*P. lacustris/L. rexroadensis*	third metatarsal, l
UMMP	316	55516	*P. lacustris/L. rexroadensis*	fourth metatarsal, r
UMMP	238	55889	*P. lacustris/L. rexroadensis*	radius, l
UMMP	306	55894	*P. lacustris/L. rexroadensis*	P4, r
UMMP	314	55943	*P. lacustris/L. rexroadensis*	calcaneum and astragalus, r

Inst.	Loc. No.	Spec. No.	Taxon	Element
UMMP	314	55944	*P. lacustris/L. rexroadensis*	third metatarsal, r
UMMP	215	56085	*P. lacustris/L. rexroadensis*	ulna, l; proximal end
UMMP	3	56392	*P. lacustris/L. rexroadensis*	humerus, r; distal end
UMMP	51	56806	*P. lacustris/L. rexroadensis*	p4, l; and fourth metacarpal, l
HAFO	68	275	*Satherium piscinarium*	humerus, l; missing distal end
HAFO	7	392	*Satherium piscinarium*	dentary, r; condyle and coronoid
HAFO	7	2412	*Satherium piscinarium*	femur, r
HAFO		3665	*Satherium piscinarium*	dentary, r; with c1-m1
HAFO	214	4515	*Satherium piscinarium*	radius, l; missing distal end
HAFO	381	4519	*Satherium piscinarium*	femur, r; proximal end
HAFO		4893	*Satherium piscinarium*	dentary, r; edentulous
HAFO	445	4927	*Satherium piscinarium*	calcaneum, l
HAFO	3	4930	*Satherium piscinarium*	dentary, l; with p4-m2
HAFO	507	5303	*Satherium piscinarium*	caudal, neural arch
HAFO	507	5304	*Satherium piscinarium*	humerus, r; distal shaft
HAFO		5945	*Satherium piscinarium*	dentary, r; with alveolus for c, p4, m1
HAFO	518	6013	*Satherium piscinarium*	phalanx, proximal
HAFO	220	6380	*Satherium piscinarium*	dentary, l; edentulous
HAFO	539	6613	*Satherium piscinarium*	metatarsal
HAFO	7	7578	*Satherium piscinarium*	radius, l; proximal end
HAFO	482	7810	*Satherium piscinarium*	humerus, r; distal half
IMNH	10	70018/4935	*Satherium piscinarium*	dentary, l; with p3-4

Inst.	Loc. No.	Spec. No.	Taxon	Element
IMNH	4	67002/4939	*Satherium piscinarium*	dentary, r; edentulous
IMNH	68	80005/5380	*Satherium piscinarium*	maxilla, r; with P4-M1
IMNH	1	31001/7941	*Satherium piscinarium*	dentary, r; edentulous
IMNH	4	67002/34548	*Satherium piscinarium*	dentary, l; edentulous
IMNH	23	70031/35149	*Satherium piscinarium*	humerus, r; distal end
IMNH		85032/38183	*Satherium piscinarium*	dentary, r; edentulous
IMNH	367	85005/38645	*Satherium piscinarium*	m1, l; in dentary fragment
IMNH	368	85005/39202	*Satherium piscinarium*	p2, r
UMMP	5	45244	*Satherium piscinarium*	rI3, lP3, lM1, lm2, proximal end of second metatarsal
UMMP	3	45299	*Satherium piscinarium*	dentaries, r and l; edentulous; and rm1
UMMP	4	49562	*Satherium piscinarium*	p4, 1l and 1r
UMMP	4	49565	*Satherium piscinarium*	P4, r
UMMP	168	49647	*Satherium piscinarium*	dentary, l; edentulous
UMMP	125	49938	*Satherium piscinarium*	radius, l
UMMP	20	50002	*Satherium piscinarium*	humerus, r
UMMP	20	50003	*Satherium piscinarium*	radius, l
UMMP	20	50005	*Satherium piscinarium*	ulna, l
UMMP	4	50090	*Satherium piscinarium*	P4, r
UMMP	4	50098	*Satherium piscinarium*	humerus, r
UMMP	285	53422	*Satherium piscinarium*	calcaneum, l
UMMP	285	53423	*Satherium piscinarium*	dentary, r; edentulous; and l humerus

Inst.	Loc. No.	Spec. No.	Taxon	Element
UMMP	37	53425	*Satherium piscinarium*	skull and dentary
UMMP	207	53428	*Satherium piscinarium*	dentary, l; edentulous
UMMP	7	53611	*Satherium piscinarium*	radius, l; proximal end
UMMP	220	53713	*Satherium piscinarium*	femora, r; 2 proximal ends
UMMP	277	53727	*Satherium piscinarium*	femur, l; proximal end
UMMP	277	53732	*Satherium piscinarium*	dentary, l; with p4-m1
UMMP	225	53741	*Satherium piscinarium*	dentary, l; edentulous
UMMP	237	53779	*Satherium piscinarium*	dentary, l; edentulous
UMMP	235	53908	*Satherium piscinarium*	dentary, l; with c and p2-4; and humerus, r
UMMP	262	54575	*Satherium piscinarium*	ulna, r
UMMP	51	54597	*Satherium piscinarium*	atlas and lp2
UMMP	191	54720	*Satherium piscinarium*	p4, r
UMMP	222	55003	*Satherium piscinarium*	ulna, l; proximal half
UMMP	52	55010	*Satherium piscinarium*	tibia, l
UMMP	215	55019	*Satherium piscinarium*	calcaneum, r
UMMP	55	55443	*Satherium piscinarium*	radius, l; proximal end
UMMP	256	55973	*Satherium piscinarium*	p4, l
UMMP	309	56284	*Satherium piscinarium*	tibia, l
UMMP	258	56808	*Satherium piscinarium*	dentary, r; edentulous
UMMP	330	56810	*Satherium piscinarium*	p2, r
UMMP	21	56814	*Satherium piscinarium*	p2, l
UMMP	49	56988	*Satherium piscinarium*	third metacarpal and third metatarsal

Inst.	Loc. No.	Spec. No.	Taxon	Element
UMMP	226	uncataloged	*Satherium piscinarium*	dentary, r; with p4-m3
UMMP	226	uncataloged	*Satherium piscinarium*	radius and ulna, l
USNM	1	12604	*Satherium piscinarium*	dentaries, r and l; premaxilla; rP4, and distal end of r humerus
USNM	1	12605	*Satherium piscinarium*	dentary, r; partial
USNM	1	12609	*Satherium piscinarium*	half endocranial cast
USNM	1	12610	*Satherium piscinarium*	dentary, r; with p3-m3
UMMP	5	52756	*Sminthosinis bowleri*	dentary, r; with p3-m1
UMMP	5	52868	*Sminthosinis bowleri*	maxilla, r; with I3, C, P1-M1
UMMP	63	53344	*Sminthosinis bowleri*	P4, l
UMMP	7	55174	*Sminthosinis bowleri*	M1, r; and m1, l
UMMP	63	55214	*Sminthosinis bowleri*	P3-M1, r
UMMP	7	55952	*Sminthosinis bowleri*	P4, r
UMMP	7	55953	*Sminthosinis bowleri*	M1, l
UMMP	1	56025	*Sminthosinis bowleri*	m1, l
UMMP	63	53345	*Taxidea* sp.	dentary, l; anterior portion with partial c and p4
HAFO	246	870	*Trigonictis cookii*	ulna, r; olecranon
HAFO	7	2913	*Trigonictis cookii*	m1, l
HAFO	424	4526	*Trigonictis cookii*	dentary, l; with p3-m1
HAFO	424	4527	*Trigonictis cookii*	humerus, l; proximal end
HAFO	501	5742	*Trigonictis cookii*	premaxilla, l and r; edentulous
HAFO	1	6688	*Trigonictis cookii*	maxilla, r; with P4

Inst.	Loc. No.	Spec. No.	Taxon	Element
HAFO	25	6797	*Trigonictis cookii*	dentary, r; partial
HAFO	220	7999	*Trigonictis cookii*	dentary, r; edentulous
IMNH	367	85005/9973	*Trigonictis cookii*	maxillae and premaxillae, r and l; with lP2-M1 and rP2
IMNH	367	85005/9974	*Trigonictis cookii*	maxillae and premaxillae, r and l; with lP2-M1 and rP3
IMNH	3	65006/35140	*Trigonictis cookii*	dentary, r; with p2-m2
UMMP	117	54659	*Trigonictis cookii*	P4, l
UMMP	318	55514	*Trigonictis cookii*	dentary, l; with p2-m1
UMMP	330	56165	*Trigonictis cookii*	dentary, l; edentulous
UMMP	3	56807	*Trigonictis cookii*	M1, r
HAFO	25	749	*Trigonictis macrodon*	dentary, l; edentulous
HAFO	68	6527	*Trigonictis macrodon*	c1; tip broken
HAFO	485	7983	*Trigonictis macrodon*	m1, r; partial
IMNH	50	70058/5349	*Trigonictis macrodon*	dentary, l; edentulous
IMNH	68	80005/5440	*Trigonictis macrodon*	dentary, r; edentulous
IMNH	4	67002/8125	*Trigonictis macrodon*	dentary, l; edentulous
IMNH	367	85005/38647	*Trigonictis macrodon*	dentary, r; with c-m1
UMMP	3	45304	*Trigonictis macrodon*	maxilla, r
UMMP	104	48862	*Trigonictis macrodon*	dentary, r; with p2-m1
UMMP	123	48863	*Trigonictis macrodon*	dentary, r; with p2-m1
UMMP	4	49566	*Trigonictis macrodon*	P4, l
UMMP	103	49646	*Trigonictis macrodon*	dentary, r; with p4-m3
UMMP	162	49649	*Trigonictis macrodon*	dentaries, r and l

Inst.	Loc. No.	Spec. No.	Taxon	Element
UMMP	149	49654	*Trigonictis macrodon*	dentary, r; with p4-m1
UMMP	149	49655	*Trigonictis macrodon*	dentary, r; with p4
UMMP	156	49657	*Trigonictis macrodon*	dentary, r; edentulous
UMMP	117	49659	*Trigonictis macrodon*	dentary, l; edentulous
UMMP	117	49660	*Trigonictis macrodon*	dentary, r; with m1
UMMP	117	49661	*Trigonictis macrodon*	dentary, l; with m1
UMMP	136	49662	*Trigonictis macrodon*	dentary, l; with p3-4
UMMP	136	49663	*Trigonictis macrodon*	dentary, l; edentulous
UMMP	100	49728	*Trigonictis macrodon*	P4, l
UMMP	100	49729	*Trigonictis macrodon*	maxilla, r; with P3
UMMP	170	50253	*Trigonictis macrodon*	ulna, l
UMMP	104	50739	*Trigonictis macrodon*	femur, r; distal end
UMMP	128	51049	*Trigonictis macrodon*	humerus, r; distal end
UMMP	136	51376	*Trigonictis macrodon*	humerus, r; distal end
UMMP	34	53273	*Trigonictis macrodon*	M1, l
UMMP	258	53547	*Trigonictis macrodon*	dentary, l; partial
UMMP	261	53554	*Trigonictis macrodon*	humerus, l; distal end
UMMP	180	53556	*Trigonictis macrodon*	humerus, l; distal end
UMMP	141	54821	*Trigonictis macrodon*	dentary, r; with m1 talonid
UMMP	287	54997	*Trigonictis macrodon*	dentary, r; with c, p3-m2
UMMP	243	55001	*Trigonictis macrodon*	humerus, r; distal end
UMMP	189	55005	*Trigonictis macrodon*	humerus, r; partial

Inst.	Loc. No.	Spec. No.	Taxon	Element
UMMP	177	55009	*Trigonictis macrodon*	tibia, r
UMMP	7	55951	*Trigonictis macrodon*	P4, l
UMMP	3	56070	*Trigonictis macrodon*	P4, l
UMMP	220	56082	*Trigonictis macrodon*	dentary, r; with m1
UMMP	339	56096	*Trigonictis macrodon*	tibia, l
UMMP	331	56201	*Trigonictis macrodon*	dP3, l
UMMP	220	56929	*Trigonictis macrodon*	dentary, r; with p2-m1
HAFO	390	3817	*Ursus abstrusus*	m1, r; partial
UMMP	26	49950	*Ursus abstrusus*	humerus, l; distal half
UMMP	231	53419	*Ursus abstrusus*	dentary, r; with m1

APPENDIX D. INSECTIVORAN SPECIMEN LIST

This list includes all the insectivoran material from HAFO that is housed onsite or at IMNH. Specimens curated at UMMP and USNM were previously reported elsewhere (Gazin, 1933a; Hibbard and Bjork, 1971; Hutchison, 1987). There are other specimens representing insectivorans from HAFO that are not included in this study because they lack locality data. Some specimens listed here do have locality data, but are not associated with a HAFO locality number. IMNH specimen numbers are prefixed with the IMNH locality numbers; the corresponding HAFO locality number is given here also.

Abbreviations: l, left; m, lower molar; Loc. No., HAFO locality number; M, upper molar; p, lower premolar; P, upper premolar; r, right; Spec. No., specimen number; u, lower unicuspid; x, indeterminable tooth number.

Inst.	Loc. No.	Spec. No.	Taxon	Element
HAFO	6	74	*Paracryptotis gidleyi*	dentary, r; edentulous
HAFO		419	*Paracryptotis gidleyi*	dentary, l; edentulous
HAFO	7	711	*Paracryptotis gidleyi*	dentary, r; with u1-m3
HAFO	7	712	*Paracryptotis gidleyi*	dentary, l; with m1
HAFO	7	713A	*Paracryptotis gidleyi*	dentary, r; with m1-2
HAFO	7	713B	*Paracryptotis gidleyi*	dentary, l; with m2-3
HAFO	7	714	*Paracryptotis gidleyi*	dentary, l; with m1
HAFO		1048	*Paracryptotis gidleyi*	dentary, r; edentulous
HAFO		1173	*Paracryptotis gidleyi*	dentary, r; with m1-3
HAFO	7	2912	*Paracryptotis gidleyi*	dentary, r; with m1-2
HAFO	7	3022	*Paracryptotis gidleyi*	dentary, r; with m1-3
HAFO	7	3057	*Paracryptotis gidleyi*	dentary, r; with m1-2
HAFO	557	3895	*Paracryptotis gidleyi*	dentary, l; with m2
HAFO	479	4297	*Paracryptotis gidleyi*	dentary, l; with m2
HAFO	432	4440	*Paracryptotis gidleyi*	dentary, l; with m2
HAFO	214	4441	*Paracryptotis gidleyi*	dentary, l; with partial m1
HAFO	214	4442	*Paracryptotis gidleyi*	dentary, r; with m1-2
HAFO	381	4485	*Paracryptotis gidleyi*	maxillae and premaxillae, fused; edentulous
HAFO	454	4834	*Paracryptotis gidleyi*	dentary, l; with m1-3
HAFO	6	5079	*Paracryptotis gidleyi*	dentary, r; with m1-3

Inst.	Loc. No.	Spec. No.	Taxon	Element
HAFO	7	5509	*Paracryptotis gidleyi*	dentary, r; with m1-3
HAFO	7	5512	*Paracryptotis gidleyi*	dentary, l; edentulous
HAFO	503	5879	*Paracryptotis gidleyi*	dentary, r; with m1-2
HAFO	68	6522	*Paracryptotis gidleyi*	dentary, l; edentulous
HAFO	68	6523	*Paracryptotis gidleyi*	dentary, l; edentulous
HAFO	68	6524	*Paracryptotis gidleyi*	dentary, r; edentulous
HAFO	68	6525	*Paracryptotis gidleyi*	dentary, r; with m2-3
HAFO		6623	*Paracryptotis gidleyi*	dentary, l; edentulous
HAFO	461	6994	*Paracryptotis gidleyi*	dentary, r; edentulous
HAFO	461	6995	*Paracryptotis gidleyi*	dentary, l; edentulous
HAFO	461	6996	*Paracryptotis gidleyi*	dentary, l; edentulous
HAFO		7741	*Paracryptotis gidleyi*	dentary, r; edentulous
HAFO	488	8233	*Paracryptotis gidleyi*	dentary, r; with roots of m1-3
HAFO	25	8281	*Paracryptotis gidleyi*	dentary, r; with m1-2
HAFO	7	8669	*Paracryptotis gidleyi*	dentary, r; with m1
HAFO	7	8704G	*Paracryptotis gidleyi*	m2, r
IMNH	110	110/38618	*Paracryptotis gidleyi*	dentary, l; with m1-3
IMNH	1	31001/4933	*Paracryptotis gidleyi*	dentary, r; with m3
IMNH	4	67002/8111	*Paracryptotis gidleyi*	dentary, r; with m1-2
IMNH	5	69003/35125	*Paracryptotis gidleyi*	dentary, r; with partial m2
IMNH	5	69003/5295	*Paracryptotis gidleyi*	dentary, r; with ux, p4-m3
IMNH	6	69007/28862	*Paracryptotis gidleyi*	dentary, r; edentulous

Inst.	Loc. No.	Spec. No.	Taxon	Element
IMNH	6	69007/28863	*Paracryptotis gidleyi*	dentary, l; with m1-3
IMNH	6	69007/28864	*Paracryptotis gidleyi*	dentary, l; with m2
IMNH	6	69007/28865	*Paracryptotis gidleyi*	dentary, l; with m2
IMNH	6	69007/28866	*Paracryptotis gidleyi*	dentary, r; with m1
IMNH	6	69007/28867	*Paracryptotis gidleyi*	dentary, l; edentulous
IMNH	6	69007/28868	*Paracryptotis gidleyi*	dentary, r; with m1-2
IMNH	6	69007/28869	*Paracryptotis gidleyi*	dentary, r; with m2-3
IMNH	6	69007/28870	*Paracryptotis gidleyi*	dentary, r; with p2-m3
IMNH	6	69007/28871	*Paracryptotis gidleyi*	dentary, r;; with m1-2
IMNH	6	69007/28872	*Paracryptotis gidleyi*	dentary, l; with p4-m2
IMNH	6	69007/28873	*Paracryptotis gidleyi*	dentary, r; edentulous
IMNH	6	69007/28874	*Paracryptotis gidleyi*	dentary, r; edentulous
IMNH	6	69007/5306	*Paracryptotis gidleyi*	dentary, r; edentulous
IMNH	7	69008/33668	*Paracryptotis gidleyi*	dentary, r; with m2-3
IMNH	7	69008/33669	*Paracryptotis gidleyi*	dentary, r; with m1-3
IMNH	7	69008/33670	*Paracryptotis gidleyi*	dentary, l; with m1-3
IMNH	7	69008/33671	*Paracryptotis gidleyi*	maxillae, fused; with l P3-M2 and r P3-M2
IMNH	7	69008/34407	*Paracryptotis gidleyi*	dentary, r; with m1
IMNH	7	69008/34408	*Paracryptotis gidleyi*	dentary, l; edentulous
IMNH	7	69008/34409	*Paracryptotis gidleyi*	dentary, r; with m1-2
IMNH	7	69008/34410	*Paracryptotis gidleyi*	dentary, l; with p4-m3
IMNH	7	69008/4932	*Paracryptotis gidleyi*	dentary, l; edentulous

Inst.	Loc. No.	Spec. No.	Taxon	Element
IMNH	20	70028/5333	*Paracryptotis gidleyi*	dentary, l; edentulous
IMNH	68	80005/31461	*Paracryptotis gidleyi*	dentary, l; with m1-3
IMNH	68	80005/31462	*Paracryptotis gidleyi*	dentary, l; with p2, p4-m2
IMNH	68	80005/4923	*Paracryptotis gidleyi*	dentary, l; with m1
IMNH	68	80005/4924	*Paracryptotis gidleyi*	dentary, l; edentulous
IMNH	68	80005/4925	*Paracryptotis gidleyi*	dentary, r; with m1-2
IMNH	68	80005/4926	*Paracryptotis gidleyi*	dentary, r; with m1
IMNH	68	80005/4927	*Paracryptotis gidleyi*	dentary, r; with p4-m2
IMNH	68	80005/4928	*Paracryptotis gidleyi*	dentary, l; with m1
IMNH	68	80005/4929	*Paracryptotis gidleyi*	dentary, l; with m1
IMNH	68	80005/4930	*Paracryptotis gidleyi*	dentary, r; with m1-3
IMNH	68	80005/4931	*Paracryptotis gidleyi*	dentary, l; with m1-2
IMNH	367	85005/39206	*Paracryptotis gidleyi*	dentary, r; with u2-m2
IMNH	98	85029/38473	*Paracryptotis gidleyi*	dentary, l; edentulous
IMNH	98	85029/38474	*Paracryptotis gidleyi*	dentary, l; with m1-3
IMNH	98	85029/6138	*Paracryptotis gidleyi*	maxilla, r; with P4-M2
IMNH	98	85029/6182	*Paracryptotis gidleyi*	dentary, r; edentulous
IMNH	98	85029/6188	*Paracryptotis gidleyi*	dentary, r; edentulous
HAFO		398	*Scapanus hagermanensis*	humerus
HAFO		3080	*Scapanus hagermanensis*	radius
HAFO		6990	*Scapanus hagermanensis*	m1 or m2, r
HAFO		4698	*Sorex meltoni*	dentary, l; with m1-2

Inst.	Loc. No.	Spec. No.	Taxon	Element
HAFO		2329e	*Sorex meltoni*	dentary, l; with m1-2

APPENDIX E. MEASUREMENTS OF LOWER MOLARS OF *PARACRYPTOTIS GIDLEYI*

Abbreviations are as in Appendix D.

		m1		m2		m3	
Inst.	Spec. No.	length	width	length	width	length	width
HAFO	712	2.02	1.38				
HAFO	713A	1.98	1.22	1.65	1.13		
HAFO	713B			1.64	1.19	1.19	0.82
HAFO	714	1.96	1.39				
HAFO	1173	2.10	1.38	1.65	1.08	1.24	0.83
HAFO	2912	1.98	1.31	1.53	1.16		
HAFO	3022	2.00	1.34	1.57	1.08	1.12	0.72
HAFO	3057	1.99	1.34	1.60	1.13		
HAFO	3895			1.74	1.14		
HAFO	4297			1.77	1.06		
HAFO	4440			1.70	1.18		
HAFO	4442	1.98	1.18	1.61	0.96		
HAFO	4834	1.95	1.28	1.70	1.03	1.13	0.70

		m1		m2		m3	
Inst.	Spec. No.	length	width	length	width	length	width
HAFO	5079	1.85	1.38	1.62	1.10	1.13	0.83
HAFO	5509	1.86	1.34	1.55	1.12	1.18	0.78
HAFO	5879	1.85	1.31	1.62	1.02		
HAFO	6525			1.63	1.27	0.95	0.75
HAFO	8281	2.00	1.32	1.68	1.23		
HAFO	8669	1.98	1.31				
HAFO	8704g	1.64	1.02				
IMNH	110/38618	2.18	1.35	1.65	1.26	0.99	0.72
IMNH	31001/4933					1.22	0.85
IMNH	67002/8111		1.28	1.61	1.00		
IMNH	69003/5295	1.95	1.31	1.67	1.14	1.28	0.90
IMNH	69007/28863	1.72	1.03	1.40	0.82		
IMNH	69007/28864			1.41	0.98		
IMNH	69007/28865			1.49	1.03		
IMNH	69007/28866	1.97	1.36				
IMNH	69007/28867						
IMNH	69007/28868	1.83	1.19	1.37	0.99		
IMNH	69007/28869			1.62	0.81	0.95	0.60
IMNH	69007/28870	1.82	1.19	1.56	0.93	0.98	0.63
IMNH	69007/28871	2.00	1.28	1.50	1.10		
IMNH	69007/28872	2.00	1.20	1.41	1.04		

		m1		m2		m3	
Inst.	Spec. No.	length	width	length	width	length	width
IMNH	69008/33668			1.59	1.02	1.09	0.70
IMNH	69008/33669	2.05	1.27	1.6	1.16	1.22	0.71
IMNH	69008/33670	1.97	1.22	1.48	1.23	1.05	0.73
IMNH	69008/34407	2.09	1.31				
IMNH	69008/34409	1.88	1.35	1.58	1.15		
IMNH	69008/34410	2.05	1.27	1.65	1.13	1.08	0.76
IMNH	80005/31461	1.91	1.08	1.42	0.86	0.76	0.54
IMNH	80005/31462	1.92	1.10	1.37	1.09		
IMNH	80005/4923	1.81	1.08				
IMNH	80005/4925	1.80	1.00	1.65	0.89		
IMNH	80005/4926	1.88	1.09				
IMNH	80005/4927	1.85	1.03	1.49	0.88		
IMNH	80005/4928	2.05	1.14				
IMNH	80005/4929	1.96	1.98				
IMNH	80005/4930	2.00	1.08	1.45	0.80	1.00	0.40
IMNH	80005/4931		1.00	1.30	0.82		
IMNH	85005/39206	1.97	1.2	1.50	0.99		
IMNH	85029/38474	1.99	1.40	1.62	1.10	1.10	0.74

APPENDIX F. LEPORID SPECIMEN LIST

This list includes all the leporid material from HAFO that is housed onsite or at IMNH. Specimens curated at UMMP and USNM, and some at IMNH, were previously reported elsewhere (Gazin, 1934a; Campbell, 1969; Hibbard, 1969; White, 1987, 1991) and included in my analyses if identified to species level and with precise locality data. Abbreviations: l, left; i, lower incisor; I, upper incisor; Loc. No., HAFO locality number; m, lower molar; M, upper molar; p, lower premolar; P, upper premolar; r, right; Spec. No., specimen number. Specimens without locality data are not listed here and were not included in this study. Specimens without a HAFO locality number listed do have locality data on file with the respective institution.

Inst.	Loc. No.	Spec. No.	Taxon	Element
HAFO	197	110	*Alilepus vagus*	calcaneum, r
HAFO		1177	*Alilepus vagus*	tibia, l; distal end
HAFO	3	5385	*Alilepus vagus*	tibia, l; distal end
HAFO	1	7499	*Alilepus vagus*	p3, r
HAFO	18	7969	*Alilepus vagus*	p3, l
HAFO		8511	*Alilepus vagus*	tibia, r; distal end
HAFO	7	8640	*Alilepus vagus*	calcaneum, l
HAFO	461	8966	*Alilepus vagus*	tibia, r; unfused distal epiphysis
IMNH	5	69003/4944	*Alilepus vagus*	p3, r
IMNH	5	69003/4943	*Alilepus vagus*	dentary, r; with p3-m2
IMNH	367	80005/4948	*Alilepus vagus*	p3, r
IMNH	367	80005/4955	*Alilepus vagus*	P2, r
IMNH	7	69008/4982	*Alilepus vagus*	dentary, l; with i-m/
IMNH	7	69008/4987	*Alilepus vagus*	p3, r
IMNH	47	70055/30516	*Alilepus vagus*	dentary, l; with p3-2
IMNH	7	69008/30903	*Alilepus vagus*	p3, r
IMNH	7	69008/30904	*Alilepus vagus*	p3, l
IMNH	7	69008/32412	*Alilepus vagus*	p3, l
IMNH	7	69008/34400	*Alilepus vagus*	p3, r
IMNH	1	31001/34752	*Alilepus vagus*	p3, r
IMNH	5	69003/35100	*Alilepus vagus*	p3, l

Inst.	Loc. No.	Spec. No.	Taxon	Element
IMNH	7	69008/38517	*Alilepus vagus*	p3, r
IMNH	367	85005/39191	*Alilepus vagus*	p3, r
IMNH	367	85005/39190	*Alilepus vagus*	p3, l
UMMP		23574	*Alilepus vagus*	dentaries, r and l fused; with l and r p3-m3
UMMP		48943	*Alilepus vagus*	dentary, l; with p3-m3
UMMP		52754	*Alilepus vagus*	dentary, r; with p3-m3
UMMP		55050	*Alilepus vagus*	dentary, l; with p3-m3
UMMP		55051	*Alilepus vagus*	dentary, l; with p3-m3
USNM	1	12622	*Alilepus vagus*	dentary, r; with p3
USNM	1	23574	*Alilepus vagus*	skull and 50 parts of associated skeleton
HAFO	7	216	*Hypolagus edensis*	dentary, r; with p/3-m/2 and partial i
HAFO	7	671	*Hypolagus edensis*	calcaneum, l
HAFO	39	989	*Hypolagus edensis*	p3, r
HAFO		1017	*Hypolagus edensis*	calcaneum, r
HAFO		1131	*Hypolagus edensis*	p3, r; base
HAFO	213	1165	*Hypolagus edensis*	p3, l
HAFO	7	3070a	*Hypolagus edensis*	p3, r
HAFO	7	3070b	*Hypolagus edensis*	p3, l
HAFO	7	3096a	*Hypolagus edensis*	p3, r
HAFO	3	6591	*Hypolagus edensis*	calcaneum, l
HAFO	63	8549	*Hypolagus edensis*	dentary, r; with 1-p3

Inst.	Loc. No.	Spec. No.	Taxon	Element
IMNH	367	80005/4951	*Hypolagus edensis*	P2, l
IMNH	367	80005/4952	*Hypolagus edensis*	P2, r
IMNH	367	80005/4953	*Hypolagus edensis*	P2, r
IMNH	7	69008/4984	*Hypolagus edensis*	p3, r
IMNH	7	69008/4985	*Hypolagus edensis*	p3, r
IMNH	7	69008/4986	*Hypolagus edensis*	p3, r
IMNH	7	69008/4988	*Hypolagus edensis*	p3, l
IMNH	7	69008/30905	*Hypolagus edensis*	p3, r
IMNH	7	69008/33639	*Hypolagus edensis*	p3, l
IMNH	7	69008/33640	*Hypolagus edensis*	p3, l
IMNH	7	69008/33641	*Hypolagus edensis*	p3, l
IMNH	7	69008/34391	*Hypolagus edensis*	p3, r
IMNH	7	69008/34401	*Hypolagus edensis*	p3, l
UMMP		54782	*Hypolagus edensis*	p3, r
USNM		12619	*Hypolagus edensis*	skull, r dentary, and atlas; with r P2-M3, l P3-M3 and r p3-m3
HAFO	68	7	*Hypolagus gidleyi*	calcaneum, r
HAFO	68	155	*Hypolagus gidleyi*	p3, r
HAFO	247	295	*Hypolagus gidleyi*	astragalus, r
HAFO		297	*Hypolagus gidleyi*	tibia, l; distal half
HAFO	129	314	*Hypolagus gidleyi*	humerus, r; distal half
HAFO		916	*Hypolagus gidleyi*	calcaneum, l

Inst.	Loc. No.	Spec. No.	Taxon	Element
HAFO	39	991	*Hypolagus gidleyi*	p3, r
HAFO	7	1140	*Hypolagus gidleyi*	dentary, r; with partial p3, p4-m1
HAFO		1204	*Hypolagus gidleyi*	calcaneum, r
HAFO	68	1283b	*Hypolagus gidleyi*	p3, l
HAFO	68	1283c	*Hypolagus gidleyi*	p3, r
HAFO	68	1283d	*Hypolagus gidleyi*	p3, l
HAFO	68	1283e	*Hypolagus gidleyi*	p3, r
HAFO	68	1283f	*Hypolagus gidleyi*	p3, l; partial
HAFO	68	1283g	*Hypolagus gidleyi*	p3, l
HAFO	68	1311b	*Hypolagus gidleyi*	p3, r
HAFO		2271	*Hypolagus gidleyi*	dentary, l; with p3-m3
HAFO		2329g	*Hypolagus gidleyi*	p3, l
HAFO	66	3081	*Hypolagus gidleyi*	dentary, r; with p3-m3
HAFO	68	3757	*Hypolagus gidleyi*	P2, r
HAFO		3885	*Hypolagus gidleyi*	p3, l
HAFO	76	3913	*Hypolagus gidleyi*	p3, r
HAFO	112	4465	*Hypolagus gidleyi*	dentary, l; with p3-m2
HAFO	428	4616	*Hypolagus gidleyi*	p3, r
HAFO	459	4890	*Hypolagus gidleyi*	calcaneum, r
HAFO	214	4953	*Hypolagus gidleyi*	ulna, r; proximal end
HAFO	517	5368	*Hypolagus gidleyi*	p3, l
HAFO	3	5414	*Hypolagus gidleyi*	p3, r

Inst.	Loc. No.	Spec. No.	Taxon	Element
HAFO	504	5667	*Hypolagus gidleyi*	calcaneum, l
HAFO	192	5904	*Hypolagus gidleyi*	calcaneum, r
HAFO		6211	*Hypolagus gidleyi*	astragalus, l
HAFO	355	6269	*Hypolagus gidleyi*	p3, l
HAFO	563	6366	*Hypolagus gidleyi*	calcaneum, l
HAFO		6784	*Hypolagus gidleyi*	humerus, l; distal end
HAFO	7	8409	*Hypolagus gidleyi*	tibia, r; distal end
HAFO	66	8426	*Hypolagus gidleyi*	p3, l
HAFO	66	8434	*Hypolagus gidleyi*	femur, l; distal end
HAFO	561	8825	*Hypolagus gidleyi*	calcaneum, r
HAFO	76	8861	*Hypolagus gidleyi*	calcaneum, r
HAFO	461	8967	*Hypolagus gidleyi*	calcaneum, l
IMNH	367	80005/4949	*Hypolagus gidleyi*	p3, l
IMNH	367	80005/4950	*Hypolagus gidleyi*	p3, l
IMNH	367	80005/4954	*Hypolagus gidleyi*	P2, r
IMNH	4	67002/4978	*Hypolagus gidleyi*	dentary, r; with p3-4
IMNH	4	67002/4980	*Hypolagus gidleyi*	p3, r
IMNH	367	80005/5443	*Hypolagus gidleyi*	P2, l
IMNH	197	85006/6094	*Hypolagus gidleyi*	p3, l
IMNH	197	85006/6095	*Hypolagus gidleyi*	p3, l
IMNH	197	85006/15413	*Hypolagus gidleyi*	p3, r
IMNH	1	31001/29534	*Hypolagus gidleyi*	dentary, l; with i-m3

Inst.	Loc. No.	Spec. No.	Taxon	Element
IMNH	4	67002/29535	*Hypolagus gidleyi*	dentary, l; with i-m/
IMNH	88	83028/33736	*Hypolagus gidleyi*	p3, l
IMNH	1	31001/34849	*Hypolagus gidleyi*	p3, r
IMNH	1	31001/34858	*Hypolagus gidleyi*	p3, l
IMNH	1	31001/34860	*Hypolagus gidleyi*	p3, r
IMNH	1	31001/34864	*Hypolagus gidleyi*	p3, l
IMNH	367	85005/39189	*Hypolagus gidleyi*	p3, r
IMNH	367	85005/39170	*Hypolagus gidleyi*	dentary, r; with p3-m2
UMMP		48946	*Hypolagus gidleyi*	dentary, l; with p3-m3
UMMP		49713	*Hypolagus gidleyi*	p3, l
UMMP		55053	*Hypolagus gidleyi*	p3, r
USNM		12620	*Hypolagus gidleyi*	dentary, r; with p4-m2
USNM		12621	*Hypolagus gidleyi*	dentary, r; with p3
USNM		23573	*Hypolagus gidleyi*	skull, complete; with complete l and r dentaries
HAFO	68	2	Leporidae	calcaneum, r; distal end
HAFO	197	111	Leporidae	calcaneum, l; missing proximal end
HAFO	197	112	Leporidae	phalanges, 2 proximal and 1 medial; 2 partial metacarpals
HAFO	197	115	Leporidae	calcaneum, l; partial
HAFO	197	117	Leporidae	astragalus, r
HAFO	68	183	Leporidae	phalanx, medial
HAFO	68	184	Leporidae	calcaneum, l

Inst.	Loc. No.	Spec. No.	Taxon	Element
HAFO	68	185	Leporidae	phalanx, proximal
HAFO	197	186	Leporidae	phalanx, proximal
HAFO	68	190	Leporidae	radius, distal half; proximal end metatarsal; 2 proximal phalanges
HAFO	68	192	Leporidae	metatarsal, proximal half; ungual phalanx
HAFO	7	234	Leporidae	m2, r
HAFO	7	235	Leporidae	m2, l
HAFO	7	236	Leporidae	P3, l
HAFO	20	271	Leporidae	M2, l
HAFO	7	278	Leporidae	humerus, l; distal half
HAFO	129	316	Leporidae	calcaneum, r
HAFO		400	Leporidae	P2, l
HAFO		420	Leporidae	phalanx, proximal
HAFO	7	667	Leporidae	cheekteeth, 5 lower
HAFO	7	668	Leporidae	cheekteeth, 4 upper
HAFO	7	669	Leporidae	vertebra, lumbar
HAFO	7	672	Leporidae	scapula, l; glenoid portion
HAFO	7	673	Leporidae	phalanges, 2 proximal
HAFO	7	698	Leporidae	phalanges, 2 medial
HAFO	7	710	Leporidae	i1, r
HAFO	103	747	Leporidae	phalanx, proximal
HAFO	352	837	Leporidae	tibia, r; distal end

Inst.	Loc. No.	Spec. No.	Taxon	Element
HAFO	68	897	Leporidae	metatarsal 4, l
HAFO	68	899	Leporidae	dentary, l; with m1-2
HAFO	68	905	Leporidae	humeri, distal ends; 1r and 1l
HAFO	7	981	Leporidae	tibia, l; missing distal end and unfused proximal epiphysis
HAFO	39	990	Leporidae	P2, l
HAFO	39	1005	Leporidae	M1, r; partial
HAFO	68	1269	Leporidae	astragalus, l; partial
HAFO	68	1270	Leporidae	phalanges, proximal; 2 complete, 3 proximal ends
HAFO	68	1271	Leporidae	humerus, r; distal end
HAFO	68	1272	Leporidae	ulna, r; proximal end
HAFO	68	1273	Leporidae	metapodials, 2 partial
HAFO	68	1283	Leporidae	cheekteeth, 9 upper; partial
HAFO	68	1285	Leporidae	i1
HAFO	68	1311a	Leporidae	cheektooth, upper partial
HAFO	68	1312	Leporidae	i1, 2; lower cheektooth fragment
HAFO	68	1317	Leporidae	ungual
HAFO	220	2249	Leporidae	calcaneum, r
HAFO	7	2292	Leporidae	humerus, r; missing unfused proximal epiphysis
HAFO		2309	Leporidae	radius, l; missing unfused distal epiphysis; and distal half associated humerus
HAFO	7	2455	Leporidae	humerus, r; distal end
HAFO	20	2523	Leporidae	calcaneum, l; missing unfused epiphysis

Inst.	Loc. No.	Spec. No.	Taxon	Element
HAFO	20	2525	Leporidae	maxilla, l; with P3-4
HAFO	7	3055	Leporidae	axis
HAFO	7	3069	Leporidae	m2, l
HAFO	7	3070c	Leporidae	m/3, r
HAFO	7	3096b	Leporidae	cheektooth, upper
HAFO	7	3096c	Leporidae	cheektooth, upper
HAFO	7	3105a	Leporidae	m2, r
HAFO	7	3105b	Leporidae	m1, r
HAFO	7	3105c	Leporidae	m1, r
HAFO	7	3146	Leporidae	m3, l
HAFO	1	3167	Leporidae	dentary, r; with p4-m2
HAFO	1	3172	Leporidae	m1, l
HAFO	1	3175	Leporidae	humerus, l; distal half
HAFO	144	3337	Leporidae	phalanx, proximal
HAFO	14	3348	Leporidae	metatarsal 5
HAFO	43	3350	Leporidae	astragalus, r; partial
HAFO	427	3676	Leporidae	phalanx, medial
HAFO	219	3685	Leporidae	phalanx, proximal; missing proximal end
HAFO	429	3698	Leporidae	premolar, upper left
HAFO	404	3729	Leporidae	cheektooth, upper; partial
HAFO	404	3730	Leporidae	cheektooth, partial
HAFO	471	3745	Leporidae	metatarsal 5, proximal end

Inst.	Loc. No.	Spec. No.	Taxon	Element
HAFO	68	3756	Leporidae	patella
HAFO	68	3758	Leporidae	cheektooth, upper; partial
HAFO	68	3759	Leporidae	humeri, distal ends; 1 r and 1 l
HAFO	68	3760	Leporidae	cheektooth, lower; partial
HAFO	68	3761	Leporidae	maxilla, l; edentulous
HAFO	68	3762	Leporidae	ulna, l; proximal shaft
HAFO	68	3763	Leporidae	innominate, l; partial
HAFO	68	3769	Leporidae	cheektooth, upper left
HAFO	60	3779	Leporidae	humerus, r; distal half
HAFO	114	3786	Leporidae	vertebra, caudal
HAFO	390	3827	Leporidae	phalanx, distal half
HAFO	390	3828	Leporidae	phalanx, proximal
HAFO	390	3829	Leporidae	phalanx, distal half
HAFO	390	3830	Leporidae	astragalus, l
HAFO	390	3831	Leporidae	cheektooth, lower
HAFO	390	3832	Leporidae	cheektooth, lower
HAFO	68	3861	Leporidae	ungual
HAFO	68	3868	Leporidae	P2/, 2 l and 1 r; 2 partial upper cheekteeth, 1 partial lower cheektooth, rI1
HAFO	90	3884	Leporidae	P2, r
HAFO	407	3900	Leporidae	metapodial, distal end
HAFO	109	3906	Leporidae	I1, r

Inst.	Loc. No.	Spec. No.	Taxon	Element
HAFO	76	3911	Leporidae	metatarsal 5, missing distal end
HAFO	76	3912	Leporidae	phalanx, medial
HAFO	76	3913	Leporidae	cheektooth, lower
HAFO	76	3914	Leporidae	I1, r and l
HAFO	12	3954	Leporidae	phalanx, proximal
HAFO	488	4187	Leporidae	phalanx, medial; and proximal phalanx missing unfused epiphysis
HAFO	474	4219	Leporidae	cheektooth, upper
HAFO	474	4220	Leporidae	P4, r
HAFO	475	4289	Leporidae	innominate, r; acetabulum and partial ilium
HAFO	377	4346	Leporidae	tibia, r; proximal end
HAFO	68	4372	Leporidae	phalanges; 1 medial and 1 proximal distal half
HAFO	68	4396	Leporidae	tibia, r; proximal end
HAFO	382	4474	Leporidae	phalanx, ungual
HAFO	3	4634	Leporidae	cheektooth, lower
HAFO	383	4697	Leporidae	P2, l
HAFO	419	4768	Leporidae	metatarsal, distal end
HAFO	112	4965	Leporidae	metatarsal 2, r
HAFO	49	4971	Leporidae	femur, r; unfused distal epiphysis
HAFO	340	4985	Leporidae	innominate, l; partial
HAFO	6	5118	Leporidae	calcaneum, l
HAFO	6	5119	Leporidae	lumbar, missing unfused epiphyses

Inst.	Loc. No.	Spec. No.	Taxon	Element
HAFO	6	5120	Leporidae	radius, r; proximal end
HAFO	6	5121	Leporidae	I1, r
HAFO	6	5122	Leporidae	phalanx, proximal
HAFO	6	5123	Leporidae	humerus, l; distal half
HAFO	240	5170	Leporidae	scapula, r; partial
HAFO	240	5171	Leporidae	scapula, l; partial
HAFO	240	5172	Leporidae	humerus, r; distal half
HAFO	7	5233	Leporidae	axis, partial
HAFO	7	5244	Leporidae	maxillae, 2 l edentulous
HAFO	7	5245	Leporidae	m1, l and r; 3 partial upper cheekteeth
HAFO	7	5246	Leporidae	calcaneum, l; partial
HAFO	7	5247	Leporidae	astragalus, l
HAFO	7	5248	Leporidae	navicular, r
HAFO	7	5249	Leporidae	phalanx, medial
HAFO	508	5256	Leporidae	ischium, r
HAFO	508	5257	Leporidae	calcaneum, l; partial
HAFO	8	5291	Leporidae	vertebra, caudal
HAFO	6	5317	Leporidae	phalanx, medial; missing unfused epiphysis
HAFO	563	5339	Leporidae	femur, l; proximal shaft portion
HAFO	563	5342	Leporidae	femur, r; proximal shaft portion
HAFO	563	5344	Leporidae	navicular
HAFO	517	5363	Leporidae	I1, r

Inst.	Loc. No.	Spec. No.	Taxon	Element
HAFO	517	5372	Leporidae	m3, l
HAFO	3	5407	Leporidae	P2
HAFO	3	5408	Leporidae	metatarsal, distal end
HAFO	3	5409	Leporidae	m2, l
HAFO	3	5410	Leporidae	m2, r; posterior loph
HAFO	3	5411	Leporidae	humerus, l; proximal end fragment
HAFO	3	5413	Leporidae	metatarsal 5, proximal end
HAFO	3	5415	Leporidae	phalanges, proximal; 1 complete, 2 proximal ends, 1 distal half
HAFO	3	5426	Leporidae	i1, r
HAFO	3	5426	Leporidae	cheekteeth, 3 upper
HAFO	3	5429	Leporidae	m3, r
HAFO	7	5466	Leporidae	metatarsal, proximal end
HAFO	7	5474	Leporidae	cheekteeth, 2 uppers and 1 lower
HAFO	7	5475	Leporidae	tibia, l; distal end
HAFO	7	5476	Leporidae	humerus, l; distal end
HAFO	7	5516	Leporidae	I1, r
HAFO	488	5590	Leporidae	phalanx, medial; unfused epiphysis
HAFO	494	5691	Leporidae	cheektooth, upper; partial
HAFO	495	5698	Leporidae	vertebra, caudal
HAFO	474	5726	Leporidae	phalanx, proximal; missing unfused epiphysis
HAFO	474	5728	Leporidae	metacarpal

Inst.	Loc. No.	Spec. No.	Taxon	Element
HAFO	474	5729	Leporidae	phalanx, proximal; distal half
HAFO	501	5739	Leporidae	calcaneum, l
HAFO	490	5771	Leporidae	phalanx, medial
HAFO	496	5782	Leporidae	M2, l
HAFO	512	5821	Leporidae	M1, l
HAFO	192	5905	Leporidae	I1, r
HAFO		5934	Leporidae	phalanx, proximal
HAFO	119	5952	Leporidae	dentary, l; fragment, edentulous
HAFO	119	5953	Leporidae	metatarsal 5, r
HAFO	119	5954	Leporidae	P2, 2 l
HAFO	119	5955	Leporidae	m2, l
HAFO	119	5956	Leporidae	I1, r
HAFO	119	5957	Leporidae	metacarpal, partial
HAFO	119	5958	Leporidae	m1, l; partial
HAFO	119	5960	Leporidae	M3, indeterminate side
HAFO	518	6001	Leporidae	calcaneum, r; partial
HAFO	518	6002	Leporidae	patella
HAFO	520	6031	Leporidae	m2, r
HAFO	6	6063	Leporidae	cheektooth, upper; fragment
HAFO	6	6068	Leporidae	metatarsal, distal end
HAFO	526	6093	Leporidae	metatarsal, distal half
HAFO	526	6094	Leporidae	cheektooth, upper

Inst.	Loc. No.	Spec. No.	Taxon	Element
HAFO		6104	Leporidae	humerus, l; proximal end
HAFO	527	6115	Leporidae	humerus, l; distal end
HAFO	527	6116	Leporidae	I1, r
HAFO	5	6125	Leporidae	metatarsal, distal half
HAFO	528	6137	Leporidae	phalanx, medial
HAFO	533	6182	Leporidae	metacarpal, missing unfused epiphysis
HAFO	533	6206	Leporidae	phalanx, medial
HAFO		6209	Leporidae	P3, l
HAFO	511	6226	Leporidae	cheektooth, upper; partial
HAFO	544	6233	Leporidae	calcaneum, r; partial
HAFO	544	6234	Leporidae	phalanx, proximal; proximal end
HAFO	535	6242	Leporidae	metatarsal; proximal end
HAFO	355	6268	Leporidae	phalanges, medial; 3
HAFO	355	6270	Leporidae	cheektooth, lower; partial
HAFO	355	6280	Leporidae	phalanx, ungual
HAFO	355	6283	Leporidae	metatarsal
HAFO	60	6344	Leporidae	cheekteeth, 3 upper; fragmentary
HAFO	60	6349	Leporidae	phalanx, ungual
HAFO	563	6367	Leporidae	phalanx, proximal; proximal end
HAFO	563	6368	Leporidae	phalanx, ungual
HAFO	532	6372	Leporidae	metatarsal; missing proximal end

Inst.	Loc. No.	Spec. No.	Taxon	Element
HAFO	220	6378	Leporidae	calcaneum, r
HAFO	7	6460	Leporidae	tibia, l; distal end
HAFO	7	6461	Leporidae	cheekteeth, 2 lower and 1 upper
HAFO	7	6463	Leporidae	patella
HAFO	7	6464	Leporidae	tibia, l; distal half missing unfused epiphysis
HAFO	68	6515	Leporidae	phalanges, 2 medial; proximal half proximal phalanx; proximal phalanx missing unfused epiphysis; distal half phalanx
HAFO	68	6516	Leporidae	cheekteeth, upper; 5 partial
HAFO	68	6517	Leporidae	ulna, r; proximal end
HAFO	68	6518	Leporidae	metacarpal 3, proximal end
HAFO	68	6519	Leporidae	metatarsal; distal half
HAFO	68	6520	Leporidae	scapula, l; glenoid portion
HAFO	68	6521	Leporidae	astragalus, l
HAFO	536	6602	Leporidae	m3, r
HAFO	220	6678	Leporidae	m1, l
HAFO	1	6689	Leporidae	cheektooth, upper
HAFO	1	6690	Leporidae	cheektooth, upper
HAFO		6782	Leporidae	phalanx, ungual
HAFO		6783a	Leporidae	P4, l
HAFO		6783b	Leporidae	cheektooth, upper right
HAFO	240	6806	Leporidae	cheektooth, upper

Inst.	Loc. No.	Spec. No.	Taxon	Element
HAFO	25	6818	Leporidae	metacarpal
HAFO	543	6828	Leporidae	cheektooth, upper
HAFO		6867	Leporidae	ischium, l
HAFO		6868	Leporidae	humerus, r; distal end
HAFO		6887	Leporidae	phalanx, proximal
HAFO	25	6903	Leporidae	i1, fragment
HAFO	461	6939	Leporidae	humerus, l; distal unfused epiphysis
HAFO	461	6940	Leporidae	metatarsal, proximal portion; and distal end metapodial; not associated
HAFO	461	6943	Leporidae	astragalus, l
HAFO	461	6944	Leporidae	P2
HAFO	41	6945a	Leporidae	M1, r
HAFO	41	6945b	Leporidae	P4, r
HAFO	41	6945c	Leporidae	cheekteeth, 3 upper
HAFO	41	6946a	Leporidae	m2, l
HAFO	41	6946b	Leporidae	m2, l
HAFO	41	6946c	Leporidae	m1, r
HAFO	41	6946d	Leporidae	m1, l
HAFO	41	6946e	Leporidae	cheekteeth, 3 lower
HAFO	461	6954	Leporidae	phalanges, ungual; 5
HAFO	461	6964	Leporidae	dp3
HAFO	461	6991	Leporidae	dp3

Inst.	Loc. No.	Spec. No.	Taxon	Element
HAFO	488	7254	Leporidae	phalanx, distal end
HAFO	25	7304	Leporidae	phalanx, distal end
HAFO	488	7368	Leporidae	cheektooth, upper, partial
HAFO	487	7543	Leporidae	cheektooth, upper; immature
HAFO	7	7595	Leporidae	m2, l
HAFO	7	7596	Leporidae	I1, r
HAFO	7	7598	Leporidae	M2, l
HAFO	1	7660	Leporidae	metatarsal, proximal half
HAFO	1	7662	Leporidae	cheekteeth, 1 upper and 2 lower
HAFO	1	7678	Leporidae	phalanx, proximal
HAFO	1	7718	Leporidae	femur, l; proximal half, missing head
HAFO	20	7845	Leporidae	cheektooth, upper; partial
HAFO	20	7846	Leporidae	humerus, l; distal end
HAFO	20	7847	Leporidae	phalanx, medial
HAFO	20	7848	Leporidae	phalanx, medial
HAFO	20	7849	Leporidae	metatarsal; missing proximal end
HAFO	1	7941	Leporidae	phalanx, ungual
HAFO	1	7948	Leporidae	calcaneum, r; partial
HAFO	1	7949	Leporidae	cheektooth, upper; partial
HAFO	1	7951	Leporidae	m2, l
HAFO	1	7952	Leporidae	navicular, r
HAFO	1	7953a	Leporidae	phalanx, medial; missing unfused epiphysis

Inst.	Loc. No.	Spec. No.	Taxon	Element
HAFO	1	7953b	Leporidae	metatarsal, proximal end
HAFO	1	7954	Leporidae	M2, l
HAFO	129	8005	Leporidae	cheektooth, upper, l
HAFO	527	8051	Leporidae	metatarsal 3, r; missing distal end
HAFO	527	8052	Leporidae	phalanx, proximal; missing proximal end
HAFO	527	8058	Leporidae	cheektooth, l; upper, partial
HAFO	377	8134	Leporidae	I1, r
HAFO	220	8135	Leporidae	metatarsal
HAFO	220	8139	Leporidae	I1, l
HAFO	488	8192	Leporidae	calcaneum, r; partial
HAFO	488	8216	Leporidae	phalanx, distal half
HAFO	25	8333	Leporidae	I1, r
HAFO	25	8334	Leporidae	M2, r
HAFO	25	8336	Leporidae	m1, r
HAFO	25	8337	Leporidae	P2, r
HAFO	25	8339	Leporidae	phalanx, ungual
HAFO	25	8340	Leporidae	phalanx, medial
HAFO	7	8408	Leporidae	m3, r
HAFO	66	8428	Leporidae	maxillae, l and r fused
HAFO	66	8429	Leporidae	cheektooth, upper; partial
HAFO	66	8430	Leporidae	dentary, l; with m1
HAFO	554	8518	Leporidae	cheektooth, upper, partial

Inst.	Loc. No.	Spec. No.	Taxon	Element
HAFO	63	8550	Leporidae	P4, r
HAFO		8583	Leporidae	femur, r; proximal shaft portion
HAFO	7	8617	Leporidae	P3, l
HAFO	7	8618	Leporidae	m1, l
HAFO	7	8619	Leporidae	P4
HAFO	7	8637	Leporidae	cheekteeth, 2 upper and 3 lower; partial
HAFO	7	8638	Leporidae	calcaneum, l; partial
HAFO	7	8639	Leporidae	I1, l; 3
HAFO	7	8642	Leporidae	metapodial, distal end
HAFO	7	8643	Leporidae	humerus, r; distal end
HAFO	7	8644	Leporidae	astragalus, r; partial
HAFO	7	8689	Leporidae	phalanges, proximal; distal halves; 4
HAFO	219	8785	Leporidae	i1
HAFO	76	8859	Leporidae	phalanx, proximal; distal half
HAFO	76	8860	Leporidae	calcaneum, l; broken proximal end
HAFO	76	8862	Leporidae	metatarsal
HAFO	461	8968	Leporidae	tibia, r; unfused proximal epiphysis
HAFO	461	8969	Leporidae	metatarsal, distal half
HAFO	461	8970	Leporidae	calcaneum, l
HAFO	461	8971	Leporidae	cheekteeth fragments, 8
HAFO	461	8972	Leporidae	I1, 2

Inst.	Loc. No.	Spec. No.	Taxon	Element
HAFO	461	8973	Leporidae	phalanx, proximal; proximal end
HAFO	461	8974	Leporidae	phalanx, proximal; distal end; 2
HAFO	461	8975	Leporidae	phalanx, proximal
HAFO	461	8976	Leporidae	M1, r
IMNH	5	69003/4947	Leporidae	dentary, l; with p3-m1
IMNH	51	70059/4956	Leporidae	tibia, r; distal end
IMNH	51	70059/4957	Leporidae	tibia, l; distal end
IMNH	9	70017/5182	Leporidae	tibia, r; distal end
IMNH	49	70057/5277	Leporidae	humerus, l; distal end
IMNH	367	80005/5288	Leporidae	scapula, right
IMNH	197	85006/6087	Leporidae	calcaneum, l; missing unfused epiphysis
IMNH	197	85006/6089	Leporidae	tibia, l; distal end
IMNH	197	85006/6099	Leporidae	calcaneum, l
IMNH	367	85005/7970	Leporidae	I1, l
IMNH	6	69007/28857	Leporidae	humerus, distal end
IMNH	6	69007/28858	Leporidae	tibia, l; distal end
IMNH	6	69007/28859	Leporidae	calcaneum, l
IMNH	6	69007/28860	Leporidae	calcaneum, l
IMNH	6	69007/28861	Leporidae	metatarsal 3
IMNH	6	69007/29536	Leporidae	dentary
IMNH	367	80005/31797	Leporidae	m3, partial
IMNH	367	80005/31799	Leporidae	m3, l

Inst.	Loc. No.	Spec. No.	Taxon	Element
IMNH	367	80005/31802	Leporidae	m3, r
IMNH	367	80005/31803	Leporidae	m3
IMNH	367	80005/31804	Leporidae	i1, partial
IMNH	367	80005/31805	Leporidae	cheektooth, upper; partial
IMNH	367	80005/31806	Leporidae	I1, l; partial
IMNH	367	80005/31807	Leporidae	cheektooth, upper; partial
IMNH	88	83028/33741	Leporidae	metatarsal
IMNH	88	83028/33742	Leporidae	metapodial, distal half
IMNH	367	80005/33768	Leporidae	I1, r; partial
IMNH	68	80005/34590	Leporidae	vertebra, caudal
IMNH	367	80005/34605	Leporidae	calcaneum, l
IMNH	53	70061/34610	Leporidae	ulna, proximal end
IMNH	367	80005/34741	Leporidae	m3, l
IMNH	367	80005/34742	Leporidae	m3, l
IMNH	367	80005/34743	Leporidae	m3, r
IMNH	31	70039/34774	Leporidae	cheektooth, upper
IMNH	6	39007/34785	Leporidae	dentary, l; with p4-m2
IMNH	367	80005/34793	Leporidae	p3, r; very young individual
IMNH	367	80005/34794	Leporidae	cheekteeth, upper and lower; 20
IMNH	75	81002/34837	Leporidae	innominate, r; partial
IMNH	1	31001/34857	Leporidae	tibia, r; distal end
IMNH	1	31001/34859	Leporidae	calcaneum, r

Inst.	Loc. No.	Spec. No.	Taxon	Element
IMNH	3	65006/34883	Leporidae	calcaneum, r
IMNH	3	65006/34884	Leporidae	calcaneum, r
IMNH	3	65006/34885	Leporidae	dentary, r; with p4-m1
IMNH	68	80005/34930	Leporidae	tibia, l; distal end
IMNH	367	80005/34935	Leporidae	calcaneum, l
IMNH	367	80005/34936	Leporidae	calcaneum, r
IMNH	367	80005/34937	Leporidae	calcaneum, l
IMNH	30	70038/35152	Leporidae	calcaneum, r
IMNH	68	80005/35989	Leporidae	metatarsal 5
IMNH	367	85005/36862	Leporidae	humerus, l; distal half
IMNH	367	85005/36863	Leporidae	astragalus, l
IMNH	367	85005/37190	Leporidae	humerus, proximal half
IMNH	5	69003/38156	Leporidae	dentary, r; with i, m2
IMNH	367	85005/38168	Leporidae	metapodials, 2 partial
IMNH	91	84004/38594	Leporidae	metatarsal 5
IMNH		109/38622	Leporidae	dentary, l; edentulous fragment
IMNH	367	85005/39172	Leporidae	calcaneum, l; 3 partials
IMNH	367	85005/39173	Leporidae	calcaneum, r
IMNH	367	85005/39176	Leporidae	radius, l; proximal half
IMNH	367	85005/39179	Leporidae	metatarsal 3, r; missing distal end
IMNH	367	85005/39183	Leporidae	astragalus, r
IMNH	367	85005/39182	Leporidae	dentary, l; with p4-m1

Inst.	Loc. No.	Spec. No.	Taxon	Element
IMNH	367	85005/39186	Leporidae	astragalus, l
IMNH	367	85005/39187	Leporidae	metatarsal 4, l
IMNH	367	85005/39218	Leporidae	metatarsal 5

APPENDIX G. DIMENSIONS OF LEPORID LOWER THIRD PREMOLARS

This list contains the measurements of the lower third premolars graphed in Figure 7.4. Measurements (mm) followed the methodology of White (1987); abbreviations are as in Appendix F.

Institution	Spec. No.	Taxon	length	width
HAFO	7499	*Alilepus vagus*	3.07	2.55
HAFO	7969	*Alilepus vagus*	3.30	3.01
IMNH	69003/4943	*Alilepus vagus*	3.15	2.93
IMNH	69003/4944	*Alilepus vagus*	3.28	2.90
IMNH	69003/35100	*Alilepus vagus*	3.09	3.06
IMNH	69008/4982	*Alilepus vagus*	3.36	2.89
IMNH	69008/4987	*Alilepus vagus*	3.08	2.85
IMNH	69008/30903	*Alilepus vagus*	3.41	3.11
IMNH	69008/30904	*Alilepus vagus*	3.46	2.93
IMNH	69008/32412	*Alilepus vagus*	3.30	3.09
IMNH	69008/38517	*Alilepus vagus*	3.26	3.01
IMNH	70055/30516	*Alilepus vagus*	3.29	3.44
IMNH	80005/4948	*Alilepus vagus*	2.98	2.66

Institution	Spec. No.	Taxon	length	width
IMNH	85005/39190	*Alilepus vagus*	3.16	2.30
IMNH	85005/39191	*Alilepus vagus*	3.09	2.94
USNM	12622	*Alilepus vagus*	3.50	3.20
HAFO	989	*Hypolagus edensis*	2.56	2.18
HAFO	1165	*Hypolagus edensis*	2.12	1.61
HAFO	3070a	*Hypolagus edensis*	2.45	2.29
HAFO	3070b	*Hypolagus edensis*	2.54	2.30
HAFO	3096a	*Hypolagus edensis*	2.23	2.03
HAFO	8549	*Hypolagus edensis*	2.39	2.13
IMNH	69008/4985	*Hypolagus edensis*	2.47	2.08
IMNH	69008/4986	*Hypolagus edensis*	2.71	2.33
IMNH	69008/4988	*Hypolagus edensis*	2.42	2.17
IMNH	69008/30905	*Hypolagus edensis*	2.45	2.23
IMNH	69008/33639	*Hypolagus edensis*	2.56	2.38
IMNH	69008/33640	*Hypolagus edensis*	2.39	2.35
IMNH	69008/33641	*Hypolagus edensis*	2.65	1.41
IMNH	69008/34391	*Hypolagus edensis*	2.46	2.32
IMNH	69008/34401	*Hypolagus edensis*	2.49	2.23
HAFO	155	*Hypolagus gidleyi*	3.26	2.86
HAFO	991	*Hypolagus gidleyi*	2.94	2.72
HAFO	1283b	*Hypolagus gidleyi*	3.26	2.62
HAFO	1283c	*Hypolagus gidleyi*	3.34	2.78

Institution	Spec. No.	Taxon	length	width
HAFO	1283d	*Hypolagus gidleyi*	2.87	2.71
HAFO	1283e	*Hypolagus gidleyi*	3.40	3.17
HAFO	1283g	*Hypolagus gidleyi*	3.26	2.07
HAFO	1311b	*Hypolagus gidleyi*	3.31	2.76
HAFO	2329g	*Hypolagus gidleyi*	2.90	2.78
HAFO	3913	*Hypolagus gidleyi*	2.92	2.54
HAFO	4465	*Hypolagus gidleyi*	3.47	3.30
HAFO	4616	*Hypolagus gidleyi*	2.91	2.58
HAFO	5368	*Hypolagus gidleyi*	3.15	2.57
HAFO	5414	*Hypolagus gidleyi*	3.12	2.75
HAFO	6269	*Hypolagus gidleyi*	3.07	2.85
HAFO	8426	*Hypolagus gidleyi*	3.05	3.05
IMNH	31001/29534	*Hypolagus gidleyi*	3.13	3.22
IMNH	31001/34849	*Hypolagus gidleyi*	3.29	3.07
IMNH	31001/34858	*Hypolagus gidleyi*	3.27	3.01
IMNH	31001/34860	*Hypolagus gidleyi*	2.95	2.35
IMNH	67002/4978	*Hypolagus gidleyi*	3.28	2.74
IMNH	67002/4980	*Hypolagus gidleyi*	2.60	2.26
IMNH	67002/29535	*Hypolagus gidleyi*	2.83	2.75
IMNH	80005/4949	*Hypolagus gidleyi*	3.00	2.92
IMNH	80005/4950	*Hypolagus gidleyi*	2.98	2.40
IMNH	83028/33736	*Hypolagus gidleyi*	2.60	2.38

Institution	Spec. No.	Taxon	length	width
IMNH	85005/39170	*Hypolagus gidleyi*	3.21	3.29
IMNH	85005/39189	*Hypolagus gidleyi*	3.32	2.83
IMNH	85006/6094	*Hypolagus gidleyi*	2.83	3.16
IMNH	85006/6095	*Hypolagus gidleyi*	3.16	2.90
IMNH	85006/15413	*Hypolagus gidleyi*	3.21	2.68

APPENDIX H. MODERN FAUNA REFERENCES

Below is the list of references used to create the fauna lists for each modern ecoregion. References are listed by state or province because that is how they are commonly sorted and grouped in the published literature. Not all states are included in this list, because not all states include a locality for which I generated a fauna list.

Alabama: Paradiso and Nowak, 1972; Choate et al., 1994; Whitaker and Hamilton, 1998; McCay, 2001; Cecares and Barclay, 2000; Nowak, 2002.

Alaska: Engstrom et al., 1993; Smith and Belk, 1996.

Alberta: Soper, 1964; Smith and Belk, 1996; Cecares and Barclay, 2000; Holloway and Barclay, 2001.

Arizona: Olin, 1961; Warner, 1982; Smith and Belk, 1996; Holloway and Barclay, 2001; Jones and Baxter, 2004.

Arkansas: Paradiso and Nowak, 1972; Sealander and Heidt, 1990; Sulentich et al., 1991; Choate et al., 1994; Best and Jennings, 1997; Cecares and Barclay, 2000; McCay, 2001; Nowak, 2002.

British Columbia: Smith and Belk, 1996; Holloway and Barclay, 2001; Gillihan and Foresman, 2004.

California: Olin, 1961; Ingles, 1965; Hennings and Hoffman, 1977; Carraway, 1985; Kelt, 1988; Zevelloff and Collett, 1988; Carraway, 1990; Johnson and George, 1991; Best and Granai, 1994; Cockrum and Petryszyn, 1994; Smith and Belk, 1996; Sullivan and Best, 1997; Verts and Carraway, 2000; Holloway and Barclay, 2001; Matocq, 2002; Gillihan and Foresman, 2004; Jones and Baxter, 2004.

Colorado: Olin, 1961; Zegers, 1984; Zevelloff and Collett, 1988; Smith and Belk, 1996; Holloway and Barclay, 2001; Jones and Baxter, 2004.

Florida: Paradiso and Nowak, 1972; Whitaker and Hamilton, 1998; McCay, 2001; Nowak, 2002.

Idaho: Davis, 1939; Zevelloff and Collett, 1988; Smith and Belk, 1996; Holloway and Barclay, 2001;Gillihan and Foresman, 2004.

Illinois: Hoffmeister and Mohr, 1972; George et al., 1986; Whitaker and Hamilton, 1998; Cecares and Barclay, 2000; Nowak, 2002.

Iowa: George et al., 1986; Cecares and Barclay, 2000.

Kansas: Hall, 1955; George et al., 1986; Cecares and Barclay, 2000; Holloway and Barclay, 2001.

Kentucky: Paradiso and Nowak, 1972; Barbour and Davis, 1974; George et al., 1986; Best and Jennings, 1997; Cecares and Barclay, 2000; Nowak, 2002.

Louisiana: Paradiso and Nowak, 1972; Sulentich et al., 1991; Choate et al., 1994; McCay, 2001; Nowak, 2002.

Manitoba: George et al., 1986; Engstrom et al., 1993; Cecares and Barclay, 2000.

Massachusetts: George et al., 1986; Best and Jennings, 1997; Whitaker and Hamilton, 1998; Cecares and Barclay, 2000; Nowak, 2002.

Michigan: Burt, 1946; George et al., 1986; Whitaker and Hamilton, 1998; Cecares and Barclay, 2000.

Minnesota: Hazard, 1982; George et al., 1986; Cecares and Barclay, 2000.

Mississippi: Paradiso and Nowak, 1972; Choate et al., 1994; Whitaker and Hamilton, 1998; McCay, 2001; Nowak, 2002.

Missouri: Schwartz and Schwartz, 1959; Paradiso and Nowak, 1972; Best and Jennings, 1997; Cecares and Barclay, 2000; Nowak, 2002.

Montana: Zegers, 1984; Smith and Belk, 1996; Foresman, 2001;Holloway and Barclay, 2001.

Nebraska: Cecares and Barclay, 2000; Holloway and Barclay, 2001.

Nevada: Olin, 1961; Zevelloff and Collett, 1988; Cockrum and Petryszyn, 1994; Smith and Belk, 1996; Holloway and Barclay, 2001; Jones and Baxter, 2004.

New Brunswick: George et al., 1986; Cecares and Barclay, 2000; Nowak, 2002.

New Hampshire: George et al., 1986; Best and Jennings, 1997; Whitaker and Hamilton, 1998; Cecares and Barclay, 2000; Nowak, 2002.

New Jersey: George et al., 1986; Best and Jennings, 1997; Whitaker and Hamilton, 1998; Nowak, 2002.

New Mexico: Olin, 1961; Smith and Belk, 1996; Edwards et al., 2001; Holloway and Barclay, 2001; Frey, 2004; Jones and Baxter, 2004; Mantooth and Best, 2005.

New York: George et al., 1986; Best and Jennings, 1997; Whitaker and Hamilton, 1998; Cecares and Barclay, 2000; Nowak, 2002.

Newfoundland: Cecares and Barclay, 2000.

North Carolina: Paradiso and Nowak, 1972; George et al., 1986; Hayes and Richmond, 1993; Whitaker and Hamilton, 1998; Best and Jennings, 1997; Cecares and Barclay, 2000; McCay, 2001; Nowak, 2002.

North Dakota: George et al., 1986; Cecares and Barclay, 2000.

Northwest Territories: Engstrom et al., 1993; Smith and Belk, 1996.

Nunavut: Engstrom et al., 1993.

Ohio: George et al., 1986; Best and Jennings, 1997; Whitaker and Hamilton, 1998; Cecares and Barclay, 2000; Nowak, 2002.

Oklahoma: Paradiso and Nowak, 1972; Caire et al., 1989; Sulentich et al., 1991; Cecares and Barclay, 2000; Holloway and Barclay, 2001; Nowak, 2002

Onatario: George et al., 1986; Best and Jennings, 1997; Cecares and Barclay, 2000.

Oregon: Ingles, 1965; Hennings and Hoffman, 1977; Carraway, 1985; Verts and Carraway, 1987; Zevelloff and Collett, 1988; Carraway, 1990; Smith and Belk, 1996; Verts and Carraway, 1998; Verts and Carraway, 2000; Holloway and Barclay, 2001;Eder, 2002; Gillihan and Foresman, 2004; Jones and Baxter, 2004.

Pennsyvlania: George et al., 1986; Merritt, 1987; Hayes and Richmond, 1993; Best and Jennings, 1997; Whitaker and Hamilton, 1998; Cecares and Barclay, 2000; Nowak, 2002.

Prince Edward Island: George et al., 1986; Cecares and Barclay, 2000.

Quebec: George et al., 1986; Best and Jennings, 1997; Cecares and Barclay, 2000.

Saskatchewan: Beck, 1958; George et al., 1986; Cecares and Barclay, 2000; Holloway and Barclay, 2001.

South Carolina: Paradiso and Nowak, 1972; Whitaker and Hamilton, 1998; Cecares and Barclay, 2000; McCay, 2001; Nowak, 2002.

South Dakota: George et al., 1986; Cecares and Barclay, 2000; Holloway and Barclay, 2001.

Texas: Paradiso and Nowak, 1972; Sulentich et al., 1991; Williams and Cameron, 1991; Davis and Schmidly, 1994; McCay, 2001; Edwards et al., 2001; Holloway and Barclay, 2001; Nowak, 2002; Jones and Baxter, 2004; Mantooth and Best, 2005.

Utah: Olin, 1961; Zevelloff and Collett, 1988; Smith and Belk, 1996; Holloway and Barclay, 2001; Gillihan and Foresman, 2004; Jones and Baxter, 2004.

Washington: Ingles, 1965; Hennings and Hoffman, 1977; Carraway, 1990; Smith and Belk, 1996; Holloway and Barclay, 2001; Verts and Carraway, 2000; Eder, 2002; Gillihan and Foresman, 2004.

West Virginia: George et al., 1986; Hayes and Richmond, 1993; Best and Jennings, 1997; Whitaker and Hamilton, 1998; Cecares and Barclay, 2000; Nowak, 2002.

Wisconsin: Jackson, 1961; George et al., 1986; Cecares and Barclay, 2000.

Wyoming: Zegers, 1984; Zevelloff and Collett, 1988; Smith and Belk, 1996; Holloway and Barclay, 2001.

Yukon Territory: Engstrom et al., 1993; Smith and Belk, 1996.

all: Hall and Kelson, 1959; Wilson and Reeder, 2005.

APPENDIX I. FAUNA, CLIMATE, AND LOCATION OF MODERN ECOREGIONS OF THE UNITED STATES AND CANADA

Localities were chosen based on the availability of complete climate data and updated mammalian distribution information. Due to the paucity of climate stations in northern Canada, some localities are listed with the temperature and precipitation data of the nearest climate station; these climate stations are indicated parenthetically after the locality name. Preference was given to localities not near ecoregion boundaries, but the ability to do this varied with the availability of climate data and the shape and size of the ecoregion.

The lists were compiled using the references given in Appendix H. The order of the mammals in each list follows that suggested by Jones et al. (1997) for North American mammals. Species are arranged alphabetically within each genus.

Climate data are taken from the interval of 1971-2000 with the following exceptions: Fort Yukon (1899-1990), Chignik (1927-1978), Déline (1991-2003), Fort McPherson (1982-1977), Carmacks (1963-2001), Ennedai Lake (1949-1979), Cape Romanzof (1953-1985), Cape Newenham (1953-1984), Hyder (1936-2005), McMillan (2001-2006), Tungsten (1966-1990), Arctic Village (1962-1996), Ambler (1981-1992), Point Hope (1924-1982), Saglek (1955-1960; 1989-1993).

When multiple climate stations exists in close proximity, preference was given to the station that had temperature and precipitation data for the 1971-2000 period and that me the World Meteorological Organization standards of data completeness. In cases where the name of the station still does not uniquely or accurately match the locality name used here, the National Oceanographic and Atmospheric Administration or Canadian Department of the Environment station name is specified parenthetically.

Names of the ecoregions follow Ricketts et al. (2000). The numbers associated with the ecoregions also follow Ricketts et al. (2000), even though not all ecoregions are included in my analyses. The numbers are retained to simplify labeling of maps and to facilitate reference to the ecoregion descriptions in Ricketts et al. (2000). Abbreviations: max. temp., mean-annual maximum-daily temperature; mean temp., mean-annual mean-daily temperature; min. temp., mean-annual minimum-daily temperature; precipitation, mean annual precipitation.

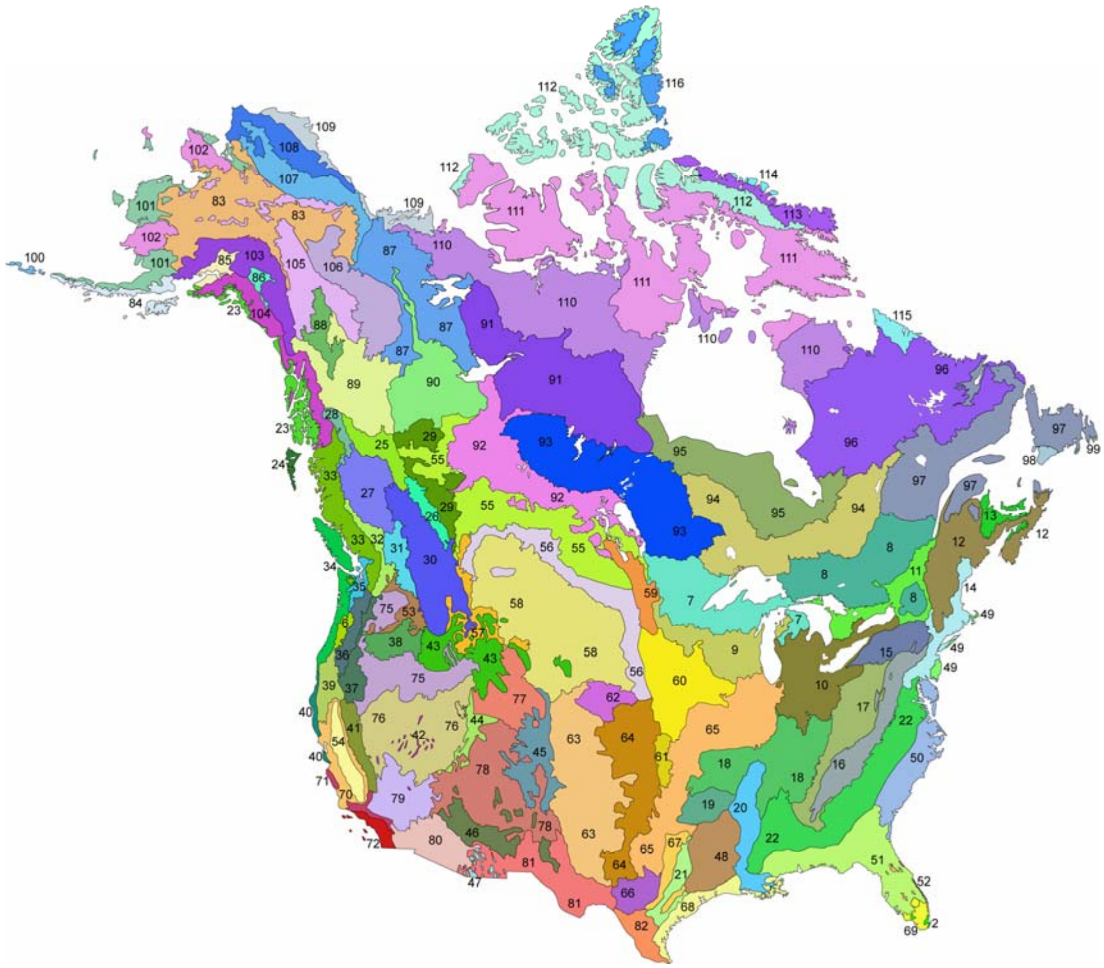


Figure I1. Ecoregions of the United States and Canada. Redrawn from Ricketts et al. (1999).

2. South Florida Rocklands

Homestead, Florida

25° 30’ N, 90° 30’ W

max. temp. – 28.9 °C

mean temp. – 23.8 °C

min. temp. – 18.6 °C

precipitation – 147.8 cm/yr

Miami, Florida

25° 49’ N, 90° 19’ W

max. temp. – 29.0 °C

mean temp. – 24.8 °C

min. temp. – 20.6 °C

precipitation – 148.7 cm/yr

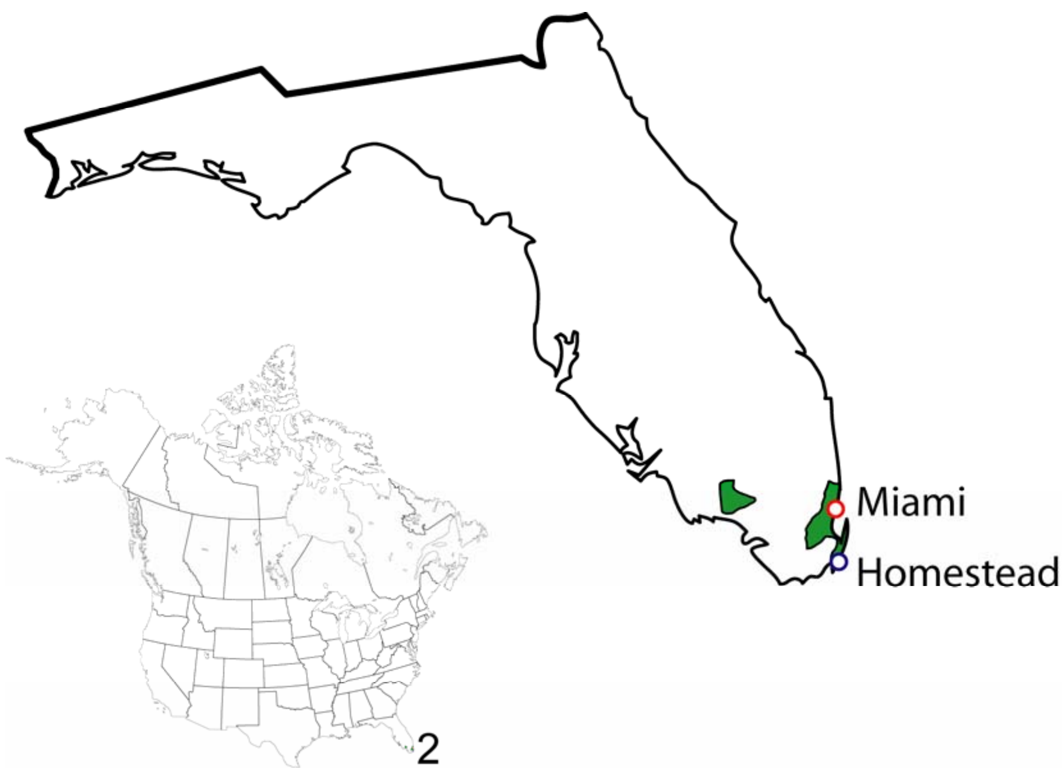


Figure I2. South Florida Rocklands.

Homestead, Florida

Didelphis virginiana
Blarina carolinensis
Cryptotis parva
Nycticeius humeralis
Tadarida brasiliensis
Sylvilagus floridanus
Sylvilagus palustris
Sciurus carolinensis
Sciurus niger
Oryzomys palustris
Reithrodontomys humulis
Peromyscus gossypinus
Sigmodon hispidus
Neofiber alleni
Canis rufus
Vulpes vulpes
Urocyon cinereoargenteus
Ursus americanus
Procyon lotor
Mustela vison
Lontra canadensis
Spilogale putorius
Mephitis mephitis
Puma concolor
Lynx rufus
Odocoileus virginianus

Miami, Florida

Didelphis virginiana
Blarina carolinensis
Cryptotis parva
Lasiurus intermedius
Nycticeius humeralis
Tadarida brasiliensis
Eumops glaucinus
Sylvilagus floridanus
Sylvilagus palustris
Sciurus carolinensis
Sciurus niger
Glaucomys volans
Oryzomys palustris
Reithrodontomys humulis
Peromyscus gossypinus
Podomys floridanus
Sigmodon hispidus
Neofiber alleni
Canis rufus
Vulpes vulpes
Urocyon cinereoargenteus
Ursus americanus
Procyon lotor
Lontra canadensis
Spilogale putorius
Mephitis mephitis
Puma concolor
Lynx rufus
Odocoileus virginianus

6. Williamette Valley Forests

Salem, Oregon

44° 54’ N, 123° 00’ W

max. temp. – 17.4 °C

mean temp. – 11.4 °C

min. temp. – 5.4 °C

precipitation – 101.6 cm/yr

Vancouver, Washington

45° 41’ N, 122° 39’ W

max. temp. – 16.3 °C

mean temp. – 11.0 °C

min. temp. – 5.7 °C

precipitation – 106.5 cm/yr

Figure I3. Williamette Valley Forests.

Salem, Oregon

Sorex sonomae
Sorex obscurus
Sorex vagrans
Sorex bairdi
Sorex palustris
Sorex bendirii
Sorex trowbridgii
Neurotrichus gibbsii
Scapanus townsendii
Scapanus orarius
Myotis lucifugus
Myotis thysanodes
Myotis californicus
Myotis volans
Myotis evotis
Myotis yumanensis
Lasiurus cinereus
Lasionycteris noctivagans
Eptesicus fuscus
Corynorhinus townsendii
Antrozous pallidus
Lepus americanus
Aplodontia rufa
Neotamias townsendii
Spermophilus beecheyi
Sciurus griseus
Tamiasciurus douglasii
Glaucomys sabrinus
Thomomys bulbivorus
Castor canadensis
Peromyscus maniculatus
Neotoma cinerea
Clethrionomys californicus
Arborimus longicaudus
Arborimus albipes
Microtus canicaudus
Microtus townsendii
Microtus oregoni
Ondatra zibethicus
Zapus trionatus
Erethizon dorsatum
Canis latrans
Vulpes vulpes
Urocyon cinereoargenteus
Ursus americanus
Procyon lotor
Martes americana
Martes pennanti
Mustela vison
Mustela frenata
Lontra canadensis
Spilogale putorius
Mephitis mephitis
Lynx rufus
Odocoileus hemionus

Vancouver, Washington

Sorex obscurus
Sorex vagrans
Sorex bairdi
Sorex bendirii
Sorex trowbridgii
Neurotrichus gibbsii
Scapanus townsendii
Scapanus orarius
Myotis thysanodes
Myotis californicus
Myotis volans
Myotis evotis
Myotis yumanensis
Lasiurus cinereus
Lasionycteris noctivagans
Eptesicus fuscus
Corynorhinus townsendii
Antrozous pallidus
Lepus americanus
Aplodontia rufa
Neotamias townsendii
Spermophilus beecheyi
Tamiasciurus douglasii
Glaucomys sabrinus
Thomomys talpoides
Castor canadensis
Peromyscus maniculatus
Neotoma cinerea
Clethrionomys californicus
Arborimus longicaudus
Microtus canicaudus
Microtus townsendii
Microtus richardsoni
Microtus oregoni
Ondatra zibethicus
Zapus trionatus
Erethizon dorsatum
Canis latrans
Vulpes vulpes
Ursus americanus
Procyon lotor
Martes americana
Martes pennanti
Mustela vison
Mustela frenata
Lontra canadensis
Spilogale putorius
Mephitis mephitis
Lynx rufus
Odocoileus hemionus
Odocoileus viginianus

7. Western Great Lakes Forests

International Falls, Minnesota

48° 34’ N, 93° 24’ W

max. temp. – 9.3 °C

mean temp. – 3.0 °C

min. temp. – -3.3 °C

precipitation – 60.8 cm/yr

Stambaugh, Michigan

46° 03’ N, 88° 37’ W

max. temp. – 9.9 °C

mean temp. – 3.2 °C

min. temp. – -3.5 °C

precipitation – 77.1 cm/yr

Figure I4. Western Great Lakes Forests.

International Falls, Minnesota

Sorex cinereus
Sorex palustris
Blarina brevicauda
Condylura cristata
Myotis lucifugus
Myotis septentrionalis
Lasiurus borealis
Lasiurus cinereus
Lasionycteris noctivagans
Eptesicus fuscus
Lepus americanus
Lepus townsendii
Neotamias minimus
Tamias striatus
Marmota monax
Spermophilus franklinii
Sciurus carolinensis
Sciurus niger
Tamiasciurus hudsonicus
Glaucomys sabrinus
Castor canadensis
Peromyscus maniculatus
Clethrionomys gapperi
Phenacomys ungava
Microtus pennsylvanicus
Ondatra zibethicus
Synaptomys cooperi
Zapus hudsonius
Napaeozapus insignis
Erethizon dorsatum
Canis latrans
Canis lupus
Vulpes vulpes
Urocyon cinereoargenteus
Ursus americanus
Martes americanus
Martes pennanti
Mustela erminea
Mustela nivalis
Mustela frenata
Mustela vison
Gulo gulo
Taxidea taxus
Lontra canadensis
Spilogale putorius
Mephitis mephitis
Puma concolor
Lynx canadensis
Lynx rufus
Cervus canadensis
Odocoileus virginianus
Alces alces
Rangifer tarandus

Stambaugh, Michigan

Sorex arcticus
Sorex cinereus
Sorex hoyi
Sorex palustris
Blarina brevicauda
Condylura cristata
Myotis lucifugus
Myotis septentrionalis
Lasiurus borealis
Lasiurus cinereus
Lasionycteris noctivagans
Eptesicus fuscus
Sylvilagus floridanus
Lepus americanus
Neotamias minimus
Tamias striatus
Marmota monax
Spermophilus tricedemlineatus
Sciurus carolinensis
Tamiasciurus hudsonicus
Glaucomys sabrinus
Glaucomys volans
Castor canadensis
Peromyscus maniculatus
Clethrionomys gapperi
Microtus pennsylvanicus
Ondatra zibethicus
Synaptomys cooperi
Zapus hudsonius
Napaeozapus insignis
Erethizon dorsatum
Canis latrans
Canis lupus
Vulpes vulpes
Urocyon cinereoargenteus
Ursus americanus
Procyon lotor
Martes americana
Martes pennanti
Mustela erminea
Mustela frenata
Mustela nivalis
Mustela vison
Gulo gulo
Taxidea taxus
Lontra canadensis
Mephitis mephitis
Puma concolor
Lynx canadensis
Lynx rufus
Cervus elephus
Odocoileus virginianus
Alces alces
Rangifer tarandus
Bos bison

8. Eastern Forest/Boreal Transition

Sudbury, Ontario	La Tuque, Quebec
46° 37’ N, 80° 48’ W	47° 24’ N, 72° 46’ W
max. temp. – 8.8 °C	max. temp. – 9.3 °C
mean temp. – 3.7 °C	mean temp. – 3.4 °C
min. temp. – -1.4 °C	min. temp. – -2.6 °C
precipitation – 89.9 cm/yr	precipitation – 94.0 cm/yr

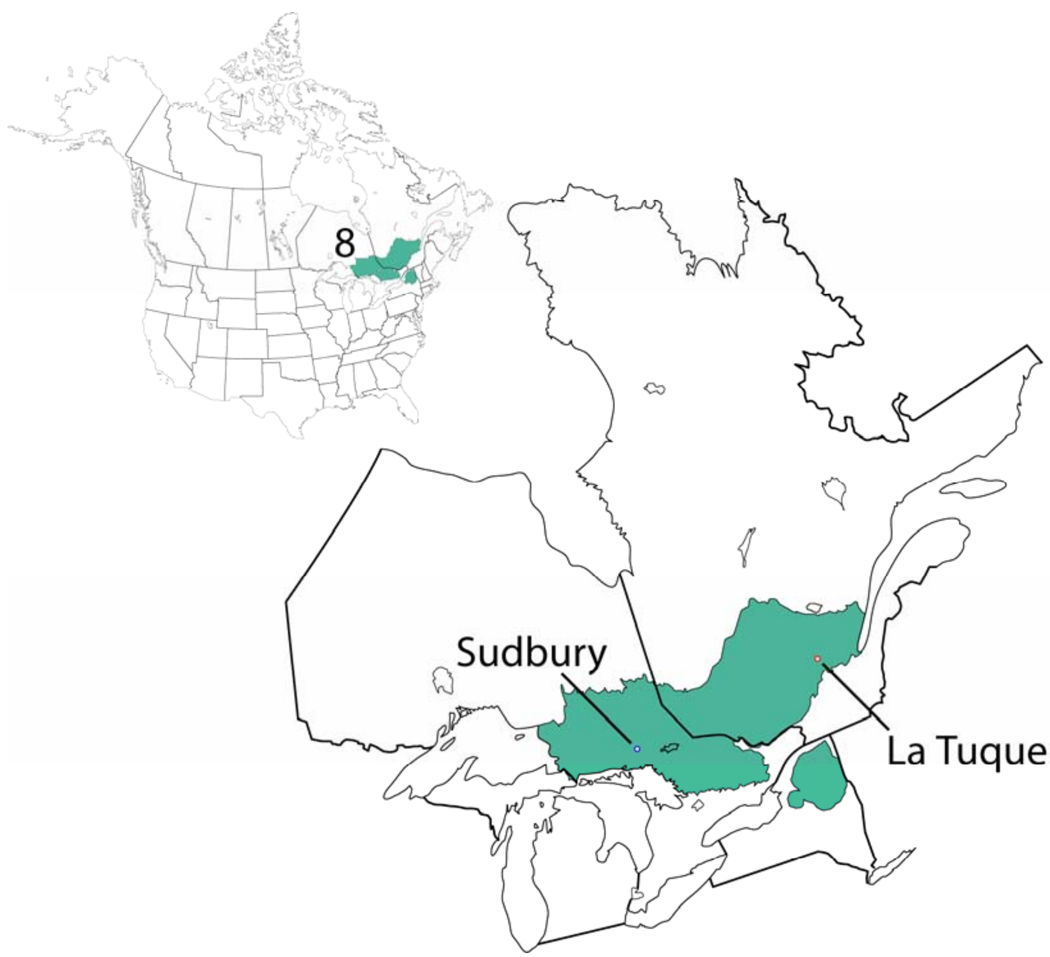


Figure I5. Eastern Forest/Boreal Transition.

Sudbury, Ontario

Sorex cinereus
Sorex palustris
Sorex fumeus
Sorex arcticus
Blarina brevicauda
Parascalops breweri
Condylura cristata
Myotis lucifugus
Myotis septentrionalis
Lasiurus cinereus
Lasionycteris noctivagans
Eptesicus fuscus
Lepus americanus
Tamias striatus
Marmota monax
Tamiasciurus hudsonicus
Glaucomys sabrinus
Castor canadensis
Peromyscus maniculatus
Clethrionomys gapperi
Phenacomys ungava
Microtus pennsylvanicus
Microtus chrotorrhinus
Ondatra zibethicus
Synaptomys cooperi
Zapus hudsonius
Napaeozapus insignis
Erethizon dorsatum
Canis latrans
Canis lupus
Vulpes vulpes
Ursus americanus
Procyon lotor
Martes americana
Martes pennanti
Mustela erminea
Mustela nivalis
Mustela vison
Gulo gulo
Lontra canadensis
Mephitis mephitis
Puma concolor
Lynx canadensis
Odocoileus virginianus
Alces alces
Rangifer tarandus

La Tuque, Quebec

Sorex cinereus
Sorex palustris
Sorex fumeus
Sorex arcticus
Blarina brevicauda
Parascalops breweri
Condylura cristata
Myotis lucifugus
Myotis septentrionalis
Lasiurus borealis
Lasiurus cinereus
Lasionycteris noctivagans
Eptesicus fuscus
Lepus americanus
Neotamias minimus
Tamias striatus
Marmota monax
Tamiasciurus hudsonicus
Glaucomys sabrinus
Castor canadensis
Peromyscus maniculatus
Clethrionomys gapperi
Phenacomys ungava
Microtus pennsylvanicus
Microtus chrotorrhinus
Ondatra zibethicus
Synaptomys cooperi
Zapus hudsonius
Napaeozapus insignis
Erethizon dorsatum
Canis latrans
Canis lupus
Vulpes vulpes
Ursus americanus
Procyon lotor
Martes americana
Martes pennanti
Mustela erminea
Mustela nivalis
Mustela frenata
Mustela vison
Gulo gulo
Lontra canadensis
Mephitis mephitis
Lynx canadensis
Cervus canadensis
Odocoileus virginianus
Alces alces
Rangifer tarandus

9. Upper Midwest Forest/Savanna Transition Zone

St. Cloud, Minnesota

45° 33' N, 94° 03' W

max. temp. – 11.4 °C

mean temp. – 5.4 °C

min. temp. – -0.5 °C

precipitation – 68.9 cm/yr

Madison, Wisconsin

43° 08' N, 89° 21' W

max. temp. – 13.2 °C

mean temp. – 7.8 °C

min. temp. – 2.4 °C

precipitation – 83.7 cm/yr

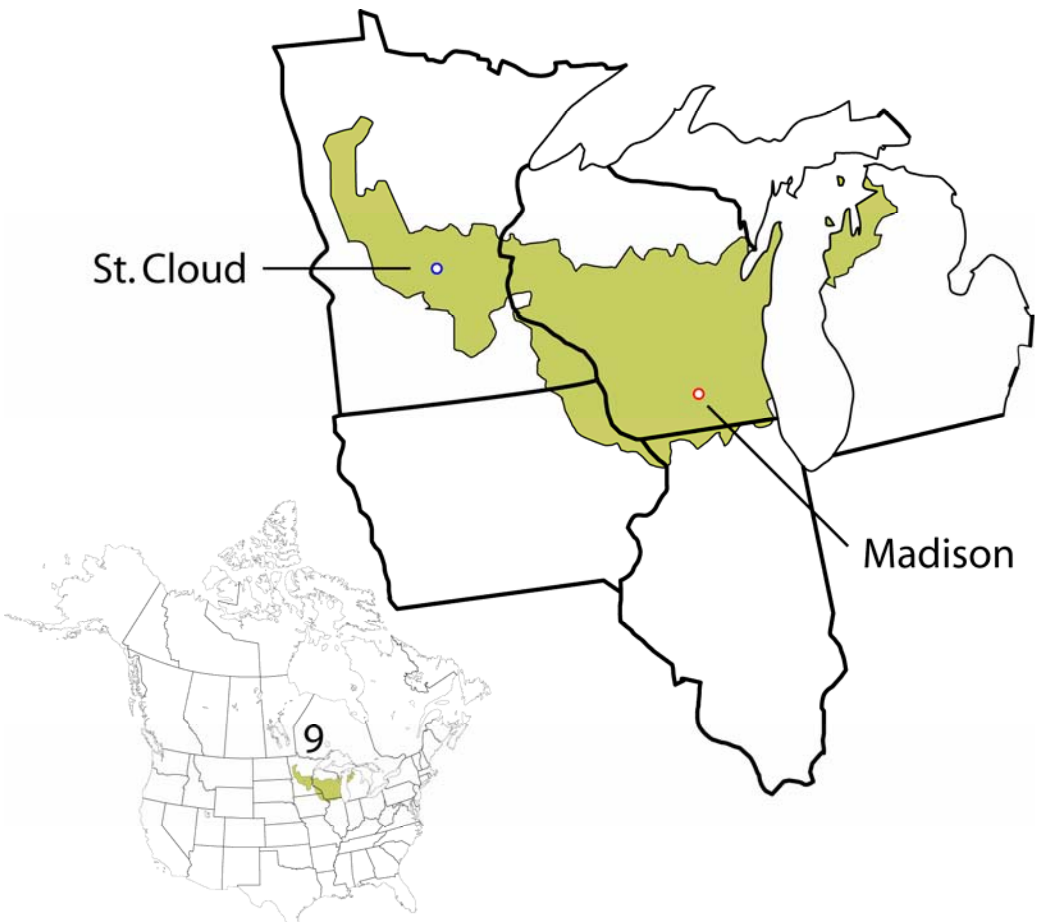


Figure I6. Upper Midwest Forest/Savanna Transition Zone.

St. Cloud, Minnesota

Didelphis virginiana
Sorex cinereus
Sorex palustris
Sorex arcticus
Blarina brevicauda
Condylura cristata
Myotis lucifugus
Myotis septentrionalis
Lasiurus borealis
Lasiurus cinereus
Lasionycteris noctivagans
Pipistrellus subflavus
Eptesicus fuscus
Sylvilagus floridanus
Lepus americanus
Lepus townsendii
Tamias striatus
Marmota monax
Spermophilus tridecemlineatus
Spermophilus franklinii
Sciurus carolinensis
Sciurus niger
Tamiasciurus hudsonicus
Glaucomys volans
Glaucomys sabrinus
Geomys bursarius
Castor canadensis
Peromyscus maniculatus
Peromyscus leucopus
Clethrionomys gapperi
Microtus pennsylvanicus
Microtus ochrogaster
Ondatra zibethicus
Synaptomys cooperi
Zapus hudsonius
Erethizon dorsatum
Canis latrans
Canis lupus
Vulpes vulpes
Urocyon cinereoargenteus
Ursus americanus
Procyon lotor
Mustela erminea
Mustela nivalis
Mustela frenata
Mustela vison
Taxidea taxus
Lontra canadensis
Spilogale putorius
Mephitis mephitis
Puma concolor
Lynx canadensis
Lynx rufus
Cervus canadensis
Odocoileus hemionus
Odocoileus virginianus
Alces alces
Bos bison

Madison, Wisconsin

Didelphis virginiana
Sorex cinereus
Sorex hoyi
Blarina brevicauda
Cryptotis parva
Scalopus aquaticus
Myotis lucifugus
Myotis septentrionalis
Lasiurus borealis
Lasiurus cinereus
Lasionycteris noctivagans
Eptesicus fuscus
Sylvilagus floridanus
Tamias striatus
Marmota monax
Spermophilus franklinii
Spermophilus tricedemlineatus
Sciurus carolinensis
Sciurus niger
Tamiasciurus hudsonicus
Glaucomys volans
Castor canadensis
Reithrodontomys megalotis
Peromyscus leucopus
Peromyscus maniculatus
Microtus ochrogaster
Microtus pennsylvanicus
Microtus pinetorum
Ondatra zibethicus
Synaptomys cooperi
Zapus hudsonius
Erethizon dorsatum
Canis latrans
Canis lupus
Vulpes vulpes
Urocyon cinereoargenteus
Ursus americanus
Procyon lotor
Martes americana
Martes pennanti
Mustela erminea
Mustela frenata
Mustela nivalis
Mustela vison
Gulo gulo
Taxidea taxus
Lontra canadensis
Mephitis mephitis
Puma concolor
Lynx canadensis
Lynx rufus
Cervus elephus
Odocoileus virginianus
Bos bison

10. Southern Great Lakes Forests

Lansing, Michigan	Dayton, Ohio
42° 47' N, 84° 35' W	39° 54' N, 84° 13' W
max. temp. – 13.8 °C	max. temp. – 15.9 °C
mean temp. – 8.2 °C	mean temp. – 10.8 °C
min. temp. – 2.6 °C	min. temp. – 5.7 °C
precipitation – 80.1 cm/yr	precipitation – 100.5 cm/yr

Figure I7. Southern Great Lakes Forests.

Lansing, Michigan

Didelphis virginiana
Sorex cinereus
Blarina brevicauda
Scalopus aquaticus
Condylura cristata
Myotis lucifugus
Myotis septentrionalis
Lasiurus borealis
Lasiurus cinereus
Lasionycteris noctivagans
Eptesicus fuscus
Sylvilagus floridanus
Lepus americanus
Tamias striatus
Marmota monax
Spermophilus tricedemlineatus
Sciurus carolinensis
Sciurus niger
Tamiasciurus hudsonicus
Glaucomys volans
Castor canadensis
Peromyscus leucopus
Peromyscus maniculatus
Microtus pennsylvanicus
Microtus pinetorum
Ondatra zibethicus
Synaptomys cooperi
Zapus hudsonius
Erethizon dorsatum
Canis latrans
Canis lupus
Vulpes vulpes
Urocyon cinereoargenteus
Ursus americanus
Procyon lotor
Martes americana
Martes pennanti
Mustela erminea
Mustela frenata
Mustela nivalis
Mustela vison
Gulo gulo
Taxidea taxus
Lontra canadensis
Mephitis mephitis
Puma concolor
Lynx canadensis
Lynx rufus
Cervus elephus
Odocoileus virginianus
Bos bison

Dayton, Ohio

Didelphis virginiana
Sorex cinereus
Blarina brevicauda
Cryptotis parva
Scalopus aquaticus
Myotis lucifugus
Myotis septentrionalis
Myotis sodalis
Lasiurus borealis
Lasiurus cinereus
Lasionycteris noctivagans
Pipistrellus subflavus
Eptesicus fuscus
Nycticeius humeralis
Sylvilagus floridanus
Tamias striatus
Marmota monax
Spermophilus tricedemlineatus
Sciurus carolinensis
Sciurus niger
Tamiasciurus hudsonicus
Glaucomys volans
Castor canadensis
Peromyscus leucopus
Peromyscus maniculatus
Microtus ochrogaster
Microtus pennsylvanicus
Microtus pinetorum
Ondatra zibethicus
Synaptomys cooperi
Zapus hudsonius
Erethizon dorsatum
Canis lupus
Canis rufus
Vulpes vulpes
Urocyon cinereoargenteus
Ursus americanus
Procyon lotor
Martes pennanti
Mustela frenata
Mustela nivalis
Mustela vison
Gulo gulo
Taxidea taxus
Lontra canadensis
Mephitis mephitis
Puma concolor
Lynx rufus
Cervus elephus
Odocoileus virginianus
Bos bison

11. Eastern Great Lakes Lowland Forests

Waterloo, Ontario

43° 27' N, 80° 22' W

max. temp. – 11.8 °C

mean temp. – 6.7 °C

min. temp. – 1.6 °C

precipitation – 90.8 cm/yr

Cornwall, Ontario

45° 01' N, 74° 45' W

max. temp. – 11.7 °C

mean temp. – 7.2 °C

min. temp. – 2.7 °C

precipitation – 100.2 cm/yr

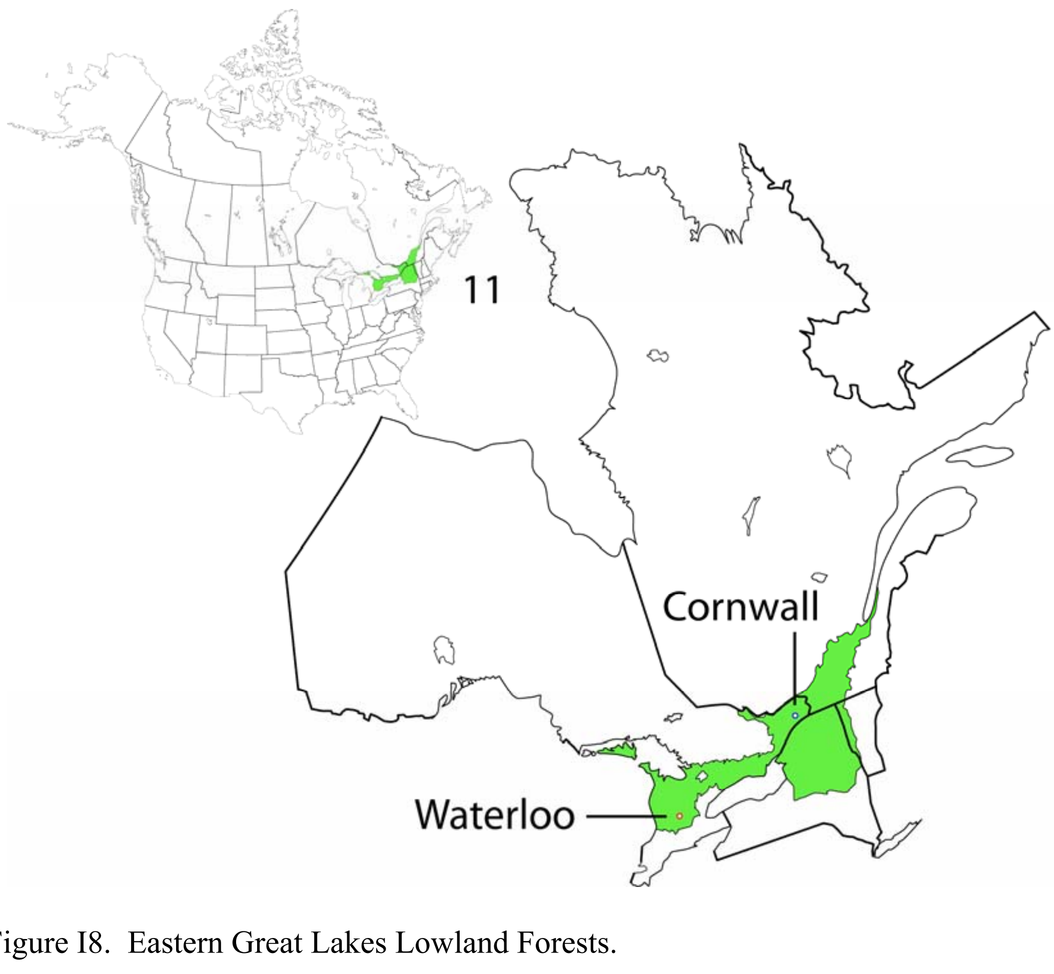


Figure I8. Eastern Great Lakes Lowland Forests.

Waterloo, Ontario

Didelphis virginiana
Sorex cinereus
Sorex fumeus
Blarina brevicauda
Parascalops breweri
Condylura cristata
Myotis lucifugus
Myotis septentrionalis
Myotis leibii
Lasiurus borealis
Lasiurus cinereus
Lasionycteris noctivagans
Pipistrellus subflavus
Eptesicus fuscus
Sylvilagus floridanus
Lepus americanus
Tamias striatus
Marmota monax
Sciurus carolinensis
Tamiasciurus hudsonicus
Glacomys volans
Glaucomys sabrinus
Castor canadensis
Peromyscus maniculatus
Peromyscus leucopus
Clethrionomys gapperi
Microtus pennsylvanicus
Ondatra zibethicus
Synaptomys cooperi
Zapus hudsonius
Napaeozapus insignis
Erethizon dorsatum
Canis latrans
Canis lupus
Vulpes vulpes
Ursus americanus
Procyon lotor
Martes americana
Martes pennanti
Mustela erminea
Mustela frenata
Mustela vison
Gulo gulo
Taxidea taxus
Lontra canadensis
Mephitis mephitis
Puma concolor
Lynx canadensis
Lynx rufus
Cervus canadensis
Odocoileus virginianus
Alces alces

Cornwall, Ontario

Didelphis virginiana
Sorex cinereus
Sorex palustris
Sorex fumeus
Blarina brevicauda
Parascalops breweri
Condylura cristata
Myotis lucifugus
Myotis septentrionalis
Myotis leibii
Lasiurus borealis
Lasiurus cinereus
Lasionycteris noctivagans
Pipistrellus subflavus
Eptesicus fuscus
Sylvilagus floridanus
Lepus americanus
Tamias striatus
Marmota monax
Sciurus carolinensis
Tamiasciurus hudsonicus
Glacomys volans
Glaucomys sabrinus
Castor canadensis
Peromyscus maniculatus
Peromyscus leucopus
Clethrionomys gapperi
Phenacomys ungava
Microtus pennsylvanicus
Microtus chrotorrhinus
Ondatra zibethicus
Synaptomys cooperi
Zapus hudsonius
Napaeozapus insignis
Erethizon dorsatum
Canis latrans
Canis lupus
Vulpes vulpes
Ursus americanus
Procyon lotor
Martes americana
Martes pennanti
Mustela erminea
Mustela frenata
Mustela vison
Gulo gulo
Lontra canadensis
Mephitis mephitis
Puma concolor
Lynx canadensis
Cervus canadensis
Odocoileus virginianus
Alces alces
Rangifer tarandus

12. New England/Acadian Forests

Bethlehem, New Hampshire

44° 17’ N, 71° 41’ W

max. temp. – 11.8 °C

mean temp. – 5.9 °C

min. temp. – -0.2 °C

precipitation – 99.9 cm/yr

Grand Falls, New Brunswick

(Grand Falls Drummond station)

47° 01’ N, 67° 42’ W

max. temp. – 8.2 °C

mean temp. – 3.5 °C

min. temp. – -1.2 °C

precipitation – 113.4 cm/yr

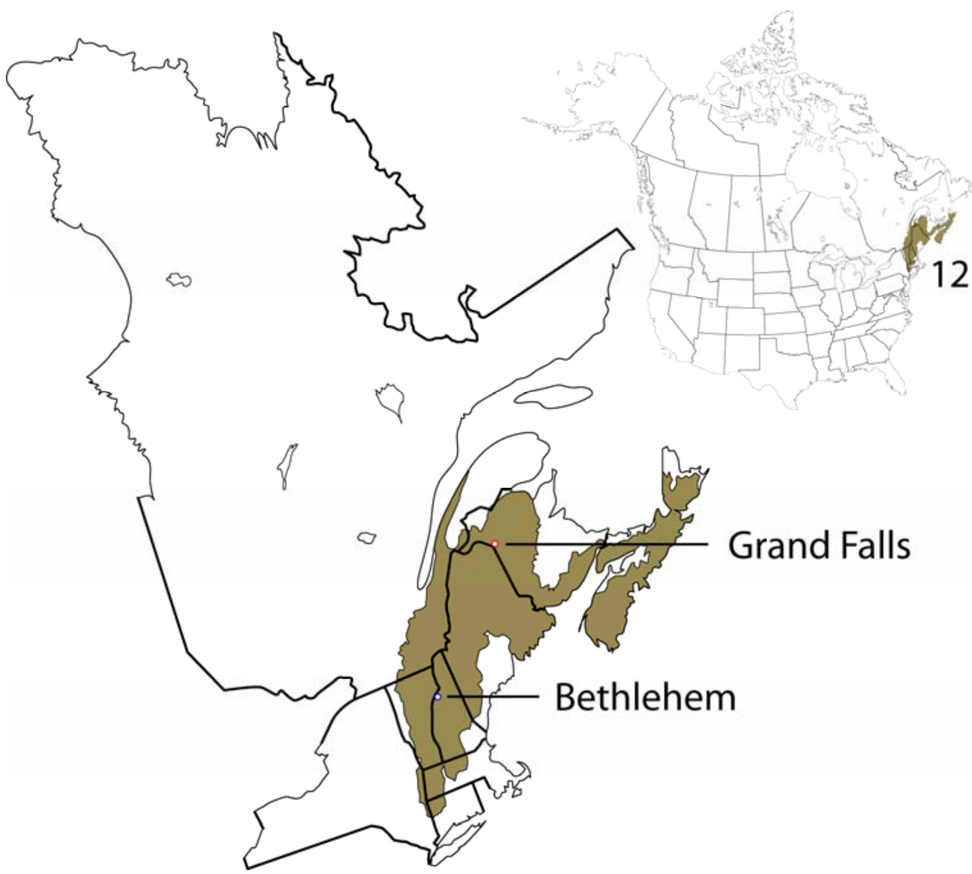


Figure I9. New England/Acadian Forests.

Bethlehem, New Hampshire

Sorex cinereus
Sorex dispar
Sorex fumeus
Sorex hoyi
Sorex palustris
Blarina brevicauda
Parascalops breweri
Condylura cristata
Myotis leibii
Myotis lucifugus
Myotis septentrionalis
Lasiurus borealis
Lasiurus cinereus
Lasionycteris noctivagans
Eptesicus fuscus
Lepus americanus
Tamias striatus
Marmota monax
Sciurus carolinensis
Tamiasciurus hudsonicus
Glaucomys sabrinus
Glaucomys volans
Castor canadensis
Peromyscus leucopus
Peromyscus maniculatus
Clethrionomys gapperi
Microtus chrotorrhinus
Microtus pennsylvanicus
Ondatra zibethicus
Synaptomys borealis
Synaptomys cooperi
Zapus hudsonius
Napaeozapus insignis
Erethizon dorsatum
Canis rufus
Canis latrans
Canis lupus
Vulpes vulpes
Urocyon cinereoargenteus
Ursus americanus
Procyon lotor
Martes americana
Martes pennanti
Mustela erminea
Mustela frenata
Mustela vison
Gulo gulo
Lontra canadensis
Mephitis mephitis
Puma concolor
Lynx canadensis
Lynx rufus
Cervus elephus
Odocoileus virginianus
Alces alces
Rangifer tarandus
Bos bison

Grand Falls, New Brunswick

Sorex cinereus
Sorex palustris
Sorex fumeus
Blarina brevicauda
Condylura cristata
Myotis lucifugus
Myotis septentrionalis
Lasiurus cinereus
Lasionycteris noctivagans
Eptesicus fuscus
Lepus americanus
Tamias striatus
Marmota monax
Tamiasciurus hudsonicus
Glaucomys sabrinus
Castor canadensis
Peromyscus maniculatus
Clethrionomys gapperi
Microtus pennsylvanicus
Microtus chrotorrhinus
Ondatra zibethicus
Synaptomys cooperi
Synaptomys borealis
Zapus hudsonius
Napaeozapus insignis
Erethizon dorsatum
Canis rufus
Canis lupus
Vulpes vulpes
Ursus americanus
Procyon lotor
Martes americana
Martes pennanti
Mustela erminea
Mustela vison
Gulo gulo
Lontra canadensis
Mephitis mephitis
Puma concolor
Lynx canadensis
Lynx rufus
Odocoileus virginianus
Alces alces
Rangifer tarandus

13. Gulf of St. Lawrence Lowland Forests

Minto, New Brunswick

46° 01’ N, 66° 01’ W

max. temp. – 11.1 °C

mean temp. – 5.7 °C

min. temp. – 0.3 °C

precipitation – 98.7 cm/yr

Charlottetown, Prince Edward Island

(Charlottetown A station)

46° 17’ N, 63° 07’ W

max. temp. – 9.7 °C

mean temp. – 5.3 °C

min. temp. – 0.9 °C

precipitation – 117.3 cm/yr

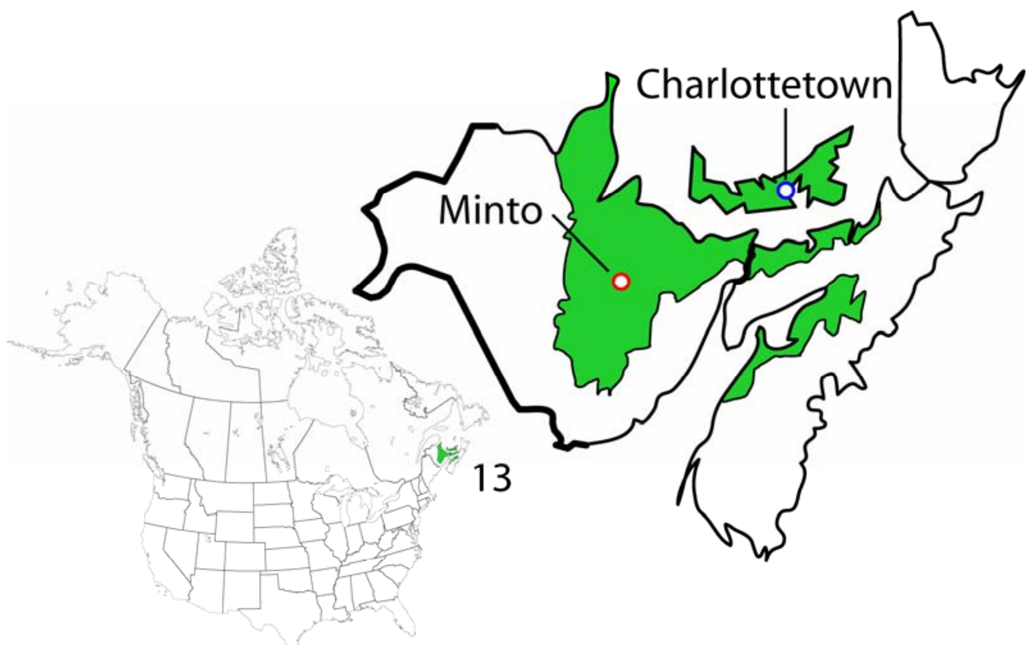


Figure I10. Gulf of St. Lawrence Lowland Forests.

Minto, New Brunswick

Sorex cinereus
Sorex palustris
Sorex fumeus
Sorex maritimensis
Blarina brevicauda
Condylura cristata
Myotis lucifugus
Myotis septentrionalis
Lasiurus borealis
Lasiurus cinereus
Lasionycteris noctivagans
Lepus americanus
Tamias striatus
Marmota monax
Tamiasciurus hudsonicus
Glaucomys sabrinus
Castor canadensis
Peromyscus maniculatus
Clethrionomys gapperi
Microtus pennsylvanicus
Ondatra zibethicus
Synaptomys cooperi
Zapus hudsonius
Napaeozapus insignis
Erethizon dorsatum
Canis lupus
Vulpes vulpes
Ursus americanus
Procyon lotor
Martes americana
Martes pennanti
Mustela erminea
Mustela vison
Lontra canadensis
Puma concolor
Lynx canadensis
Lynx rufus
Odocoileus virginianus
Alces alces
Rangifer tarandus

Charlottetown, Prince Edward Island

Sorex cinereus
Blarina brevicauda
Lepus americanus
Peromyscus maniculatus
Clethrionomys gapperi
Microtus pennsylvanicus
Zapus hudsonius
Napaeozapus insignis
Erethizon dorsatum
Canis lupus
Mustela erminea
Mustela vison
Lontra canadensis
Lynx canadensis
Odocoileus virginianus
Alces alces
Rangifer tarandus

14. Northeastern Coastal Forests

Norristown, Pennsylvania

40° 07' N, 75° 22' W

max. temp. – 17.8 °C

mean temp. – 12.2 °C

min. temp. – 6.6 °C

precipitation – 119.8 cm/yr

Lowell, Massachusetts

42° 39' N, 71° 22' W

max. temp. – 15.2 °C

mean temp. – 9.1 °C

min. temp. – 3.0 °C

precipitation – 109.6 cm/yr

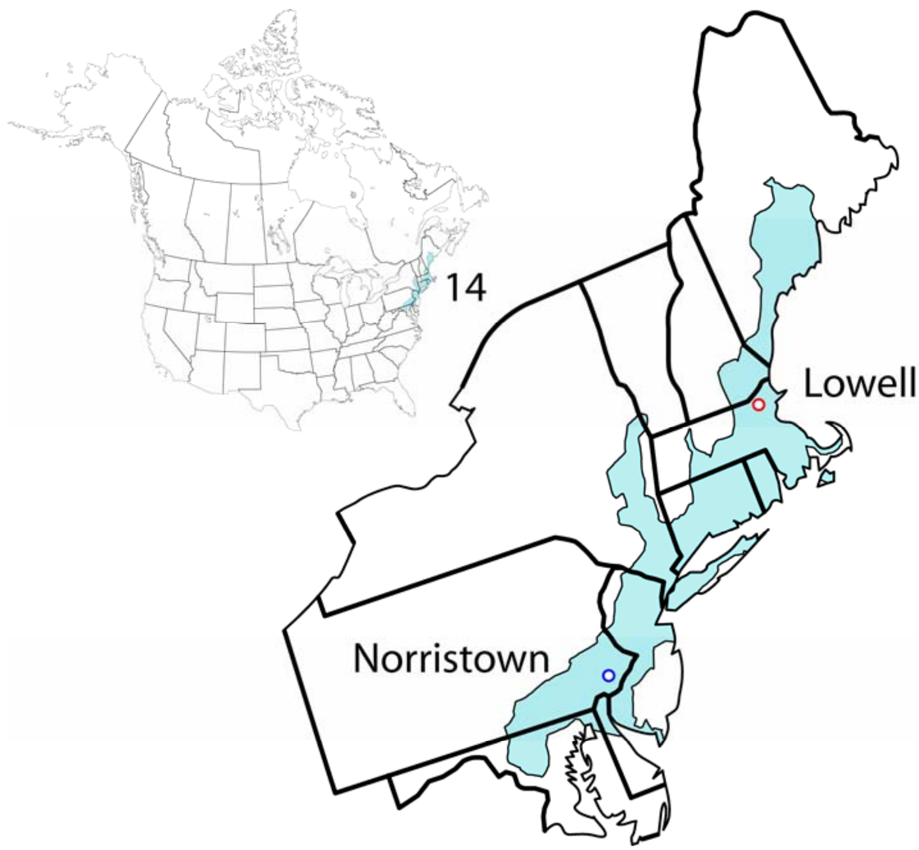


Figure I11. Northeastern Coastal Forests.

Norristown, Pennsylvania

Didelphis virginiana
Sorex cinereus
Sorex fontinalis
Sorex fumeus
Blarina brevicauda
Cryptotis parva
Parascalops breweri
Scalopus aquaticus
Condylura cristata
Myotis lucifugus
Myotis septentrionalis
Myotis leibii
Lasiurus borealis
Lasiurus seminolus
Lasiurus cinereus
Lasionycteris noctivagans
Nycticeus humeralis
Sylvilagus floridanus
Sylvilagus obscurus
Tamias striatus
Marmota monax
Sciurus carolinensis
Sciurus niger
Tamiasciurus hudsonicus
Glaucomys volans
Castor canadensis
Oryzomys palustris
Peromyscus leucopus
Neotoma magister
Clethrionomys gapperi
Microtus pennsylvanicus
Microtus pinetorum
Synaptomys cooperi
Ondatra zibethicus
Zapus hudsonius
Canis lupus
Canis rufus
Vulpes vulpes
Urocyon cinereoargenteus
Ursus americanus
Procyon lotor
Mustela erminea
Mustela frenata
Mustela vison
Gulo gulo
Lontra canadensis
Mephitis mephitis
Puma concolor
Lynx rufus
Odocoileus virginianus

Lowell, Massachusetts

Didelphis virginiana
Sorex cinereus
Sorex fumeus
Sorex palustris
Blarina brevicauda
Parascalops breweri
Condylura cristata
Myotis lucifugus
Myotis septentrionalis
Lasiurus borealis
Lasiurus cinereus
Lasionycteris noctivagans
Pipistrellus subflavus
Eptesicus fuscus
Sylvilagus floridanus
Sylvilagus transitionalis
Tamias striatus
Marmota monax
Sciurus carolinensis
Tamiasciurus hudsonicus
Glaucomys volans
Castor canadensis
Peromyscus leucopus
Peromyscus maniculatus
Clethrionomys gapperi
Microtus pennsylvanicus
Microtus pinetorum
Ondatra zibethicus
Synaptomys cooperi
Zapus hudsonius
Erethizon dorsatum
Canis rufus
Canis latrans
Canis lupus
Vulpes vulpes
Urocyon cinereoargenteus
Ursus americanus
Procyon lotor
Mustela erminea
Mustela frenata
Mustela vison
Gulo gulo
Lontra canadensis
Mephitis mephitis
Puma concolor
Lynx canadensis
Lynx rufus
Odocoileus virginianus

15. Allegheny Highlands Forests

Bradford, Pennsylvania	Binghamton, New York
41° 48’ N, 78° 38’ W	42° 12’ N, 75° 59’ W
max. temp. – 12.4 °C	max. temp. – 12.2 °C
mean temp. – 6.9 °C	mean temp. – 7.7 °C
min. temp. – 1.4 °C	min. temp. – 3.1 °C
precipitation – 118.3 cm/yr	precipitation – 98.2 cm/yr

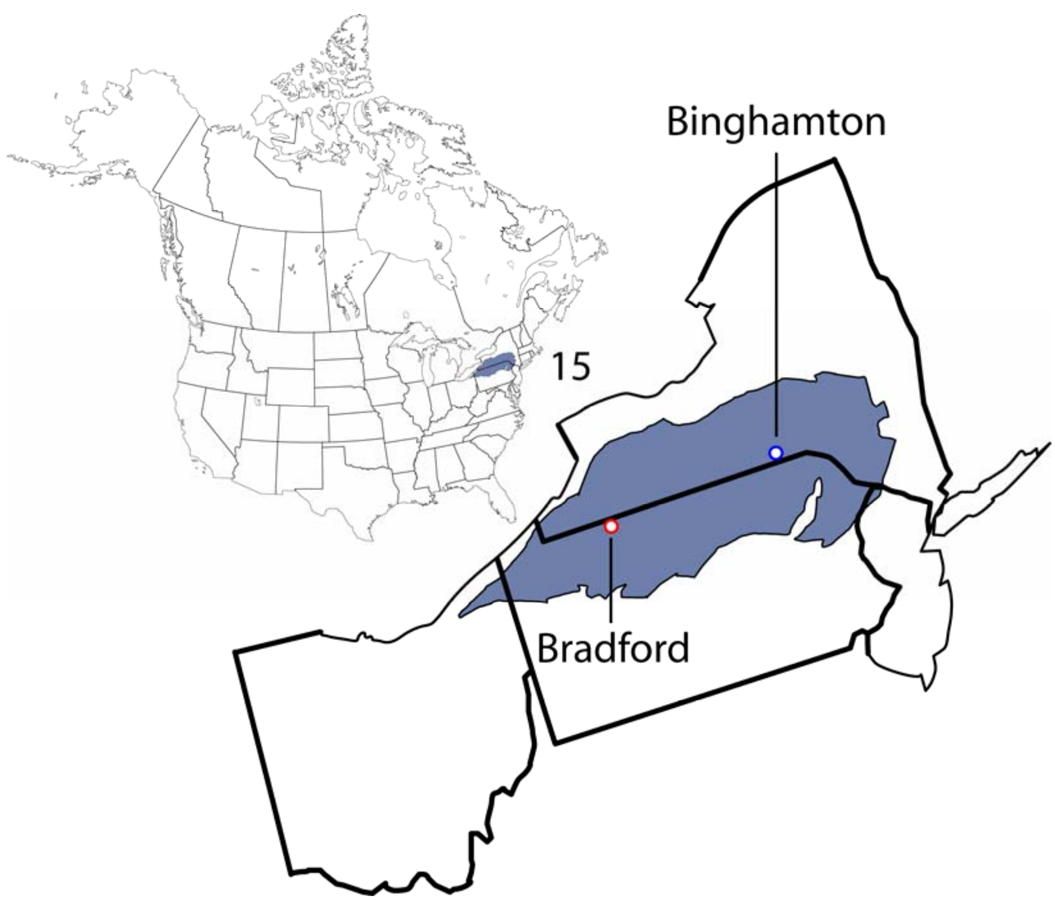


Figure I12. Allegheny Highlands Forests.

Bradford, Pennsylvania

Didelphis virginiana
Sorex cinereus
Sorex palustris
Sorex dispar
Sorex hoyi
Blarina brevicauda
Cryptotis parva
Parascalops breweri
Condylura cristata
Myotis lucifugus
Myotis septentrionalis
Myotis leibii
Lasiurus borealis
Lasiurus cinereus
Lasionycteris noctivagans
Pipistrellus subflavus
Sylvilagus obscurus
Sylvilagus floridanus
Lepus americanus
Tamias striatus
Marmota monax
Sciurus carolinensis
Sciurus niger
Tamiasciurus hudsonicus
Glaucomys volans
Glaucomys sabrinus
Castor canadensis
Peromyscus maniculatus
Peromyscus leucopus
Neotoma magister
Clethrionomys gapperi
Microtus pennsylvanicus
Microtus pinetorum
Synaptomys cooperi
Ondatra zibethicus
Zapus hudsonius
Napeozapus insignis
Erethizon dorsatum
Canis lupus
Vulpes vulpes
Urocyon cinereoargenteus
Ursus americanus
Procyon lotor
Mustela erminea
Mustela nivalis
Mustela frenata
Mustela vison
Martes americana
Martes pennanti
Gulo gulo
Lontra canadensis
Mephitis mephitis
Puma concolor
Lynx canadensis
Lynx rufus
Odocoileus virginianus
Cervus elephaus
Alces alces
Bos bison

Binghamton, New York

Didelphis virginiana
Sorex cinereus
Sorex fumeus
Sorex hoyi
Blarina brevicauda
Cryptotis parva
Parascalops breweri
Condylura cristata
Myotis leibii
Myotis lucifugus
Myotis septentrionalis
Myotis sodalis
Lasiurus borealis
Lasiurus cinereus
Lasionycteris noctivagans
Pipistrellus subflavus
Eptesicus fuscus
Sylvilagus floridanus
Lepus americanus
Tamias striatus
Marmota monax
Sciurus carolinensis
Tamiasciurus hudsonicus
Glaucomys sabrinus
Glaucomys volans
Castor canadensis
Peromyscus leucopus
Peromyscus maniculatus
Clethrionomys gapperi
Microtus pennsylvanicus
Microtus pinetorum
Ondatra zibethicus
Synaptomys cooperi
Zapus hudsonius
Napaeozapus insignis
Erethizon dorsatum
Canis rufus
Canis lupus
Vulpes vulpes
Urocyon cinereoargenteus
Ursus americanus
Procyon lotor
Martes americana
Martes pennanti
Mustela erminea
Mustela frenata
Mustela vison
Gulo gulo
Lontra canadensis
Mephitis mephitis
Puma concolor
Lynx canadensis
Lynx rufus
Cervus elephus
Odocoileus virginianus
Alces alces
Bos bison

16. Appalachian/Blue Ridge Forests

Tapoco, North Carolina

35° 27’ N, 83° 56’ W

max. temp. – 21.3 °C

mean temp. – 14.6 °C

min. temp. – 7.8 °C

precipitation – 152.5 cm/yr

Lewiston, Pennsylvania

40° 35’ N, 77° 34’ W

max. temp. – 16.4 °C

mean temp. – 10.4 °C

min. temp. – 4.3 °C

precipitation – 103.8 cm/yr

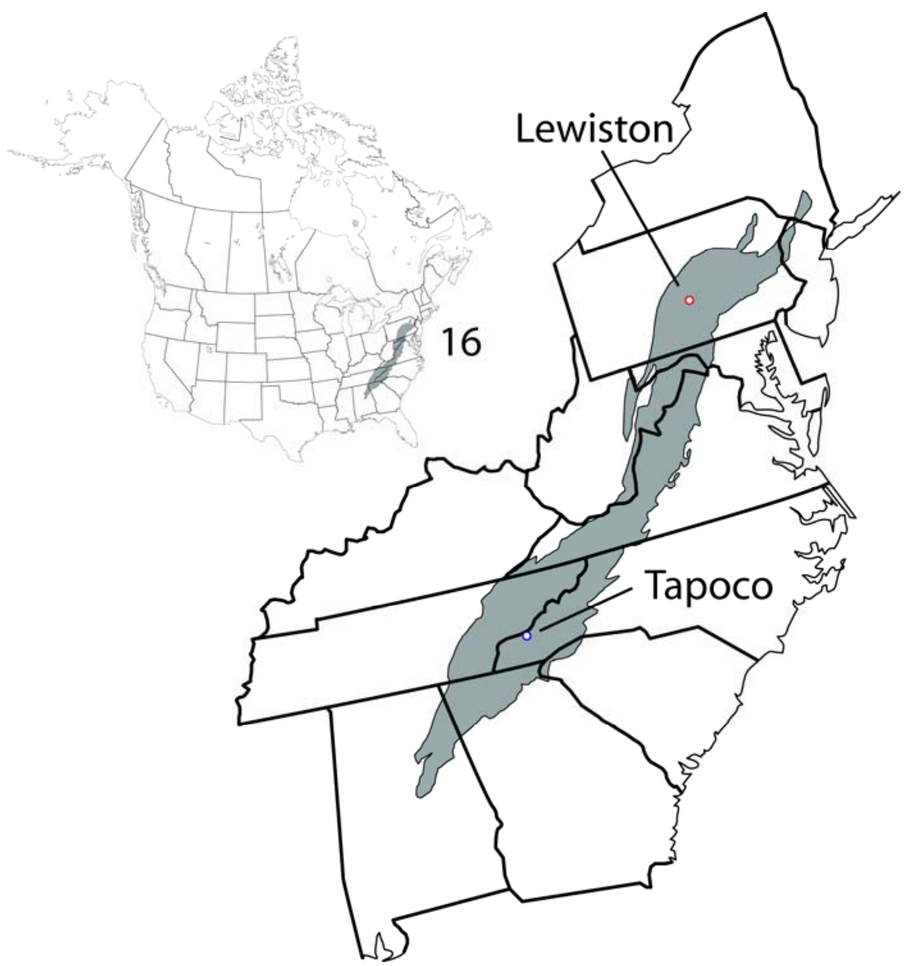


Figure I13. Appalachian/Blue Ridge Forests.

Tapoco, North Carolina

Didelphis virginiana
Sorex cinereus
Sorex dispar
Sorex fumeus
Sorex hoyi
Sorex palustris
Blarina brevicauda
Cryptotis parva
Parascalops breweri
Condylura cristata
Myotis grisescens
Myotis leibii
Myotis lucifugus
Myotis septentrionalis
Myotis sodalis
Lasiurus borealis
Lasiurus cinereus
Lasiurus seminolus
Lasionycteris noctivagans
Pipistrellus subflavus
Eptesicus fuscus
Corynorhinus rafinesquii
Sylvilagus floridanus
Sylvilagus obscurus
Lepus americanus
Tamias striatus
Marmota monax
Sciurus carolinensis
Sciurus niger
Tamiasciurus hudsonicus
Glaucomys sabrinus
Glaucomys volans
Castor canadensis
Oryzomys palustris
Reithrodontomys humulis
Peromyscus leucopus
Peromyscus maniculatus
Ochrotomys nuttalli
Sigmodon hispidus
Neotoma magister
Clethrionomys gapperi
Microtus chrotorrhinus
Microtus pinetorum
Ondatra zibethicus
Synaptomys cooperi
Zapus hudsonius
Napaeozapus insignis
Canis lupus
Canis rufus
Vulpes vulpes
Urocyon cinereoargenteus
Ursus americanus
Procyon lotor
Mustela frenata
Mustela nivalis
Mustela vison
Lontra canadensis
Spilogale putorius
Mephitis mephitis
Puma concolor
Lynx rufus
Cervus elephus
Odocoileus virginianus
Bos bison

Lewiston, Pennsylvania

Didelphis virginiana
Sorex cinereus
Sorex hoyi
Blarina brevicauda
Cryptotis parva
Parascalops breweri
Condylura cristata
Myotis lucifugus
Myotis septentrionalis
Myotis sodalis
Myotis leibii
Lasiurus borealis
Lasiurus cinereus
Lasionycteris noctivagans
Pipistrellus subflavus
Sylvilagus floridanus
Sylvilagus obscurus
Lepus americanus
Tamias striatus
Marmota monax
Sciurus carolinensis
Sciurus niger
Tamiasciurus hudsonicus
Glaucomys volans
Castor canadensis
Peromyscus maniculatus
Peromyscus leucopus
Neotoma magister
Clethrionomys gapperi
Microtus pennsylvanicus
Microtus pinetorum
Synaptomys cooperi
Ondatra zibethicus
Zapus hudsonius
Napeozapus insignis
Erethizon dorsatum
Canis latrans
Canis lupus
Canis rufus
Vulpes vulpes
Urocyon cinereoargenteus
Ursus americanus
Procyon lotor
Mustela erminea
Mustela nivalis
Mustela frenata
Mustela vison
Martes americana
Martes pennanti
Gulo gulo
Lontra canadensis
Mephitis mephitis
Puma concolor
Lynx rufus
Odocoileus virginianus
Alces alces
Bos bison

17. Appalachian Mixed Mesophytic Forests

Birmingham, Alabama

33° 34’ N, 86° 45’ W

max. temp. – 23 °C

mean temp. – 16.8 °C

min. temp. – 10.5 °C

precipitation – 137.1 cm/yr

Charleston, West Virginia

38° 23’ N, 81° 35’ W

max. temp. – 18.6 °C

mean temp. – 12.5 °C

min. temp. – 6.4 °C

precipitation – 111.9 cm/yr

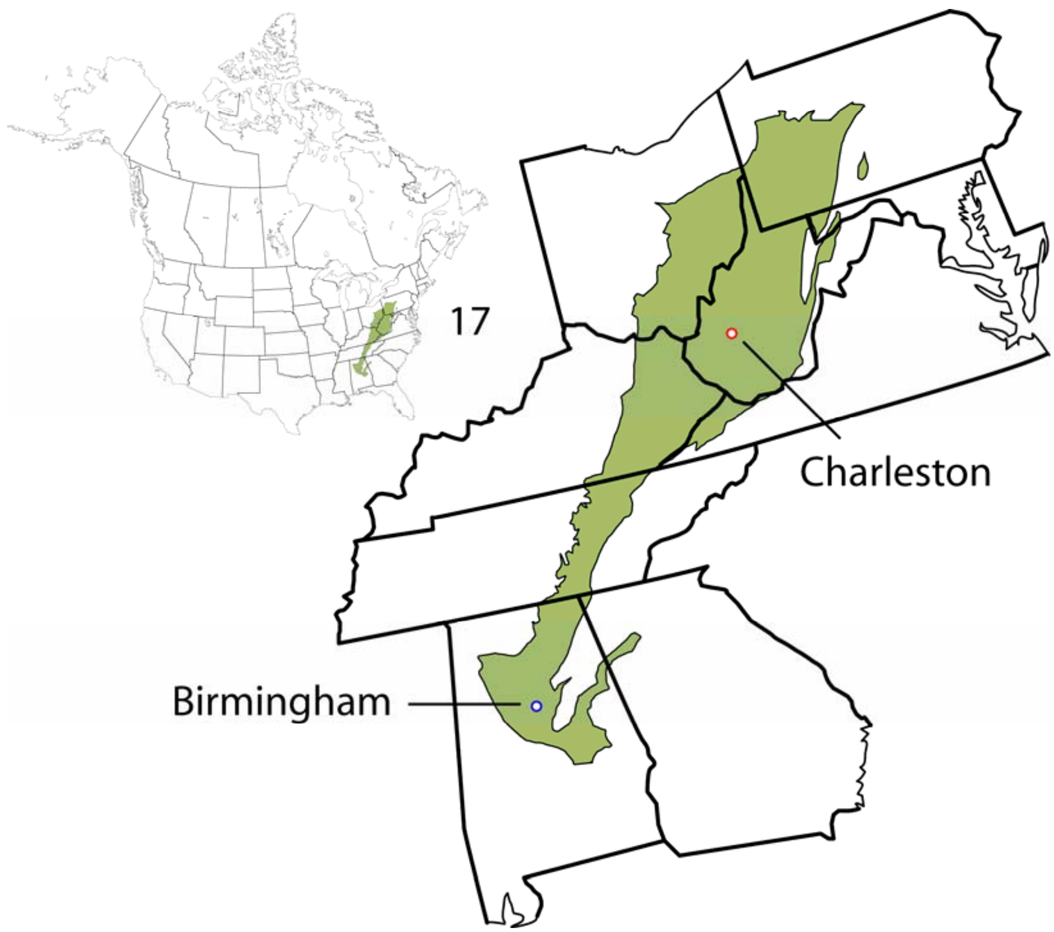


Figure I14. Appalachian Mixed Mesophytic Forests.

Birmingham, Alabama

Didelphis virginiana
Sorex longirostris
Blarina carolinensis
Cryptotis parva
Scalopus aquaticus
Myotis grisescens
Myotis septentrionalis
Myotis sodalis
Lasiurus borealis
Lasiurus cinereus
Lasiurus seminolus
Lasionycteris noctivagans
Pipistrellus subflavus
Eptesicus fuscus
Nycticeius humeralis
Corynorhinus rafinesquii
Sylvilagus aquaticus
Sylvilagus floridanus
Tamias striatus
Marmota monax
Sciurus carolinensis
Sciurus niger
Glaucomys volans
Castor canadensis
Oryzomys palustris
Reithrodontomys humulis
Peromyscus gossypinus
Peromyscus leucopus
Peromyscus polionotus
Ochrotomys nuttalli
Sigmodon hispidus
Neotoma floridana
Microtus pinetorum
Ondatra zibethicus
Canis rufus
Vulpes vulpes
Urocyon cinereoargenteus
Ursus americanus
Procyon lotor
Mustela frenata
Mustela vison
Lontra canadensis
Spilogale putorius
Mephitis mephitis
Puma concolor
Lynx rufus
Odocoileus virginianus
Bos bison

Charleston, West Virginia

Didelphis virginiana
Sorex fumeus
Sorex hoyi
Blarina brevicauda
Cryptotis parva
Parascalops breweri
Myotis lucifugus
Myotis septentrionalis
Myotis sodalis
Lasiurus borealis
Lasiurus cinereus
Lasionycteris noctivagans
Pipistrellus subflavus
Eptesicus fuscus
Sylvilagus floridanus
Tamias striatus
Marmota monax
Sciurus carolinensis
Sciurus niger
Glaucomys volans
Castor canadensis
Reithrodontomys humulis
Peromyscus leucopus
Neotoma magister
Clethrionomys gapperi
Microtus pennsylvanicus
Microtus pinetorum
Ondatra zibethicus
Synaptomys cooperi
Zapus hudsonius
Erethizon dorsatum
Canis lupus
Canis rufus
Vulpes vulpes
Urocyon cinereoargenteus
Ursus americanus
Procyon lotor
Martes pennanti
Mustela frenata
Mustela nivalis
Mustela vison
Lontra canadensis
Mephitis mephitis
Puma concolor
Lynx rufus
Cervus elephus
Odocoileus virginianus
Bos bison

18. Central United States Hardwood Forests

Houston, Missouri

37° 20’ N, 91° 57’ W

max. temp. – 19.1 °C

mean temp. – 11.9 °C

min. temp. – 4.4 °C

precipitation – 57.5 cm/yr

Bowling Green, Kentucky

36° 59’ N, 86° 26’ W

max. temp. – 19.9 °C

mean temp. – 14.0 °C

min. temp. – 8.1 °C

precipitation – 131.1 cm/yr

Figure I15. Central United States Hardwood Forests.

Houston, Missouri

Didelphis virginiana
Blarina hylophaga
Cryptotis parva
Scalopus aquaticus
Myotis lucifugus
Myotis velifer
Myotis septentrionalis
Myotis sodalis
Myotis leibii
Lasiurus borealis
Lasiurus cinereus
Lasionycteris noctivagans
Pipistrellus subflavus
Eptesicus fuscus
Nycticeius humeralis
Corynorhinus townsendii
Corynorhinus rafinesquii
Sylvilagus floridanus
Marmota monax
Sciurus carolinensis
Glaucomys volans
Castor canadensis
Reithrodontomys megalotis
Peromyscus maniculatus
Peromyscus leucopus
Neotoma floridana
Microtus ochrogaster
Microtus pinetorum
Ondatra zibethicus
Zapus hudsonius
Canis latrans
Canis rufus
Vulpes vulpes
Urocyon cinereoargenteus
Ursus americanus
Procyon lotor
Mustela frenata
Mustela vison
Lontra canadensis
Spilogale putorius
Mephitis mephitis
Puma concolor
Lynx rufus
Cervus canadensis
Odocoileus virginianus
Bos bison

Bowling Green, Kentucky

Didelphis virginiana
Sorex fumeus
Sorex longirostris
Blarina brevicauda
Cryptotis parva
Scalopus aquaticus
Myotis grisescens
Myotis lucifugus
Myotis septentrionalis
Myotis sodalis
Myotis leibii
Lasiurus borealis
Lasiurus cinereus
Lasionycteris noctivagans
Pipistrellus subflavus
Eptesicus fuscus
Nycticeius humeralis
Sylvilagus floridanus
Tamias striatus
Marmota monax
Sciurus carolinensis
Sciurus niger
Glaucomys volans
Castor canadensis
Oryzomys palustris
Reithrodontomys humulis
Peromyscus gossypinus
Peromyscus leucopus
Peromyscus maniculatus
Ochrotomys nuttalli
Neotoma magister
Microtus ochrogaster
Microtus pinetorum
Ondatra zibethicus
Synaptomys cooperi
Zapus hudsonius
Erethizon dorsatum
Canis lupus
Canis rufus
Vulpes vulpes
Urocyon cinereoargenteus
Ursus americanus
Procyon lotor
Martes pennanti
Mustela frenata
Mustela vison
Lontra canadensis
Mephitis mephitis
Puma concolor
Lynx rufus
Cervus elephus
Odocoileus virginianus
Bos bison

19. Ozark Mountain Forests

Poteau, Oklahoma

35° 03' N, 94° 38' W

max. temp. – 23.0 °C

mean temp. – 16.7 °C

min. temp. – 10.3 °C

precipitation – 117.9 cm/yr

Conway, Arkansas

35° 05' N, 92° 26' W

max. temp. – 22.2 °C

mean temp. – 16.2 °C

min. temp. – 10.2 °C

precipitation – 123.6 cm/yr

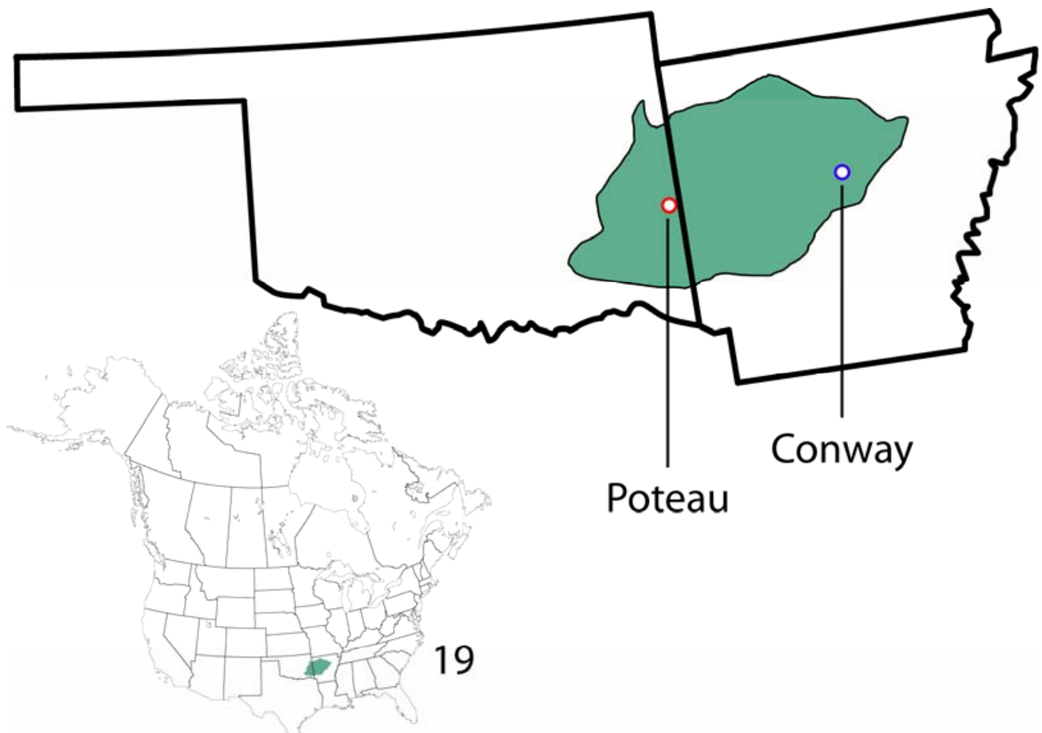


Figure I16. Ozark Mountain Forests.

Poteau, Oklahoma

Didelphis virginiana
Blarina hylophaga
Cryptotis parva
Notiosorex crawfordi
Scalopus aquaticus
Myotis septentrionalis
Lasiurus borealis
Lasiurus cinereus
Lasionycteris noctivagans
Pipistrellus subflavus
Eptesicus fuscus
Nycticeius humeralis
Corynorhinus townsendii
Sylvilagus palustris
Sylvilagus floridanus
Lepus californicus
Tamias striatus
Sciurus carolinensis
Sciurus niger
Glaucomys volans
Geomys breviceps
Castor canadensis
Oryzomys palustris
Reithrodontomys fulvescens
Peromyscus maniculatus
Peromyscus leucopus
Peromyscus gossypinus
Peromyscus attwateri
Ochrotomys nuttalli
Sigmodon hispidus
Neotoma floridana
Microtus pinetorum
Canis latrans
Canis rufus
Vulpes vulpes
Urocyon cinereoargenteus
Ursus americanus
Procyon lotor
Mustela frenata
Mustela vison
Lontra canadensis
Spilogale putorius
Mephitis mephitis
Puma concolor
Lynx rufus
Cervus canadensis
Odocoileus virginianus
Bos bison

Conway, Arkansas

Didelphis virginiana
Sorex longirostris
Blarina carolinensis
Blarina hylophaga
Cryptotis parva
Scalopus aquaticus
Myotis lucifugus
Myotis septentrionalis
Lasiurus borealis
Lasiurus cinereus
Lasionycteris noctivagans
Pipistrellus subflavus
Eptesicus fuscus
Nycticeius humeralis
Corynorhinus rafinesquii
Tadarida brasiliensis
Sylvialgus floridanus
Sylvilagus aquaticus
Tamias striatus
Marmota monax
Sciurus carolinensis
Sciurus niger
Glaucomys volans
Castor canadensis
Oryzomys palustris
Reithrodontomys fulvescens
Peromyscus maniculatus
Peromyscus leucopus
Peromyscus gossipinus
Peromyscus attwateri
Ochrotomys nuttalli
Sigmodon hispidus
Neotoma floridana
Microtus ochrogaster
Microtus pinetorum
Ondatra zibethicus
Synaptomys cooperi
Canis latrans
Canis rufus
Vulpes vulpes
Urocyon cineareoargenteus
Ursus americanus
Procyon lotor
Mustela frenata
Mustela vison
Lontra canadensis
Spilogale putorius
Mephitis mephitis
Puma concolor
Lynx rufus
Cervus elephas
Odocoileus virginianus
Bos bison

20. Mississippi Lowland Forests

Baton Rouge, Louisiana

30° 32’ N, 91° 09’ W

max. temp. – 25.2 °C

mean temp. – 19.4 °C

min. temp. – 13.8 °C

precipitation – 160.2 cm/yr

Jonesboro, Arkansas

35° 53’ N, 90° 42’ W

max. temp. – 21.4 °C

mean temp. – 15.4 °C

min. temp. – 9.4 °C

precipitation – 117.3 cm/yr

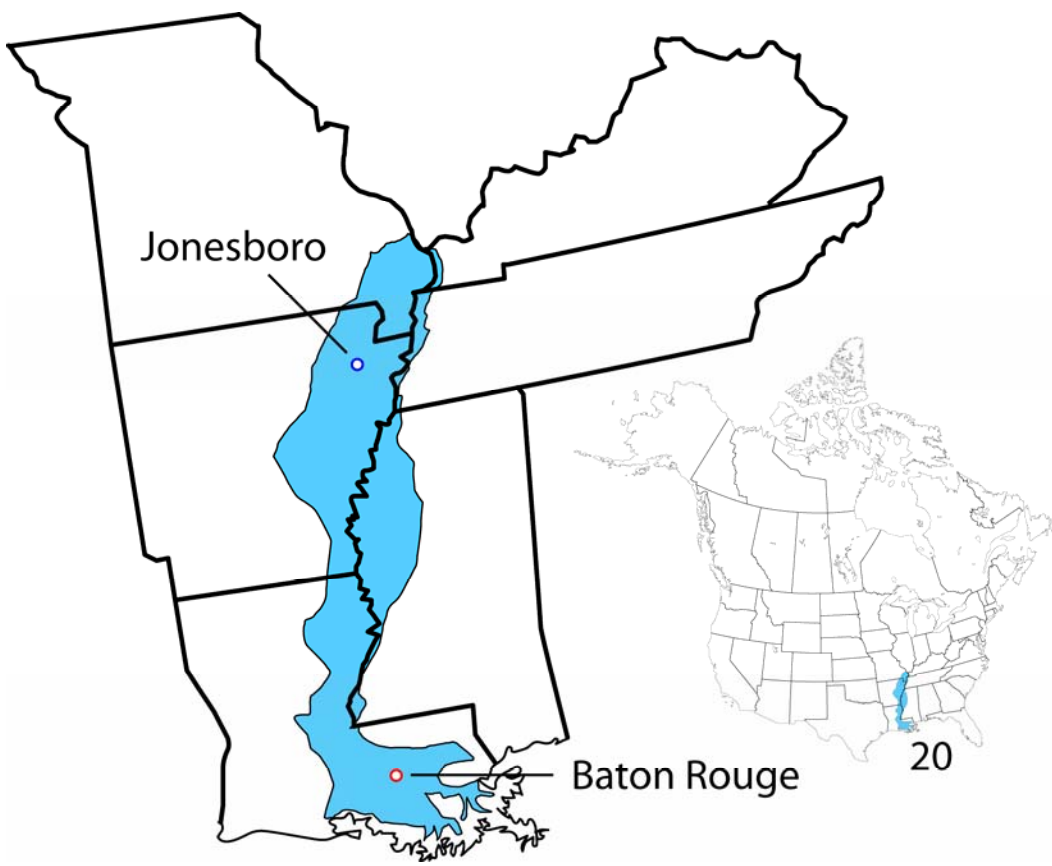


Figure I17. Mississippi Lowland Forests.

Baton Rouge, Louisiana

Didelphis virginiana
Blarina carolinensis
Cryptotis parva
Scalopus aquaticus
Myotis austroriparius
Lasiurus borealis
Lasiurus seminolus
Lasiurus cinereus
Lasiurus intermedius
Pipistrellus subflavus
Eptesicus fuscus
Nycticeius humeralis
Corynorhinus rafinesquii
Tadarida brasiliensis
Sylvilagus palustris
Sylvilagus floridanus
Tamias striatus
Sciurus carolinensis
Glaucomys volans
Castor canadensis
Oryzomys palustris
Reithrodontomys humulis
Reithrodontomys fulvescens
Peromyscus leucopus
Peromyscus gossypinus
Ochrotomys nuttalli
Sigmodon hispidus
Neotoma floridana
Microtus pinetorum
Ondatra zibethicus
Canis rufus
Vulpes vulpes
Urocyon cinereoargenteus
Ursus americanus
Procyon lotor
Mustela frenata
Mustela vison
Lontra canadensis
Spilogale putorius
Mephitis mephitis
Puma concolor
Lynx rufus
Odocoileus virginianus
Bos bison

Jonesboro, Arkansas

Didelphis virginianus
Sorex longirostris
Blarina carolinensis
Blarina hylophaga
Cryptotis parva
Scalopus aquaticus
Myotis lucifugus
Myotis austroriparius
Lasiurus borealis
Lasiurus cinereus
Lasionycteris noctivagans
Pipistrellus subflavus
Eptesicus fuscus
Nycticeius humeralis
Corynorhinus rafinesquii
Sylvilagus floridanus
Sylvilagus aquaticus
Tamias striatus
Marmota monax
Sciurus carolinensis
Sciurus niger
Glaucomys volans
Castor canadensis
Oryzomys palustris
Reithrodontomys megalotis
Reithrodontomys fulvescens
Peromyscus maniculatus
Peromyscus leucopus
Peromyscus gossipinus
Ochrotomys nuttalli
Sigmodon hispidus
Neotoma floridana
Microtus ochrogaster
Microtus pinetorum
Ondatra zibethicus
Synaptomys cooperi
Canis latrans
Canis rufus
Vulpes vulpes
Urocyon cineareoargenteus
Ursus americanus
Procyon lotor
Mustela frenata
Mustela vison
Lontra canadensis
Spilogale putorius
Mephitis mephitis
Puma concolor
Lynx rufus
Cervus elephas
Odocoileus virginianus
Bos bison

21. East Central Texas Forests

Beeville, Texas

28° 27’ N, 97° 42’ W

max. temp. – 27.1 °C

mean temp. – 21.2 °C

min. temp. – 15.3 °C

precipitation – 85.0 cm/yr

Palestine, Texas

31° 47’ N, 95° 36’ W

max. temp. – 25.3 °C

mean temp. – 19.1 °C

min. temp. – 12.8 °C

precipitation – 117.8 cm/yr

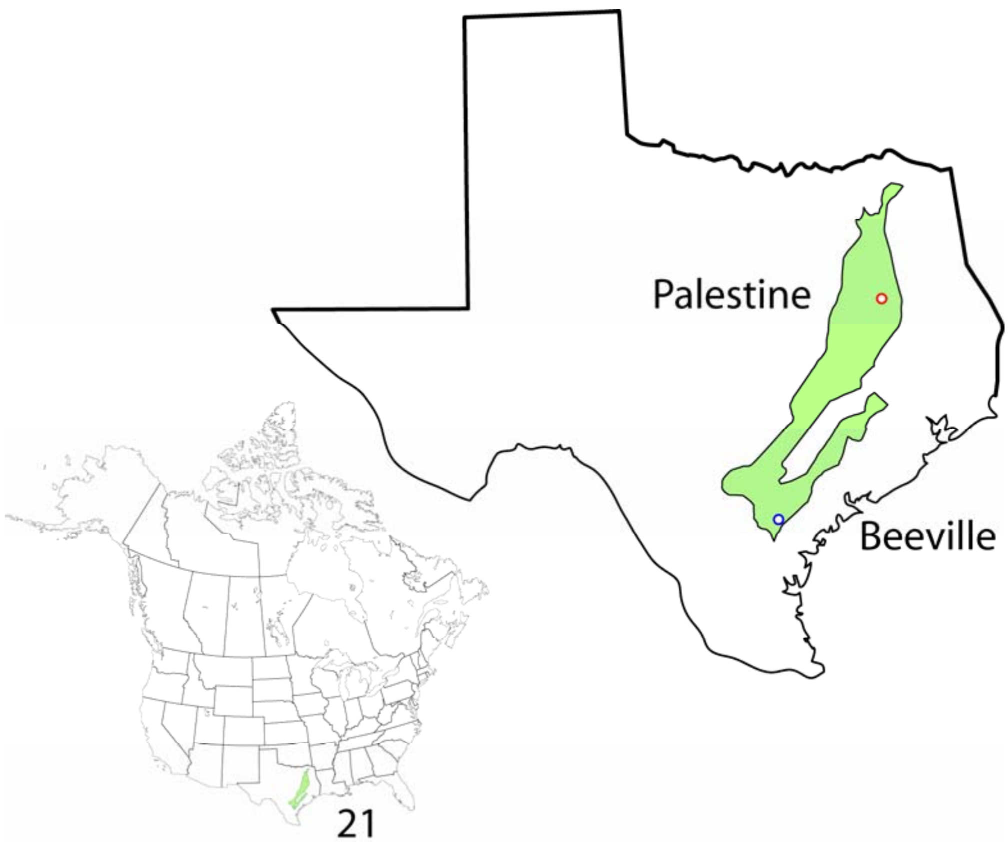


Figure I18. East Central Texas Forests.

Beeville, Texas

Didelphis virginiana
Cryptotis parva
Notiosorex crawfordi
Scalopus aquaticus
Myotis velifer
Lasiurus borealis
Lasiurus cinereus
Lasiurus intermedius
Lasionycteris noctivagans
Pipistrellus subflavus
Nycticeius humeralis
Nyctinomops macrotis
Tadarida brasiliensis
Sylvilagus aquaticus
Sylvilagus floridanus
Lepus californicus
Spermophilus tridecemlineatus
Sciurus niger
Geomys personatus
Perognathus merriami
Chaetodipus hispidus
Dipodomys compactus
Castor canadensis
Reithrodonotmys fulvescens
Peromyscus leucopus
Peromyscus maniculatus
Baiomys taylori
Onychomys leucogaster
Sigmodon hispidus
Neotoma micropus
Canis latrans
Canis rufus
Urocyon cinereoargenteus
Ursus americanus
Bassariscus astutus
Procyon lotor
Nasua narica
Mustela frenata
Taxidea taxus
Lontra canadensis
Spilogale putorius
Mephitis mephitis
Conepatus leuconotus
Puma concolor
Leopardus pardalis
Panthera onca
Lynx rufus
Pecari tajacu
Odocoileus virginianus
Antilocapra americana

Palestine, Texas

Didelphis virginiana
Blarina carolinensis
Cryptotis parva
Scalopus aquaticus
Lasiurus borealis
Lasiurus cinereus
Lasionycteris noctivagans
Pipistrellus subflavus
Eptesicus fuscus
Nycticeius humeralis
Tadarida brasiliensis
Sylvilagus aquaticus
Sylvilagus floridanus
Lepus californicus
Sciurus carolinensis
Sciurus niger
Glaucomys volans
Geomys breviceps
Chaetodipus hispidus
Castor canadensis
Oryzomys palustris
Reithrodonotmys fulvescens
Reithrodontomys humulis
Peromyscus gossypinus
Peromyscus leucopus
Peromyscus maniculatus
Ochrotomys nuttalli
Baiomys taylori
Sigmodon hispidus
Neotoma floridana
Microtus pinetorum
Ondatra zibethicus
Canis latrans
Canis rufus
Vulpes vulpes
Urocyon cinereoargenteus
Ursus americanus
Bassariscus astutus
Procyon lotor
Mustela frenata
Mustela vison
Taxidea taxus
Lontra canadensis
Spilogale putorius
Mephitis mephitis
Puma concolor
Panthera onca
Lynx rufus
Odocoileus virginianus
Bos bison

22. Southeastern Mixed Forests

Starkville, Mississippi

(State University station)

33° 28' N, 88° 47' W

max. temp. – 23.0 °C

mean temp. – 16.8 °C

min. temp. – 10.6 °C

precipitation – 140.8 cm/yr

Greensboro, North Carolina

36° 06' N, 79° 57' W

max. temp. – 20.3 °C

mean temp. – 14.5 °C

min. temp. – 8.7 °C

precipitation – 109.6 cm/yr

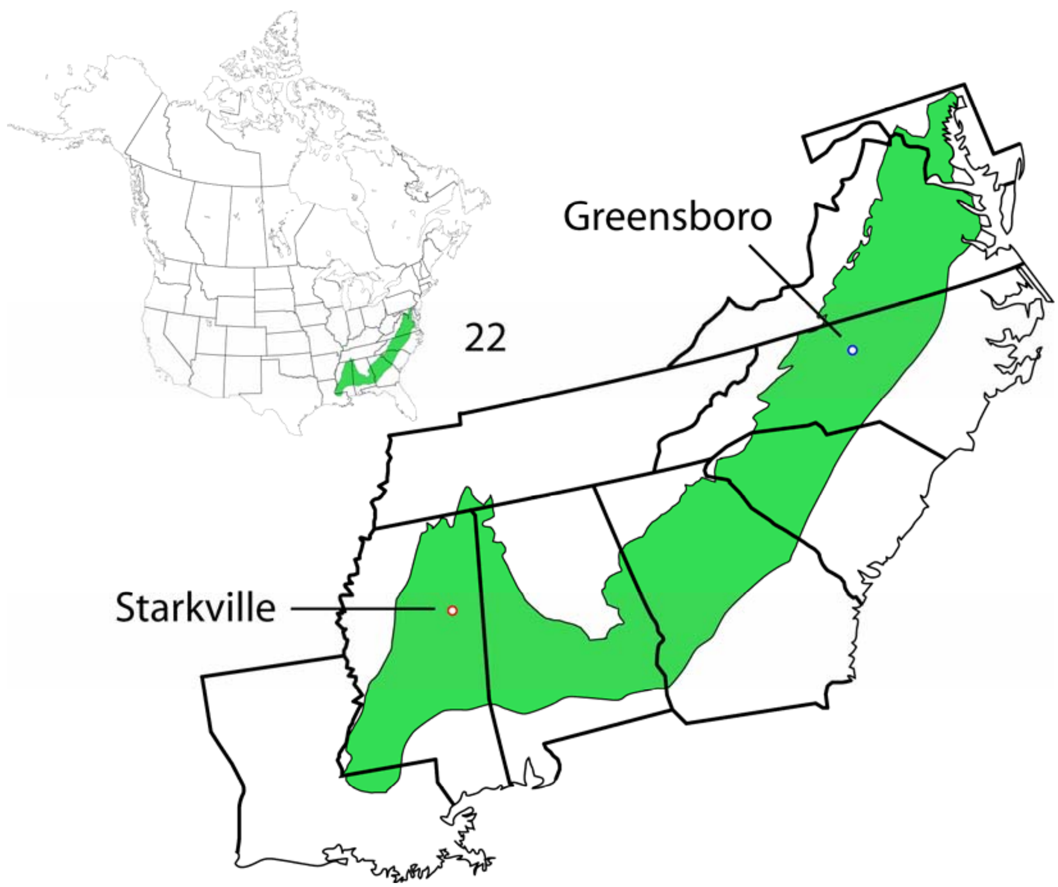


Figure I19. Southeastern Mixed Forests.

Starkville, Mississippi

Didelphis virginiana
Sorex longirostris
Blarina carolinensis
Cryptotis parva
Scalopus aquaticus
Lasiurus borealis
Lasiurus cinereus
Lasiurus seminolus
Lasionycteris noctivagans
Pipistrellus subflavus
Eptesicus fuscus
Nycticeius humeralis
Corynorhinus rafinesquii
Sylvilagus aquaticus
Sylvilagus floridanus
Tamias striatus
Sciurus carolinensis
Sciurus niger
Glaucomys volans
Castor canadensis
Oryzomys palustris
Reithrodontomys humulis
Peromyscus gossypinus
Peromyscus leucopus
Ochrotomys nuttalli
Sigmodon hispidus
Neotoma floridana
Microtus pinetorum
Ondatra zibethicus
Canis rufus
Vulpes vulpes
Urocyon cinereoargenteus
Ursus americanus
Procyon lotor
Mustela frenata
Mustela vison
Lontra canadensis
Spilogale putorius
Mephitis mephitis
Puma concolor
Lynx rufus
Odocoileus virginianus
Bos bison

Greensboro, North Carolina

Didelphis virginiana
Sorex longirostris
Blarina carolinensis
Cryptotis parva
Scalopus aquaticus
Myotis lucifugus
Myotis septentrionalis
Lasiurus borealis
Lasiurus cinereus
Lasiurus seminolus
Lasionycteris noctivagans
Pipistrellus subflavus
Eptesicus fuscus
Nycticeius humeralis
Sylvilagus floridanus
Tamias striatus
Marmota monax
Sciurus carolinensis
Glaucomys volans
Castor canadensis
Reithrodontomys humulis
Peromyscus leucopus
Ochrotomys nuttalli
Sigmodon hispidus
Microtus pennsylvanicus
Microtus pinetorum
Ondatra zibethicus
Synaptomys cooperi
Zapus hudsonius
Canis rufus
Vulpes vulpes
Urocyon cinereoargenteus
Ursus americanus
Procyon lotor
Mustela frenata
Mustela vison
Lontra canadensis
Mephitis mephitis
Puma concolor
Lynx rufus
Cervus elephus
Odocoileus virginianus
Bos bison

23. Northern Pacific Coastal Forests

Cordova, Alaska	Elfin Cove, Alaska
60° 29' N, 145° 27' W,	58° 12' N, 136° 40' W
max. temp. – 8.1 °C	max. temp. – 7.9 °C
mean temp. – 3.9 °C	mean temp. – 5.7 °C
min. temp. – -0.2 °C	min. temp. – 3.6 °C
precipitation – 244.5 cm/yr	precipitation – 256.6 cm/yr

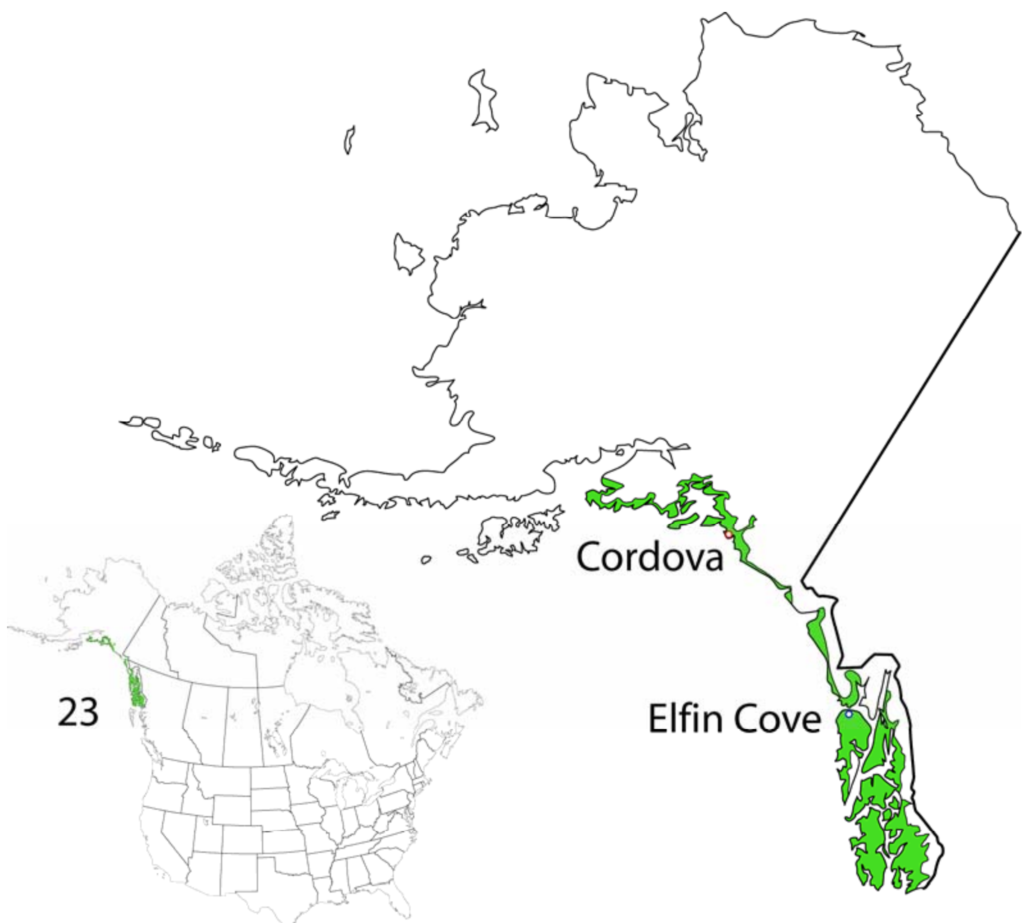


Figure I20. Northern Pacific Coastal Forests.

Cordova, Alaska

Sorex cinereus
Sorex monticolus
Sorex palustris
Myotis lucifugus
Lepus americanus
Marmota caligata
Castor canadensis
Clethrionomys rutilus
Microtus pennsylvanicus
Microtus oeconomus
Ondatra zibethicus
Synaptomys borealis
Zapus hudsonius
Erethizon dorsatum
Canis latrans
Canis lupus
Ursus americanus
Ursus arctos
Martes americanum
Mustela erminea
Mustela nivalis
Mustela vison
Gulo gulo
Lontra canadensis
Lynx canadensis
Alces alces
Rangifer tarandus
Oreamnos americanus
Ovis dalli

Elfin Cove, Alaska

Sorex cinereus
Sorex monticolus
Myotis lucifugus
Lepus americanus
Marmota caligata
Tamiasciurus hudsonicus
Glaucomys sabrinus
Castor canadensis
Peromyscus keeni
Microtus oeconomus
Microtus longicaudus
Ondatra zibethicus
Synaptomys borealis
Zapus hudsonius
Erethizon dorsatum
Canis latrans
Canis lupus
Ursus americanus
Ursus arctos
Martes americanum
Mustela erminea
Mustela vison
Gulo gulo
Lontra canadensis
Lynx canadensis
Odocoileus hemionus

24. Queen Charlotte Islands

Masset, British Columbia

(Masset Airport station)

54° 04’ N, 132° 07’ W

max. temp. – 11.3 °C

mean temp. – 7.7 °C

min. temp. – 4.1 °C

precipitation – 141.1 cm/yr

Cape Saint James, British Columbia

51° 56’ N, 131° 01’ W

max. temp. – 11.2 °C

mean temp. – 8.9 °C

min. temp. – 6.6 °C

precipitation – 161.0 cm/yr

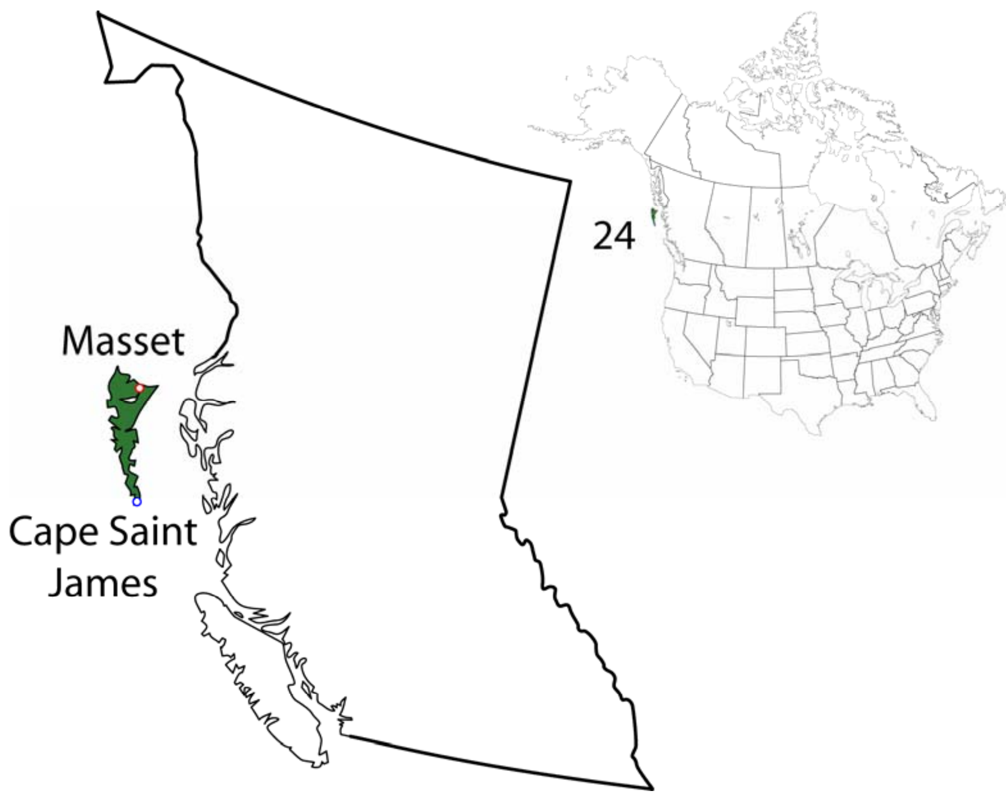


Figure I21. Queen Charlotte Islands.

Masset, British Columbia

Sorex monticolus
Sorex obscurus
Myotis keenii
Myotis californicus
Myotis lucifugus
Castor canadensis
Peromyscus maniculatus
Ondatra zibethicus
Ursus americanus
Ursus arctos
Martes americana
Mustela erminea
Mustela vison
Gulo gulo
Lontra canadensis
Lynx canadensis
Odocoileus hemionus

Cape Saint James, British Columbia

Sorex monticolus
Sorex obscurus
Myotis keenii
Myotis californicus
Myotis lucifugus
Peromyscus keeni
Ondatra zibethicus
Ursus americanus
Ursus arctos
Martes americana
Mustela erminea
Mustela vison
Gulo gulo
Lontra canadensis
Lynx canadensis
Odocoileus hemionus

25. British Columbia Mountain Forests

Germansen Landing, British Columbia

55° 47’ N, 124° 42’ W

max. temp. – 6.8 °C

mean temp. – 1.0 °C

min. temp. – -4.8 °C

precipitation – 53.8 cm/yr

Mackenzie, British Columbia

55° 18’ N, 123° 08’ W

max. temp. – 7.9 °C

mean temp. – 2.3 °C

min. temp. – -3.2 °C

precipitation – 65.5 cm/yr

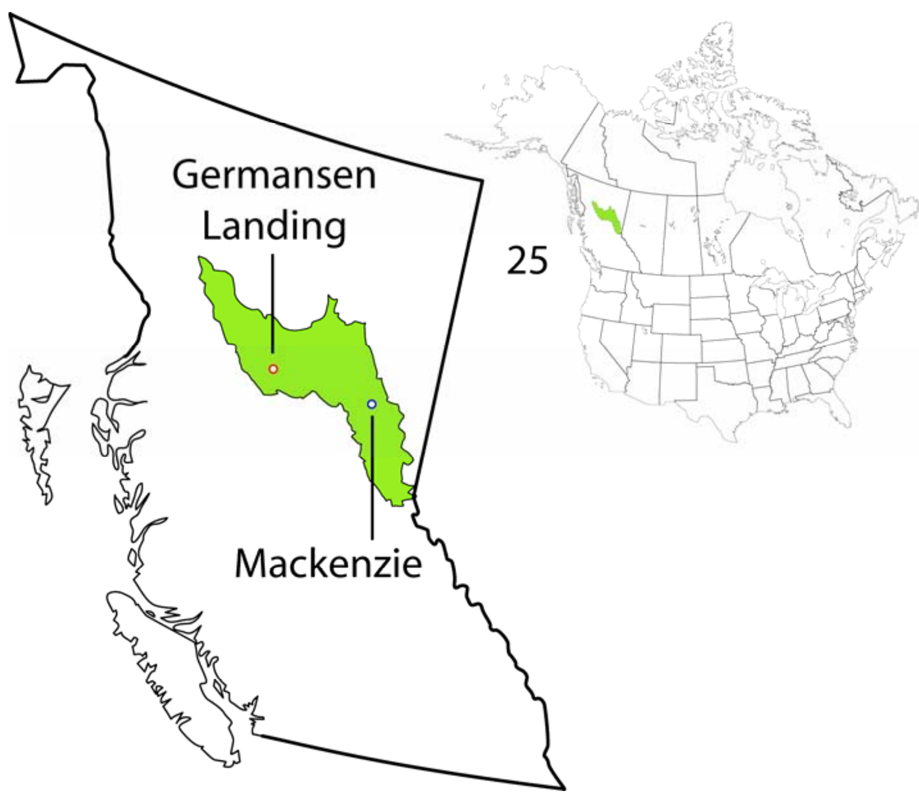


Figure I22. British Columbia Mountain Forests.

Germansen Landing, British Columbia

Sorex cinereus
Sorex monticolus
Sorex palustris
Sorex hoyi
Myotis lucifugus
Lepus americanus
Marmota monax
Marmota caligata
Tamiasciurus hudsonicus
Glaucomys sabrinus
Castor canadensis
Peromyscus maniculatus
Neotoma cinerea
Clethrionomys gapperi
Microtus pennsylvanicus
Ondatra zibethicus
Lemmus trimucronatus
Synaptomys borealis
Zapus hudsonius
Zapus princeps
Erethizon dorsatum
Canis latrans
Canis lupus
Vulpes vulpes
Ursus americanus
Ursus arctos
Martes americana
Martes pennanti
Mustela erminea
Mustela nivalis
Mustela vison
Gulo gulo
Lontra canadensis
Mephitis mephitis
Lynx canadensis
Cervus canadensis
Odocoileus hemionus
Alces alces
Rangifer tarandus
Oreamnos americanus

Mackenzie, British Columbia

Sorex cinereus
Sorex monticolus
Sorex palustris
Sorex hoyi
Myotis lucifugus
Lepus americanus
Marmota caligata
Tamiasciurus hudsonicus
Glaucomys sabrinus
Castor canadensis
Peromyscus maniculatus
Neotoma cinerea
Clethrionomys gapperi
Microtus pennsylvanicus
Microtus longicaudus
Ondatra zibethicus
Zapus hudsonius
Zapus princeps
Erethizon dorsatum
Canis latrans
Canis lupus
Vulpes vulpes
Ursus americanus
Ursus arctos
Martes americana
Martes pennanti
Mustela erminea
Mustela nivalis
Mustela vison
Gulo gulo
Lontra canadensis
Mephitis mephitis
Lynx canadensis
Cervus canadensis
Odocoileus hemionus
Alces alces
Rangifer tarandus

26. Alberta Mountain Forests

Grande Cache, Alberta

53° 54’ N, 119° 06’ W

max. temp. – 8.2 °C

mean temp. – 2.6 °C

min. temp. – -2.9 °C

precipitation – 55.0 cm/yr

Pocahontas, Alberta

(Jasper-East Gate station)

53° 14’ N, 117° 49’ W

max. temp. – 10.1 °C

mean temp. – 3.7 °C

min. temp. – -2.6 °C

precipitation – 62.0 cm/yr

Figure I23. Alberta Mountain Forests.

Grande Cache, Alberta

Sorex cinereus
Sorex monticolus
Sorex palustris
Myotis lucifugus
Myotis evotis
Myotis volans
Lasionycteris noctivagans
Eptesicus fuscus
Ochotona princeps
Lepus americanus
Neotamias minimus
Marmota caligata
Spermophilus lateralis
Tamiasciurus hudsonicus
Glaucomys sabrinus
Castor canadensis
Peromyscus maniculatus
Neotoma cinerea
Clethrionomys gapperi
Phenacomys ungava
Microtus pennsylvanicus
Microtus longicaudus
Microtus xanthognathus
Microtus richardsoni
Ondatra zibethicus
Synaptomys borealis
Zapus princeps
Erethizon dorsatum
Canis latrans
Canis lupus
Vulpes vulpes
Ursus americanus
Ursus arctos
Martes americana
Martes pennanti
Mustela erminea
Mustela nivalis
Mustela frenata
Mustela vison
Gulo gulo
Lontra canadensis
Mephitis mephitis
Puma concolor
Lynx canadensis
Cervus canadensis
Odocoileus hemionus
Odocoileus virginianus
Alces alces
Rangifer tarandus
Bos bison
Oreamnos americanus
Ovis canadensis

Pocahontas, Alberta

Sorex cinereus
Sorex monticolus
Sorex palustris
Myotis lucifugus
Myotis evotis
Myotis volans
Lasionycteris noctivagans
Eptesicus fuscus
Ochotona princeps
Lepus americanus
Neotamias minimus
Marmota monax
Marmota caligata
Spermophilus lateralis
Tamiasciurus hudsonicus
Glaucomys sabrinus
Castor canadensis
Peromyscus maniculatus
Neotoma cinerea
Clethrionomys gapperi
Phenacomys ungava
Microtus pennsylvanicus
Microtus longicaudus
Microtus xanthognathus
Microtus richardsoni
Ondatra zibethicus
Synaptomys borealis
Zapus princeps
Erethizon dorsatum
Canis latrans
Canis lupus
Vulpes vulpes
Ursus americanus
Ursus arctos
Martes americana
Martes pennanti
Mustela erminea
Mustela nivalis
Mustela frenata
Mustela vison
Gulo gulo
Lontra canadensis
Mephitis mephitis
Puma concolor
Lynx canadensis
Cervus canadensis
Odocoileus hemionus
Odocoileus virginianus
Alces alces
Rangifer tarandus
Bos bison
Oreamnos americanus
Ovis canadensis

27. Fraser Plateau and Basin Complex

Vanderhoof, British Columbia

54° 01' N, 124° 01' W

max. temp. – 10.3 °C

mean temp. – 4.4 °C

min. temp. – -1.6 °C

precipitation – 49.6 cm/yr

Williams Lake, British Columbia

52° 10' N, 122° 03' W

max. temp. – 9.6 °C

mean temp. – 4.2 °C

min. temp. – -1.3 °C

precipitation – 45.0 cm/yr

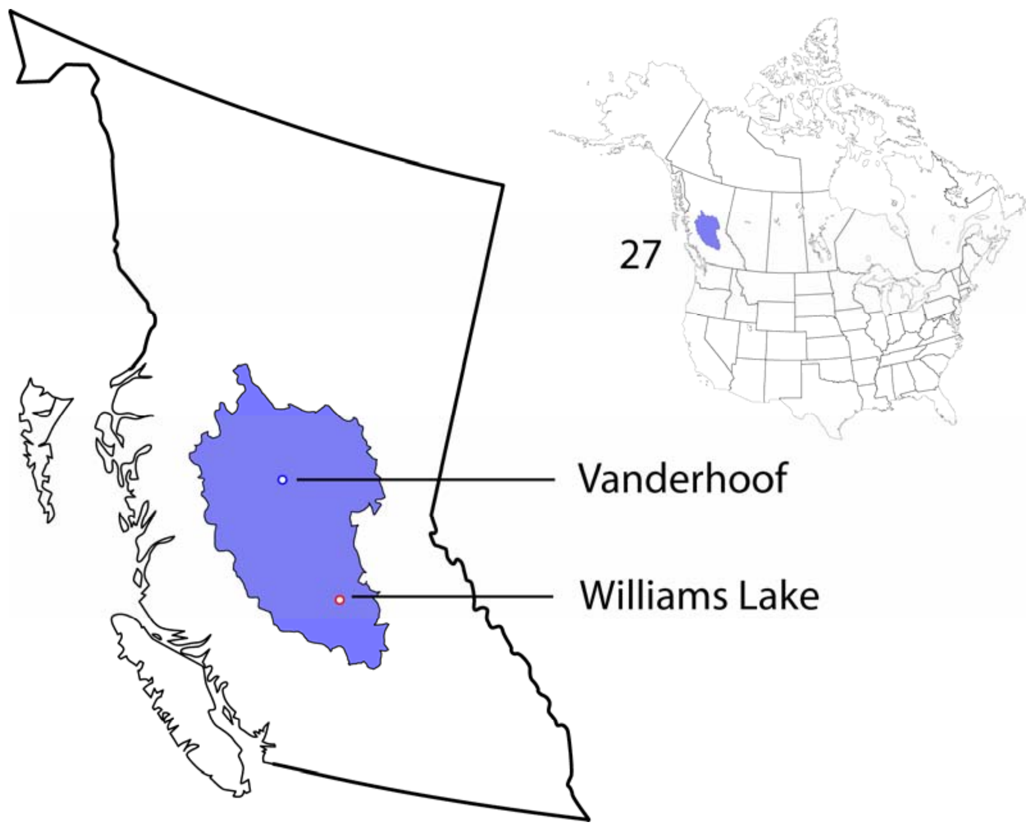


Figure I24. Fraser Plateau and Basin Complex.

Vanderhoof, British Columbia

Sorex cinereus
Sorex monticolus
Sorex palustris
Sorex hoyi
Myotis lucifugus
Lepus americanus
Neotamias amoenus
Marmota monax
Tamiasciurus hudsonicus
Glaucomys sabrinus
Castor canadensis
Peromyscus maniculatus
Neotoma cinerea
Clethrionomys gapperi
Microtus pennsylvanicus
Ondatra zibethicus
Synaptomys borealis
Zapus hudsonius
Zapus princeps
Erethizon dorsatum
Canis latrans
Canis lupus
Vulpes vulpes
Ursus americanus
Ursus arctos
Martes americana
Martes pennanti
Mustela erminea
Mustela nivalis
Mustela vison
Gulo gulo
Lontra canadensis
Mephitis mephitis
Puma concolor
Lynx canadensis
Cervus canadensis
Odocoileus hemionus
Alces alces
Rangifer tarandus

Williams Lake, British Columbia

Sorex cinereus
Sorex monticolus
Sorex palustris
Sorex hoyi
Myotis lucifugus
Lepus americanus
Neotamias amoenus
Marmota flaviventris
Tamiasciurus hudsonicus
Glaucomys sabrinus
Castor canadensis
Peromyscus maniculatus
Neotoma cinerea
Clethrionomys gapperi
Microtus pennsylvanicus
Ondatra zibethicus
Zapus hudsonius
Zapus princeps
Erethizon dorsatum
Canis latrans
Canis lupus
Vulpes vulpes
Ursus americanus
Ursus arctos
Martes americana
Martes pennanti
Mustela erminea
Mustela frenata
Mustela vison
Gulo gulo
Lontra canadensis
Mephitis mephitis
Puma concolor
Lynx rufus
Lynx canadensis
Cervus canadensis
Odocoileus hemionus
Alces alces
Rangifer tarandus

28. Northern Transitional Alpine Forests

Bob Quinn, British Columbia

56° 58’ N, 130° 15’ W

max. temp. – 8.0 °C

mean temp. – 3.1 °C

min. temp. – -1.8 °C

precipitation – 64.2 cm/yr

Hazelton, British Columbia

55° 12’ N, 127° 43’ W

max. temp. – 10.2 °C

mean temp. – 4.8 °C

min. temp. – -0.6 °C

precipitation – 61.4 cm/yr

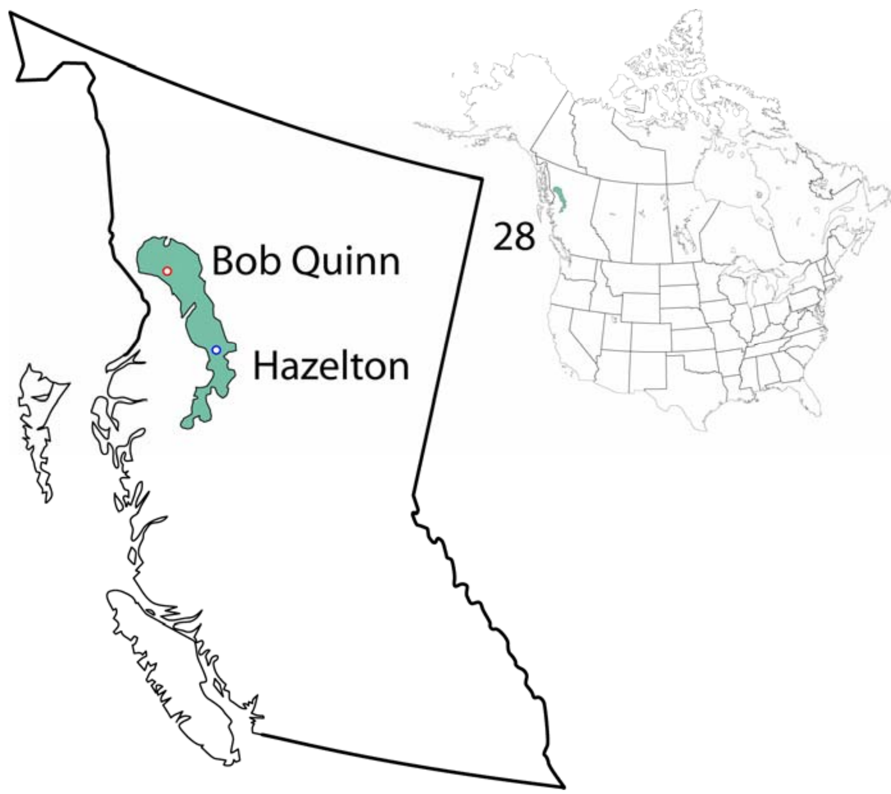


Figure I25. Northern Transitional Alpine Forests.

Bob Quinn, British Columbia

Sorex cinereus
Sorex palustris
Sorex monticolus
Sorex hoyi
Myotis keenii
Myotis lucifugus
Lepus americanus
Marmota monax
Marmota caligata
Tamiasciurus hudsonicus
Glaucomys sabrinus
Castor canadensis
Peromyscus maniculatus
Neotoma cinerea
Ondatra zibethicus
Lemmus trimucronatus
Synaptomys borealis
Zapus hudsonius
Zapus princeps
Erethizon dorsatum
Canis latrans
Canis lupus
Vulpes vulpes
Ursus americanus
Ursus arctos
Martes americana
Martes pennanti
Mustela erminea
Mustela nivalis
Mustela vison
Gulo gulo
Lontra canadensis
Lynx canadensis
Rangifer tarandus
Oreamnos americanus

Hazelton, British Columbia

Sorex cinereus
Sorex palustris
Sorex monticolus
Sorex hoyi
Myotis lucifugus
Lepus americanus
Marmota monax
Marmota caligata
Tamiasciurus hudsonicus
Glaucomys sabrinus
Castor canadensis
Peromyscus maniculatus
Neotoma cinerea
Clethrionomys gapperi
Microtus pennsylvanicus
Ondatra zibethicus
Lemmus trimucronatus
Synaptomys borealis
Zapus hudsonius
Zapus princeps
Erethizon dorsatum
Canis latrans
Canis lupus
Vulpes vulpes
Ursus americanus
Ursus arctos
Martes americana
Martes pennanti
Mustela erminea
Mustela nivalis
Mustela vison
Gulo gulo
Lontra canadensis
Mephitis mephitis
Lynx canadensis
Odocoileus hemionus
Alces alces
Rangifer tarandus
Oreamnos americanus

29. Alberta/British Columbia Foothills Forests

Wonowon, British Columbia

56° 43’ N, 121° 48’ W

max. temp. – 5.9 °C

mean temp. – 1.0 °C

min. temp. – -4.0 °C

precipitation – 54.4 cm/yr

Edson, Alberta

53° 34’ N, 116° 28’ W

max. temp. – 8.8 °C

mean temp. – 2.0 °C

min. temp. – -4.8 °C

precipitation – 56.2 cm/yr

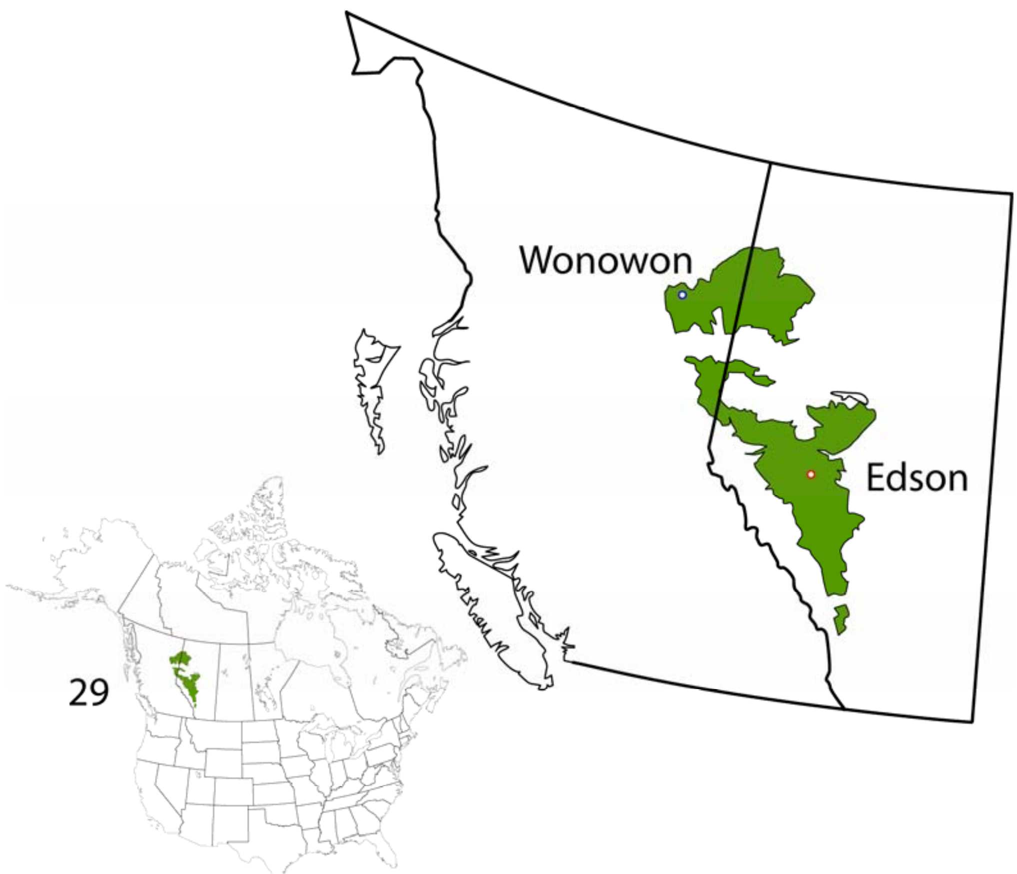


Figure I26. Alberta/British Columbia Foothills Forests.

Wonowon, British Columbia

Sorex cinereus
Sorex monticolus
Sorex palustris
Sorex hoyi
Myotis lucifugus
Myotis septentrionalis
Lepus americanus
Neotamias minimus
Tamiasciurus hudsonicus
Glaucomys sabrinus
Castor canadensis
Peromyscus maniculatus
Neotoma cinerea
Clethrionomys gapperi
Phenacomys ungava
Microtus pennsylvanicus
Microtus longicaudus
Ondatra zibethicus
Zapus hudsonius
Zapus princeps
Erethizon dorsatum
Canis latrans
Canis lupus
Vulpes vulpes
Ursus americanus
Ursus arctos
Martes americana
Martes pennanti
Mustela erminea
Mustela nivalis
Mustela vison
Gulo gulo
Lontra canadensis
Mephitis mephitis
Lynx canadensis
Cervus canadensis
Odocoileus hemionus
Alces alces
Rangifer tarandus
Bos bison

Edson, Alberta

Sorex cinereus
Sorex monticolus
Myotis lucifugus
Myotis volans
Myotis septentrionalis
Lasionycteris noctivagans
Eptesicus fuscus
Lepus americanus
Neotamias minimus
Marmota monax
Glaucomys sabrinus
Castor canadensis
Peromyscus maniculatus
Clethrionomys gapperi
Phenacomys ungava
Microtus pennsylvanicus
Ondatra zibethicus
Synaptomys borealis
Zapus princeps
Erethizon dorsatum
Canis latrans
Canis lupus
Ursus americanus
Ursus arctos
Martes americana
Martes pennanti
Mustela erminea
Mustela nivalis
Mustela frenata
Mustela vison
Gulo gulo
Taxidea taxus
Lontra canadensis
Mephitis mephitis
Lynx canadensis
Cervus canadensis
Odocoileus hemionus
Alces alces
Rangifer tarandus
Bos bison

30. North Central Rockies Forests

Dunster, British Columbia

53° 07' N, 119° 51' W

max. temp. – 10.2 °C

mean temp. – 4.5 °C

min. temp. – -1.3 °C

precipitation – 63.1 cm/yr

Bonners Ferry, Idaho

48° 42' N, 116° 19' W

max. temp. – 14.6 °C

mean temp. – 8.3 °C

min. temp. – 1.9 °C

precipitation – 54.8 cm/yr

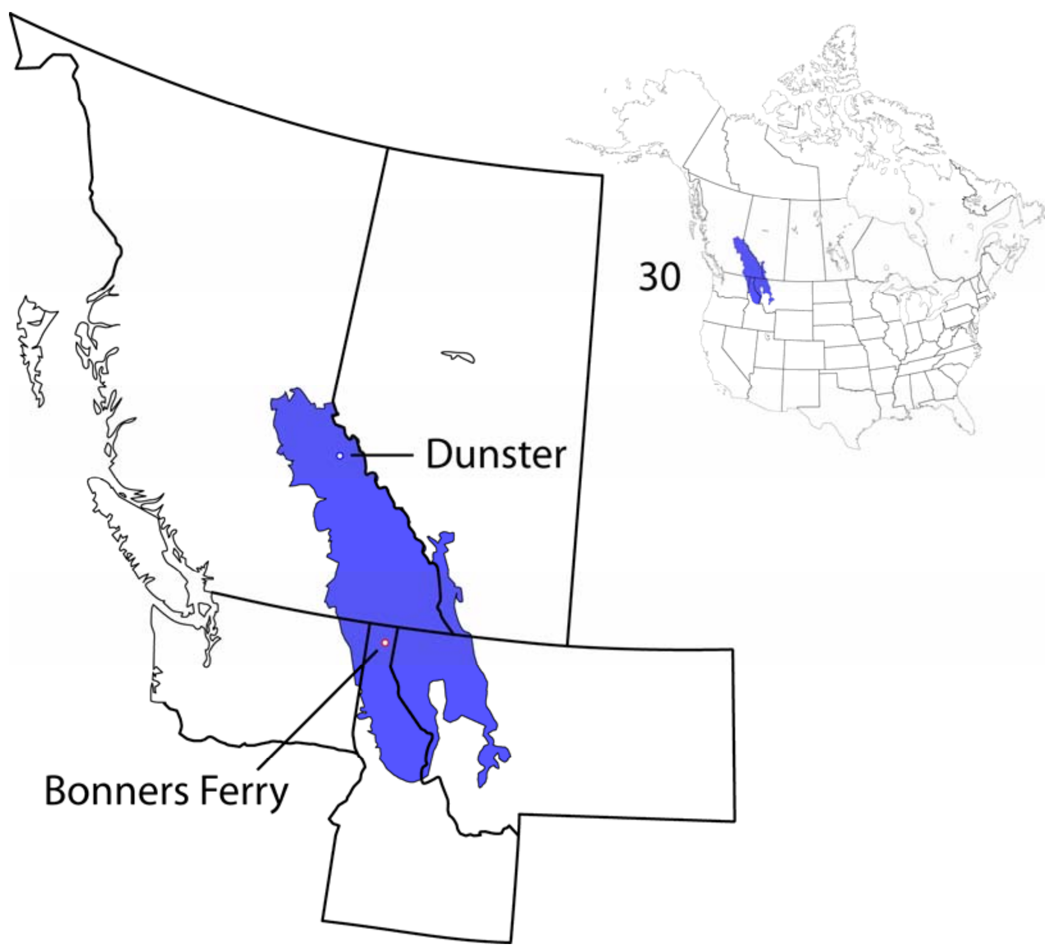


Figure I27. North Central Rockies Forests.

Dunster, British Columbia

Sorex cinereus
Sorex monticolus
Sorex palustris
Sorex hoyi
Myotis evotis
Myotis lucifugus
Lepus americanus
Neotamias amoenus
Marmota caligata
Spermophilus columbianus
Spermophilus lateralis
Tamiasciurus hudsonicus
Glaucomys sabrinus
Castor canadensis
Peromyscus maniculatus
Neotoma cinerea
Clethrionomys gapperi
Phenacomys intermedius
Microtus pennsylvanicus
Microtus longicaudus
Ondatra zibethicus
Synaptomys borealis
Zapus princeps
Erethizon dorsatum
Canis latrans
Canis lupus
Vulpes vulpes
Ursus americanus
Ursus arctos
Martes americana
Martes pennanti
Mustela erminea
Mustela nivalis
Mustela frenata
Mustela vison
Gulo gulo
Lontra canadensis
Mephitis mephitis
Puma concolor
Lynx rufus
Lynx canadensis
Cervus canadensis
Odocoileus hemionus
Alces alces
Rangifer tarandus
Oreamnos americanus
Ovis canadensis

Bonners Ferry, Idaho

Sorex cinereus
Sorex vagrans
Sorex monticolus
Sorex palustris
Sorex hoyi
Myotis lucifugus
Myotis yumanensis
Myotis evotis
Myotis volans
Lasiurus cinereus
Lasionycteris noctivagans
Eptesicus fuscus
Corynorhinus townsendii
Ochotona princeps
Lepus americanus
Neotamias amoenus
Neotamias ruficaudus
Marmota monax
Spermophilus columbianus
Spermophilus lateralis
Tamiasciurus hudsonicus
Glaucomys sabrinus
Thomomys talpoides
Castor canadensis
Peromyscus maniculatus
Neotoma cinerea
Clethrionomys gapperi
Phenacomys intermedius
Microtus pennsylvanicus
Microtus longicaudus
Microtus richardsoni
Ondatra zibethicus
Synaptomys borealis
Zapus princeps
Erethizon dorsatum
Canis latrans
Canis lupus
Vulpes vulpes
Ursus americanus
Ursus arctos
Procyon lotor
Martes americanus
Martes pennanti
Mustela erminea
Mustela frenata
Mustela vison
Gulo gulo
Taxidea taxus
Lontra canadensis
Mephitis mephitis
Puma concolor
Lynx canadensis
Lynx rufus
Cervus canadensis
Odocoileus hemionus
Odocoileus virginianus
Alces alces
Rangifer tarandus
Oreamnos americanus
Ovis canadensis

31. Okanagan Dry Forests

Kelowna, British Columbia

49° 57’ N, 119° 22’ W

max. temp. – 14.0 °C

mean temp. – 7.7 °C

min. temp. – 1.5 °C

precipitation – 38.1 cm/yr

Republic, Washington

48° 39’ N, 118° 44’ W

max. temp. – 13.1 °C

mean temp. – 6.4 °C

min. temp. – -0.4 °C

precipitation – 42.8 cm/yr

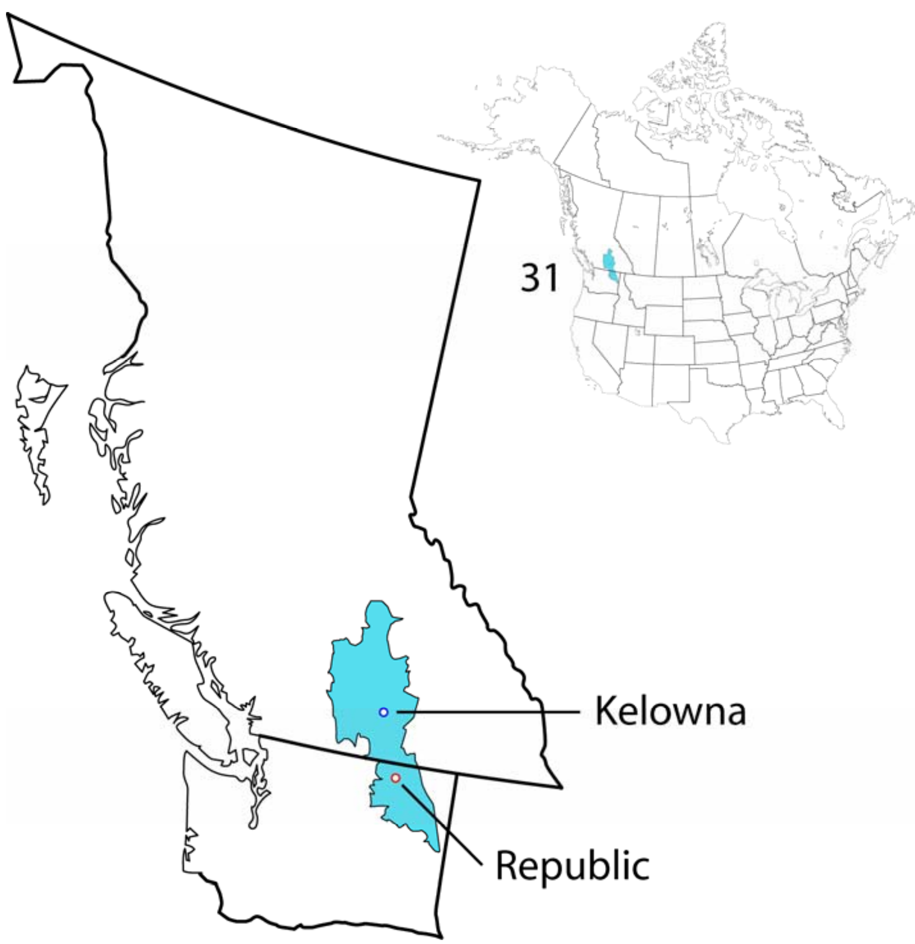


Figure I28. Okanagan Dry Forests.

Kelowna, British Columbia

Sorex cinereus
Sorex palustris
Sorex vagrans
Sorex monticolus
Myotis lucifugus
Eptesicus fuscus
Corynorhinus rafinesquii
Lepus americanus
Neotamias amoenus
Marmota flaviventris
Tamiasciurus hudsonicus
Glaucomys sabrinus
Thomomys talpoides
Castor canadensis
Peromyscus maniculatus
Neotoma cinerea
Clethrionomys gapperi
Microtus pennsylvanicus
Microtus montanus
Microtus longicaudus
Ondatra zibethicus
Synaptomys borealis
Erethizon dorsatum
Canis latrans
Canis lupus
Vulpes vulpes
Ursus americanus
Ursus arctos
Martes americana
Mustela erminea
Mustela frenata
Mustela vison
Gulo gulo
Taxidea taxus
Lontra canadensis
Mephitis mephitis
Puma concolor
Lynx rufus
Lynx canadensis
Cervus canadensis
Odocoileus hemionus
Odocoileus virginianus
Rangifer tarandus
Ovis canadensis

Republic, Washington

Sorex vagrans
Sorex monticolus
Sorex cinereus
Myotis lucifugus
Myotis californicus
Myotis yumanensis
Lasionycteris noctivagans
Eptesicus fuscus
Corynorhinus townsendii
Ochotona princeps
Sylvilagus nuttallii
Lepus americanus
Lepus townsendii
Neotamias amoenus
Marmota flaviventris
Spermophilus columbianus
Tamiasciurus hudsonicus
Glaucomys sabrinus
Thomomys talpoides
Perognathus parvus
Castor canadensis
Peromyscus maniculatus
Neotoma cinerea
Clethrionomys gapperi
Phenacomys intermedius
Microtus pennsylvanicus
Microtus montanus
Microtus longicaudus
Microtus oregoni
Ondatra zibethicus
Synaptomys borealis
Erethizon dorsatum
Canis latrans
Martes pennanti
Mustela vison
Mustela frenata
Mustela erminea
Taxidea taxus
Lontra canadensis
Mephitis mephitis
Lynx canadensis
Lynx rufus
Odocoileus hemionus
Odocoileus viginianus

32. Cascade Mountains Leeward Forests

Lillooet, British Columbia

50° 40’ N, 121° 55’ W

max. temp. – 14.4 °C

mean temp. – 9.2 °C

min. temp. – 3.9 °C

precipitation – 33.0 cm/yr

Baring, Washington

47° 46’ N, 121° 29’ W

max. temp. – 14.6 °C

mean temp. – 9.6 °C

min. temp. – 4.6 °C

precipitation – 279.2 cm/yr

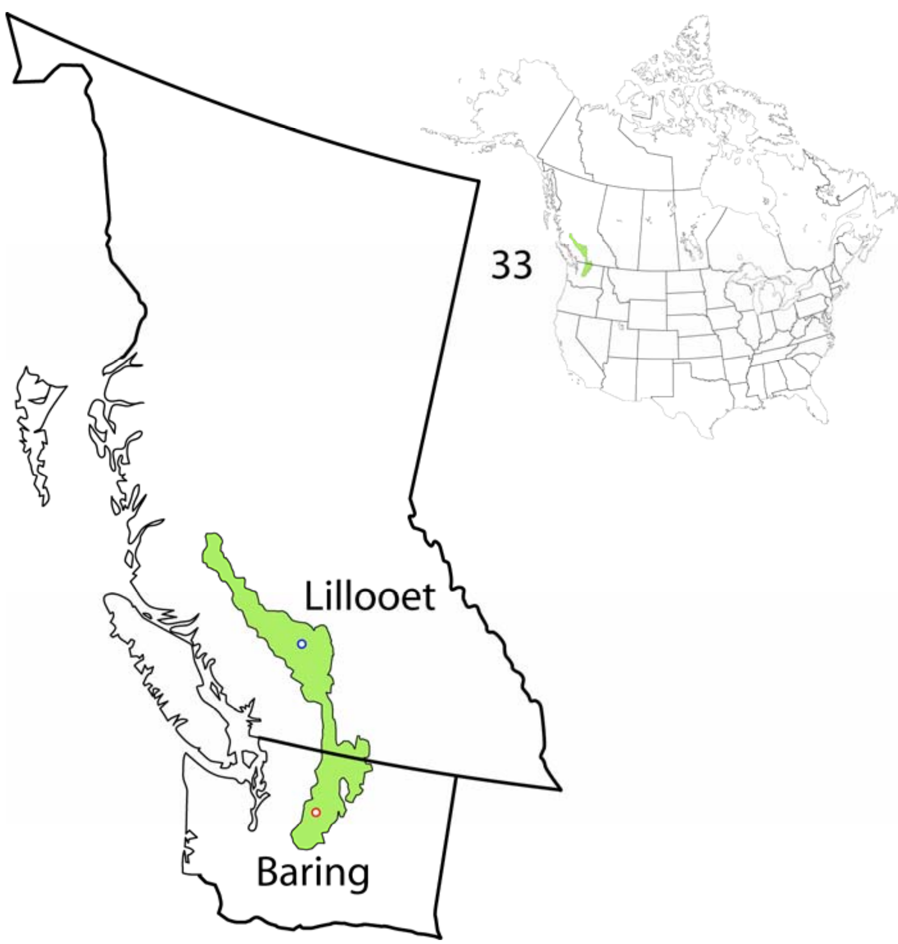


Figure I29. Cascade Mountains Leeward Forests.

Lillooet, British Columbia

Sorex cinereus
Sorex obscurus
Sorex palustris
Myotis californicus
Myotis lucifugus
Eptesicus fuscus
Corynorhinus rafinesquii
Ochotona princeps
Lepus americanus
Neotamias amoenus
Marmota flaviventris
Tamiasciurus hudsonicus
Glaucomys sabrinus
Castor canadensis
Peromyscus maniculatus
Neotoma cinerea
Clethrionomys gapperi
Microtus pennsylvanicus
Ondatra zibethicus
Erethizon dorsatum
Canis latrans
Canis lupus
Vulpes vulpes
Ursus americanus
Ursus arctos
Martes americana
Martes pennanti
Mustela erminea
Mustela frenata
Mustela vison
Gulo gulo
Lontra canadensis
Mephitis mephitis
Puma concolor
Lynx rufus
Lynx canadensis
Cervus canadensis
Odocoileus hemionus
Alces alces
Oreamnos americanus
Ovis canadensis

Baring, Washington

Sorex vagrans
Sorex monticolus
Sorex palustris
Sorex cinereus
Sorex trowbridgii
Scapanus orarius
Myotis lucifugus
Myotis californicus
Myotis yumanensis
Lasionycteris noctivagans
Eptesicus fuscus
Ochotona princeps
Lepus americanus
Lepus townsendii
Aplodontia rufa
Neotamias amoenus
Neotamias townsendii
Marmota flaviventris
Marmota caligata
Spermophilus saturatus
Tamiasciurus hudsonicus
Tamiasciurus douglasii
Glaucomys sabrinus
Thomomys talpoides
Castor canadensis
Peromyscus maniculatus
Neotoma cinerea
Clethrionomys gapperi
Phenacomys intermedius
Microtus longicaudus
Microtus richardsoni
Microtus oregoni
Ondatra zibethicus
Erethizon dorsatum
Canis latrans
Ursus americanus
Martes americana
Mustela frenata
Mustela erminea
Lontra canadensis
Puma concolor
Lynx rufus
Odocoileus hemionus
Oreamnos americanus

33. British Columbia Mainland Coastal Forests

Kitimat, British Columbia

54° 03’ N, 128° 37’ W

max. temp. – 10.6 °C

mean temp. – 6.8 °C

min. temp. – 3.0 °C

precipitation – 219.1 cm/yr

Darrington, Washington

48° 16’ N, 121° 36’ W

max. temp. – 15.7 °C

mean temp. – 10.1 °C

min. temp. – 4.4 °C

precipitation – 205.7 cm/yr

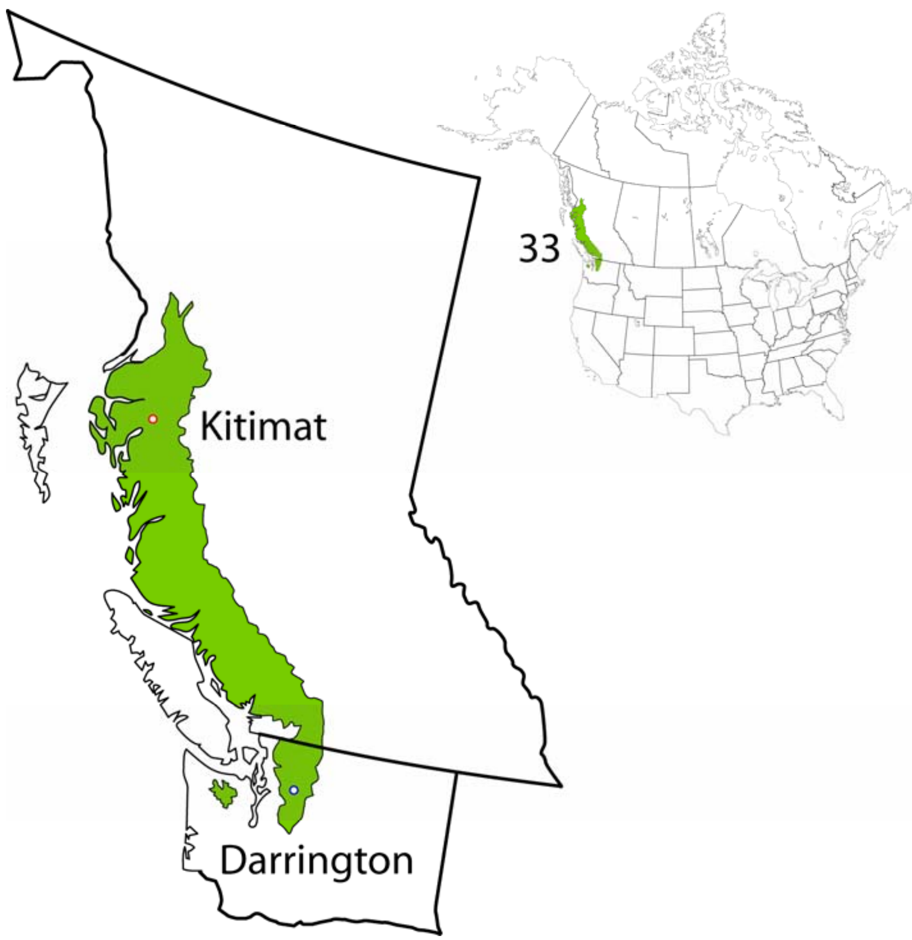


Figure I30. British Columbia Mainland Coastal Forests.

Kitimat, British Columbia

Sorex cinereus
Sorex monticolus
Sorex palustris
Myotis lucifugus
Myotis yumanensis
Myotis keenii
Lepus americanus
Tamiasciurus hudsonicus
Glaucomys sabrinus
Castor canadensis
Peromyscus maniculatus
Neotoma cinerea
Clethrionomys gapperi
Synaptomys borealis
Erethizon dorsatum

Canis latrans
Canis lupus
Vulpes vulpes
Ursus americanus
Ursus arctos
Martes americana
Martes pennanti
Mustela erminea
Mustela vison
Gulo gulo
Lontra canadensis
Puma concolor
Lynx canadensis
Odocoileus hemionus
Oreamnos americanus

Darrington, Washington

Sorex vagrans
Sorex monticolus
Sorex palustris
Sorex bendirii
Sorex cinereus
Sorex trowbridgii
Neurotrichus gibbsii
Scapanus orarius
Myotis lucifugus
Myotis californicus
Myotis volans
Myotis evotis
Myotis keenii
Myotis yumanensis
Lasionycteris noctivagans
Eptesicus fuscus
Ochotona princeps
Lepus americanus
Aplodontia rufa
Neotamias amoenus
Neotamias townsendii
Marmota caligata
Spermophilus saturatus
Tamiasciurus douglasii
Glaucomys sabrinus
Castor canadensis
Peromyscus maniculatus
Neotoma cinerea
Clethrionomys gapperi
Phenacomys intermedius
Microtus townsendii
Microtus longicaudus
Microtus richardsoni
Microtus oregoni
Ondatra zibethicus
Zapus trionatus
Erethizon dorsatum
Canis latrans
Vulpes vulpes
Ursus americanus
Martes pennanti
Mustela frenata
Mustela erminea
Gulo gulo
Lontra canadensis
Spilogale putorius
Mephitis mephitis
Puma concolor
Lynx rufus
Odocoileus hemionus

34. Central Pacific Coastal Forests

Gold River, British Columbia

49° 46' N, 126° 03' W

max. temp. – 14.2 °C

mean temp. – 9.2 °C

min. temp. – 4.1 °C

precipitation – 284.7 cm/yr

Aberdeen, Washington

46° 58' N, 123° 50' W

max. temp. – 14.5 °C

mean temp. – 10.6 °C

min. temp. – 6.6 °C

precipitation – 212.6 cm/yr

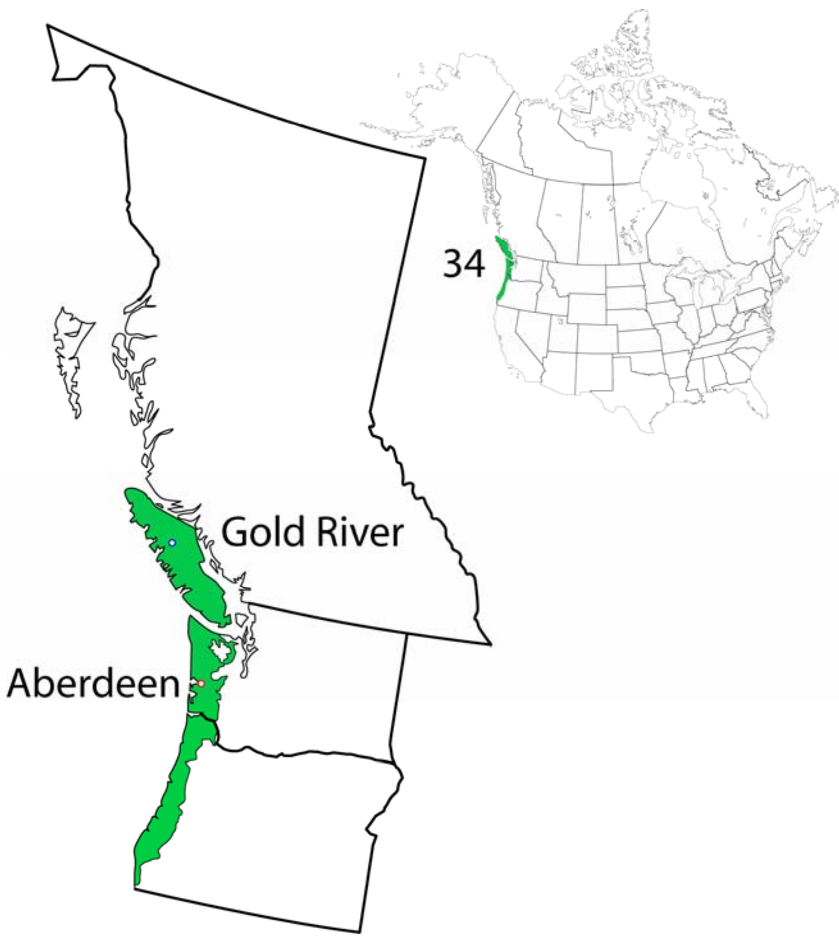


Figure I31. Central Pacific Coastal Forests.

Gold River, British Columbia

Sorex monticolus
Sorex palustris
Myotis californicus
Myotis evotis
Myotis lucifugus
Myotis yumanensis
Myotis keenii
Marmota vancouverensis
Peromyscus maniculatus
Microtus townsendii
Ondatra zibethicus
Erethizon dorsatum
Canis lupus
Ursus americanus
Ursus arctos
Procyon lotor
Martes americana
Mustela erminea
Mustela vison
Gulo gulo
Lontra canadensis
Puma concolor
Lynx canadensis
Cervus canadensis
Odocoileus hemionus

Aberdeen, Washington

Sorex monticolus
Sorex vagrans
Sorex bendirii
Sorex cinereus
Sorex trowbridgii
Neurotrichus gibbsii
Scapanus townsendii
Scapanus orarius
Myotis lucifugus
Myotis keenii
Myotis californicus
Myotis volans
Myotis evotis
Myotis yumanensis
Lasiurus cinereus
Lasionycteris noctivagans
Eptesicus fuscus
Corynorhinus townsendii
Lepus americanus
Aplodontia rufa
Neotamias townsendii
Tamiasciurus douglasii
Glaucomys sabrinus
Castor canadensis
Peromyscus maniculatus
Neotoma cinerea
Clethrionomys californicus
Phenacomys intermedius
Microtus townsendii
Microtus longicaudus
Microtus oregoni
Ondatra zibethicus
Zapus trionatus
Erethizon dorsatum
Canis latrans
Ursus americanus
Procyon lotor
Martes americana
Martes pennanti
Mustela vison
Mustela frenata
Mustela erminea
Lontra canadensis
Spilogale putorius
Mephitis mephitis
Puma concolor
Lynx rufus
Cervus canadensis
Odocoileus hemionus

35. Puget Lowland Forests

Olympia, Washington

46° 58’ N, 122° 54’ W

max. temp. – 15.4 °C

mean temp. – 9.8 °C

min. temp. – 4.2 °C

precipitation – 129.0 cm/yr

Bellingham, Washington

48° 48’ N, 122° 32’ W

max. temp. – 14.4 °C

mean temp. – 10.2 °C

min. temp. – 6.0 °C

precipitation – 92.1 cm/yr

Figure I32. Puget Lowland Forests.

Olympia, Washington

Sorex vagrans
Sorex monticolus
Sorex palustris
Sorex bendirii
Sorex cinereus
Sorex trowbridgii
Neurotrichus gibbsii
Scapanus townsendii
Scapanus orarius
Myotis lucifugus
Myotis keenii
Myotis californicus
Myotis volans
Myotis evotis
Myotis yumanensis
Lasiurus cinereus
Lasionycteris noctivagans
Eptesicus fuscus
Corynorhinus townsendii
Lepus americanus
Aplodontia rufa
Neotamias townsendii
Sciurus griseus
Tamiasciurus douglasii
Glaucomys sabrinus
Thomomys talpoides
Castor canadensis
Peromyscus maniculatus
Neotoma cinerea
Clethrionomys californicus
Phenacomys intermedius
Microtus townsendii
Microtus longicaudus
Microtus oregoni
Ondatra zibethicus
Zapus trionatus
Erethizon dorsatum
Canis latrans
Ursus americanus
Procyon lotor
Martes americana
Mustela vison
Mustela frenata
Mustela erminea
Lontra canadensis
Spilogale putorius
Mephitis mephitis
Puma concolor
Lynx rufus
Odocoileus hemionus

Bellingham, Washington

Sorex vagrans
Sorex monticolus
Sorex palustris
Sorex bendirii
Sorex cinereus
Sorex trowbridgii
Neurotrichus gibbsii
Scapanus townsendii
Scapanus orarius
Myotis lucifugus
Myotis keenii
Myotis californicus
Myotis volans
Myotis evotis
Myotis yumanensis
Lasiurus cinereus
Lasionycteris noctivagans
Eptesicus fuscus
Corynorhinus townsendii
Lepus americanus
Aplodontia rufa
Neotamias amoenus
Neotamias townsendii
Tamiasciurus douglasii
Glaucomys sabrinus
Castor canadensis
Peromyscus maniculatus
Neotoma cinerea
Clethrionomys californicus
Phenacomys intermedius
Microtus townsendii
Microtus longicaudus
Microtus oregoni
Ondatra zibethicus
Synaptomys borealis
Zapus trionatus
Erethizon dorsatum
Canis latrans
Ursus americanus
Procyon lotor
Martes americana
Mustela vison
Mustela frenata
Mustela erminea
Lontra canadensis
Spilogale putorius
Mephitis mephitis
Puma concolor
Lynx rufus
Odocoileus hemionus

36. Central and Southern Cascades Forests

Oakridge, Oregon

43° 45’ N, 122° 27’ W

max. temp. – 17.3 °C

mean temp. – 10.8 °C

min. temp. – 4.3 °C

precipitation – 116.2 cm/yr

Skamania, Washington

45° 37’ N, 122° 13’ W

max. temp. – 16.4 °C

mean temp. – 9.8 °C

min. temp. – 3.1 °C

precipitation – 218.9 cm/yr

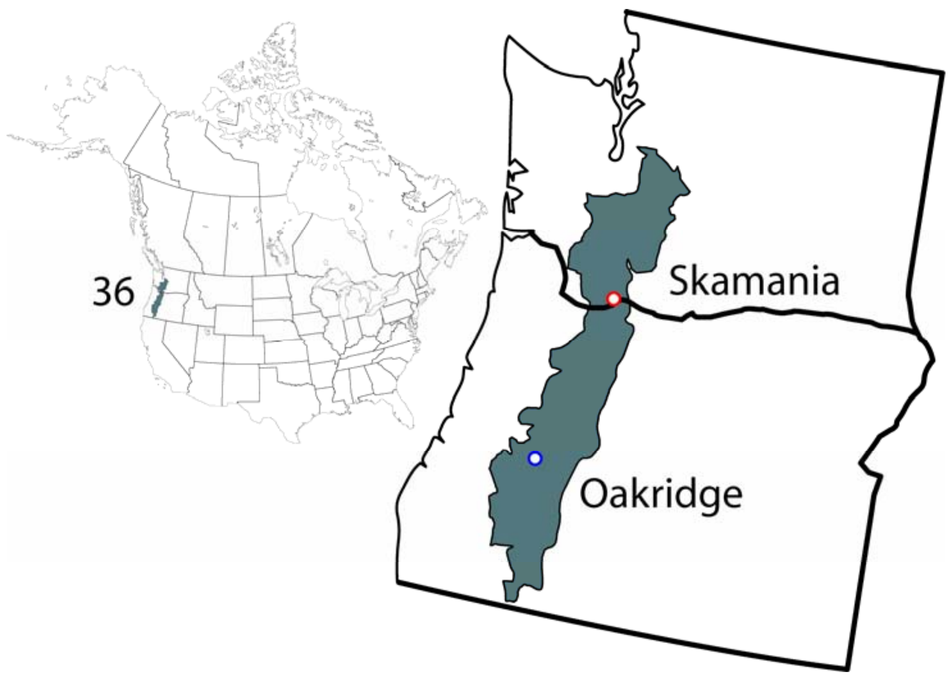


Figure I33. Central and Southern Cascades Forests.

Oakridge, Oregon

Sorex sonomae
Sorex pacificus
Sorex vagrans
Sorex bendirii
Sorex trowbridgii
Neurotrichus gibbsii
Scapanus townsendii
Scapanus orarius
Myotis lucifugus
Myotis thysanodes
Myotis californicus
Myotis volans
Myotis yumanensis
Lasiurus cinereus
Lasionycteris noctivagans
Eptesicus fuscus
Corynorhinus townsendii
Ochotona princeps
Sylvilagus bachmani
Lepus americanus
Aplodontia rufa
Neotamias amoenus
Neotamias townsendii
Marmota flaviventris
Spermophilus beecheyi
Spermophilus lateralis
Sciurus griseus
Tamiasciurus douglasii
Glaucomys sabrinus
Thomomys mazama
Castor canadensis
Peromyscus maniculatus
Neotoma cinerea
Clethrionomys californicus
Phenacomys intermedius
Microtus townsendii
Microtus longicaudus
Microtus richardsoni
Microtus oregoni
Erethizon dorsatum
Canis latrans
Vulpes vulpes
Urocyon cinereoargenteus
Ursus americanus
Procyon lotor
Martes americana
Martes pennanti
Mustela vison
Mustela frenata
Lontra canadensis
Spilogale putorius
Mephitis mephitis
Lynx rufus
Odocoileus hemionus

Skamania, Washington

Sorex vagrans
Sorex palustris
Sorex bendirii
Sorex trowbridgii
Neurotrichus gibbsii
Scapanus townsendii
Scapanus orarius
Myotis lucifugus
Myotis thysanodes
Myotis californicus
Myotis yumanensis
Lasionycteris noctivagans
Eptesicus fuscus
Ochotona princeps
Sylvilagus nuttallii
Lepus americanus
Aplodontia rufa
Neotamias amoenus
Neotamias townsendii
Marmota flaviventris
Spermophilus beecheyi
Tamiasciurus douglasii
Glaucomys sabrinus
Thomomys talpoides
Castor canadensis
Peromyscus maniculatus
Neotoma cinerea
Phenacomys intermedius
Microtus montanus
Microtus townsendii
Microtus longicaudus
Microtus richardsoni
Microtus oregoni
Ondatra zibethicus
Zapus trionatus
Erethizon dorsatum
Canis latrans
Ursus americanus
Procyon lotor
Martes pennanti
Mustela vison
Mustela frenata
Mustela erminea
Lontra canadensis
Spilogale putorius
Mephitis mephitis
Lynx rufus
Odocoileus hemionus

37. Eastern Cascades Forests

Fremont, Oregon

43° 24’ N, 121° 13’ W

max. temp. – 15.4 °C

mean temp. – 5.5 °C

min. temp. – -4.4 °C

precipitation – 31.8 cm/yr

Alturas, California

41° 30’ N, 120° 33’ W

max. temp. – 17.7 °C

mean temp. – 8.3 °C

min. temp. – -1.2 °C

precipitation – 30.8 cm/yr

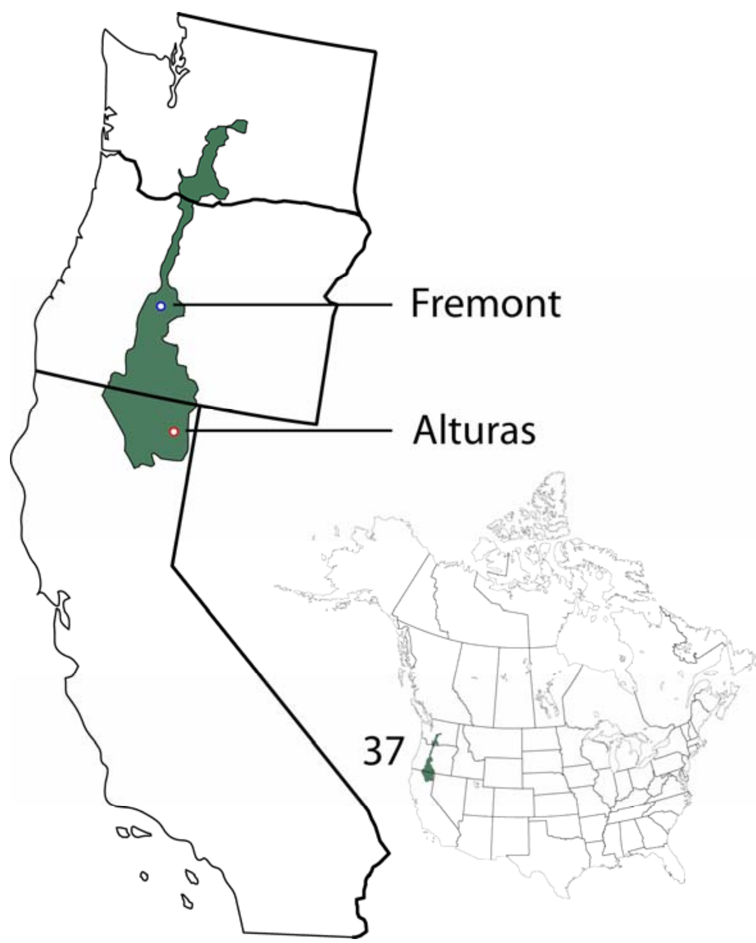


Figure I34. Eastern Cascades Forests.

Fremont, Oregon

Sorex vagrans
Sorex palustris
Sorex merriami
Scapanus orarius
Myotis lucifugus
Myotis thysanodes
Myotis californicus
Myotis evotis
Myotis yumanensis
Lasiurus cinereus
Lasionycteris noctivagans
Eptesicus fuscus
Antrozous pallidus
Tadarida brasiliensis
Ochotona princeps
Sylvilagus nuttallii
Lepus townsendii
Lepus californicus
Neotamias minimus
Neotamias amoenus
Marmota flaviventris
Spermophilus canus
Spermophilus lateralis
Tamiasciurus douglasii
Glaucomys sabrinus
Thomomys talpoides
Thomomys mazama
Microdipodomys megacephalus
Castor canadensis
Reithrodontomys megalotis
Peromyscus maniculatus
Peromyscus truei
Neotoma cinerea
Phenacomys intermedius
Microtus montanus
Microtus longicaudus
Microtus richardsoni
Lemmiscus curtatus
Zapus princeps
Zapus trionatus
Erethizon dorsatum
Canis latrans
Urocyon cinereoargenteus
Ursus americanus
Martes pennanti
Mustela vison
Mustela frenata
Taxidea taxus
Lontra canadensis
Spilogale putorius
Mephitis mephitis
Puma concolor
Lynx rufus
Odocoileus hemionus

Alturas, California

Sorex vagrans
Sorex trowbridgii
Scapanus latimanus
Myotis lucifugus
Myotis thysanodes
Myotis californicus
Myotis volans
Myotis evotis
Myotis yumanensis
Lasiurus cinereus
Lasionycteris noctivagans
Eptesicus fuscus
Antrozous pallidus
Ochotona princeps
Sylvilagus idahoensis
Sylvilagus nuttallii
Lepus americanus
Lepus townsendii
Lepus californicus
Neotamias minimus
Neotamias amoenus
Marmota flaviventris
Spermophilus beldingi
Spermophilus lateralis
Tamiasciurus douglasii
Glaucomys sabrinus
Thomomys talpoides
Perognathus parvus
Dipodomys ordii
Castor canadensis
Reithrodontomys megalotis
Peromyscus crinitus
Peromyscus maniculatus
Peromyscus truei
Onychomys leucogaster
Neotoma cinerea
Microtus montanus
Microtus longicaudus
Ondatra zibethicus
Zapus princeps
Erethizon dorsatum
Canis latrans
Mustela vison
Mustela frenata
Taxidea taxus
Lontra canadensis
Spilogale putorius
Mephitis mephitis
Lynx rufus
Odocoileus hemionus
Antilocapra americana

38. Blue Mountain Forests

Mitchell, Oregon

44° 35’ N, 120° 11’ W

max. temp. – 17.2 °C

mean temp. – 9.9 °C

min. temp. – 2.7 °C

precipitation – 28.8 cm/yr

Cambridge, Idaho

44° 34’ N, 116° 41’ W

max. temp. – 16.4 °C

mean temp. – 9.1 °C

min. temp. – 1.6 °C

precipitation – 52.1 cm/yr

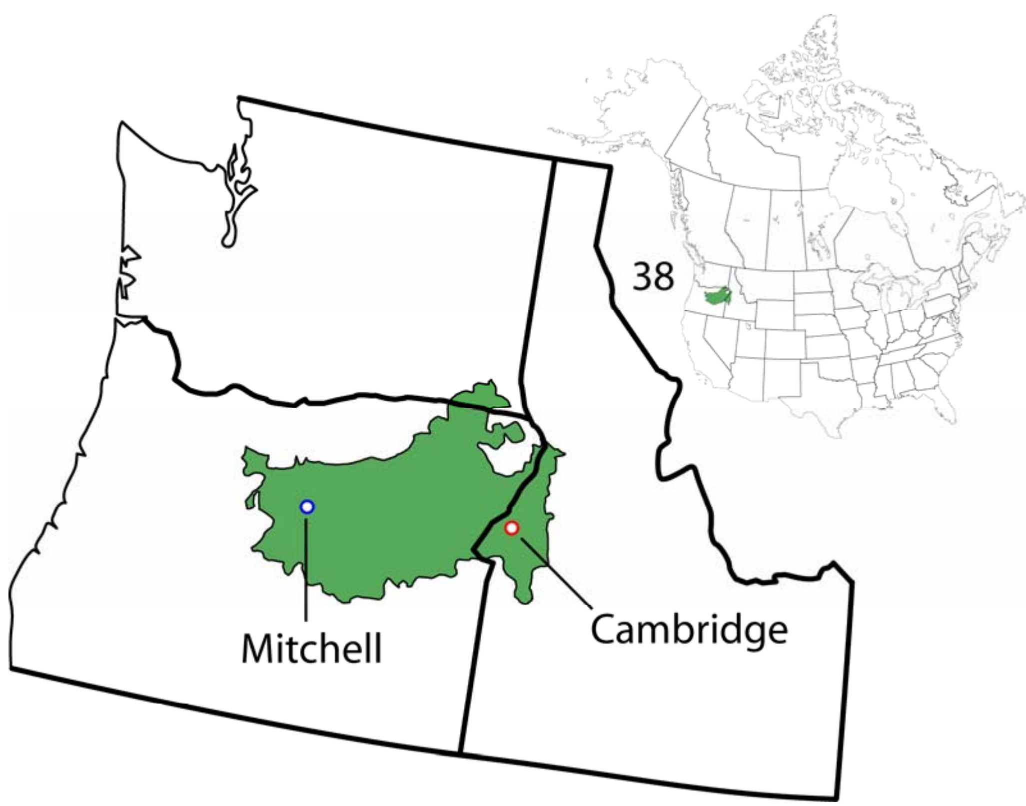


Figure I36. Blue Mountain Forests.

Mitchell, Oregon

Sorex palustris
Sorex merriami
Scapanus orarius
Myotis lucifugus
Myotis thysanodes
Myotis californicus
Myotis ciliolabrum
Myotis volans
Myotis evotis
Myotis yumanensis
Lasionycteris noctivagans
Eptesicus fuscus
Antrozous pallidus
Sylvilagus nuttallii
Lepus americanus
Lepus townsendii
Lepus californicus
Neotamias minimus
Neotamias amoenus
Marmota flaviventris
Spermophilus canus
Spermophilus beldingi
Spermophilus lateralis
Tamiasciurus douglasii
Thomomys talpoides
Perognathus parvus
Castor canadensis
Reithrodontomys megalotis
Peromyscus crinitus
Peromyscus maniculatus
Neotoma cinerea
Phenacomys intermedius
Microtus montanus
Microtus longicaudus
Lemmiscus curtatus
Ondatra zibethicus
Zapus princeps
Erethizon dorsatum
Canis latrans
Ursus americanus
Procyon lotor
Mustela frenata
Taxidea taxus
Lontra canadensis
Spilogale putorius
Mephitis mephitis
Puma concolor
Lynx rufus
Odocoileus hemionus

Cambridge, Idaho

Sorex cinereus
Sorex vagrans
Sorex monticolus
Sorex palustris
Scapanus orarius
Myotis lucifugus
Myotis yumanensis
Myotis evotis
Myotis thysanodes
Myotis volans
Myotis californicus
Myotis ciliolabrum
Lasiurus cinereus
Lasionycteris noctivagans
Eptesicus fuscus
Corynorhinus townsendii
Ochotona princeps
Sylvilagus nuttallii
Lepus americanus
Lepus townsendii
Neotamias amoenus
Marmota flaviventris
Spermophilus brunneus
Spermophilus columbianus
Tamiasciurus hudsonicus
Glaucomys sabrinus
Thomomys talpoides
Castor canadensis
Reithrodontomys megalotis
Peromyscus maniculatus
Neotoma cinerea
Clethrionomys gapperi
Phenacomys intermedius
Microtus montanus
Microtus longicaudus
Microtus richardsoni
Ondatra zibethicus
Zapus princeps
Canis latrans
Canis lupus
Vulpes vulpes
Ursus americanus
Ursus arctos
Procyon lotor
Martes americanus
Mustela frenata
Mustela vison
Gulo gulo
Taxidea taxus
Lontra canadensis
Spilogale gracilis
Puma concolor
Lynx canadensis
Lynx rufus
Cervus canadensis
Odocoileus hemionus
Odocoileus virginianus
Ovis canadensis

39. Klamath-Siskiyou Forests

Grants Pass, Oregon

42° 26’ N, 123° 21’ W

max. temp. – 19.8 °C

mean temp. – 11.8 °C

min. temp. – 3.7 °C

precipitation – 78.8 cm/yr

Weaverville, California

40° 44’ N, 122° 56’ W

max. temp. – 21.5 °C

mean temp. – 12.1 °C

min. temp. – 2.8 °C

precipitation – 97.6 cm/yr

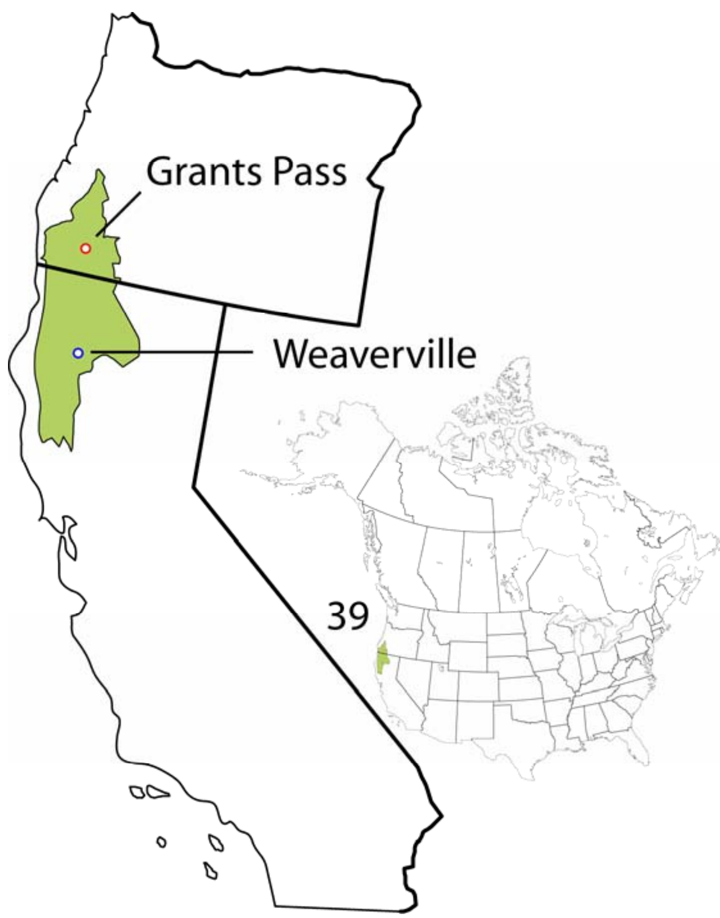


Figure I36. Klamath-Siskiyou Forests.

Grants Pass, Oregon

Sorex sonomae
Sorex pacificus
Sorex vagrans
Sorex bendirii
Neurotrichus gibbsii
Scapanus townsendii
Myotis lucifugus
Myotis thysanodes
Myotis californicus
Myotis volans
Myotis evotis
Myotis yumanensis
Lasiurus cinereus
Lasionycteris noctivagans
Eptesicus fuscus
Corynorhinus townsendii
Antrozous pallidus
Sylvilagus bachmani
Lepus americanus
Lepus californicus
Aplodontia rufa
Neotamias townsendii
Spermophilus beecheyi
Spermophilus lateralis
Sciurus griseus
Tamiasciurus douglasii
Glaucomys sabrinus
Thomomys bottae
Thomomys mazama
Castor canadensis
Reithrodontomys megalotis
Peromyscus maniculatus
Peromyscus truei
Neotoma fuscipes
Neotoma cinerea
Clethrionomys californicus
Microtus californicus
Microtus longicaudus
Zapus princeps
Erethizon dorsatum
Canis latrans
Urocyon cinereoargenteus
Ursus americanus
Bassariscus astutus
Procyon lotor
Martes pennanti
Mustela vison
Mustela frenata
Lontra canadensis
Mephitis mephitis
Spilogale putorius
Puma concolor
Lynx rufus
Odocoileus hemionus

Weaverville, California

Sorex sonomae
Sorex palustris
Neurotrichus gibbsii
Scapanus latimanus
Myotis lucifugus
Myotis thysanodes
Myotis californicus
Myotis volans
Myotis evotis
Myotis yumanensis
Lasiurus cinereus
Eptesicus fuscus
Corynorhinus townsendii
Tadarida brasiliensis
Sylvilagus bachmani
Lepus americanus
Lepus californicus
Neotamias amoenus
Neotamias senex
Neotamias sonomae
Spermophilus beecheyi
Spermophilus lateralis
Sciurus griseus
Tamiasciurus douglasii
Glaucomys sabrinus
Thomomys bottae
Dipodomys californicus
Castor canadensis
Reithrodontomys megalotis
Peromyscus maniculatus
Peromyscus boylii
Peromyscus truei
Neotoma fuscipes
Neotoma cinerea
Clethrionomys californicus
Microtus californicus
Microtus longicaudus
Microtus oregoni
Zapus princeps
Erethizon dorsatum
Canis latrans
Urocyon cinereoargenteus
Ursus americanus
Bassariscus astutus
Procyon lotor
Martes pennanti
Mustela vison
Mustela frenata
Mustela erminea
Taxidea taxus
Lontra canadensis
Spilogale putorius
Mephitis mephitis
Puma concolor
Lynx rufus
Odocoileus hemionus

40. Northern California Coastal Forests

Eureka, California

40° 49' N, 124° 10' W

max. temp. – 15.2 °C

mean temp. – 11.6 °C

min. temp. – 8.0 °C

precipitation – 96.8 cm/yr

Santa Cruz, California

36° 59' N, 121° 59' W

max. temp. – 20.5 °C

mean temp. – 14.3 °C

min. temp. – 8.0 °C

precipitation – 77.9 cm/yr

Figure I37. Northern California Coastal Forests.

Eureka, California

Sorex sonomae
Sorex vagrans
Sorex bendirii
Sorex trowbridgii
Neurotrichus gibbsii
Scapanus townsendii
Scapanus orarius
Myotis lucifugus
Myotis thysanodes
Myotis californicus
Myotis volans
Myotis evotis
Myotis yumanensis
Lasiurus cinereus
Lasiurus blossevillii
Lasionycteris noctivagans
Eptesicus fuscus
Corynorhinus townsendii
Antrozous pallidus
Sylvilagus bachmani
Lepus californicus
Aplodontia rufa
Neotamias ochrogenys
Spermophilus beecheyi
Sciurus griseus
Tamiasciurus douglasii
Glaucomys sabrinus
Thomomys bottae
Reithrodontomys megalotis
Peromyscus maniculatus
Peromyscus truei
Neotoma fuscipes
Clethrionomys californicus
Arborimus pomo
Microtus californicus
Microtus townsendii
Microtus longicaudus
Microtus oregoni
Zapus trionatus
Canis latrans
Urocyon cinereoargenteus
Ursus americanus
Bassariscus astutus
Procyon lotor
Martes americana
Mustela vison
Mustela frenata
Mustela erminea
Taxidea taxus
Lontra canadensis
Spilogale putorius
Mephitis mephitis
Puma concolor
Lynx rufus
Cervus canadensis
Odocoileus hemionus

Santa Cruz, California

Sorex pacificus
Sorex vagrans
Sorex ornatus
Sorex trowbridgii
Neurotrichus gibbsii
Scapanus latimanus
Myotis lucifugus
Myotis thysanodes
Myotis californicus
Myotis volans
Myotis evotis
Myotis yumanensis
Lasiurus cinereus
Lasiurus blossevillii
Eptesicus fuscus
Pipistrellus hesperus
Corynorhinus townsendii
Antrozous pallidus
Tadarida brasiliensis
Sylvilagus bachmani
Sylvilagus audubonii
Lepus californicus
Neotamias merriami
Spermophilus beecheyi
Sciurus griseus
Thomomys bottae
Chaetodipus californicus
Dipodomys venustus
Reithrodontomys megalotis
Peromyscus californicus
Peromyscus maniculatus
Peromyscus boylii
Peromyscus truei
Neotoma fuscipes
Microtus californicus
Canis latrans
Urocyon cinereoargenteus
Bassariscus astutus
Procyon lotor
Mustela frenata
Taxidea taxus
Spilogale putorius
Mephitis mephitis
Puma concolor
Lynx rufus
Odocoileus hemionus

41. Sierra Nevada Forests

Quincy, California

39° 56' N, 120° 57' W

max. temp. – 20.4 °C

mean temp. – 10.5 °C

min. temp. – 0.6 °C

precipitation – 97.3 cm/yr

Lodgepole, California

36° 36' N, 118° 44' W

max. temp. – 12.9 °C

mean temp. – 5.4 °C

min. temp. – -2.1 °C

precipitation – 113.6 cm/yr

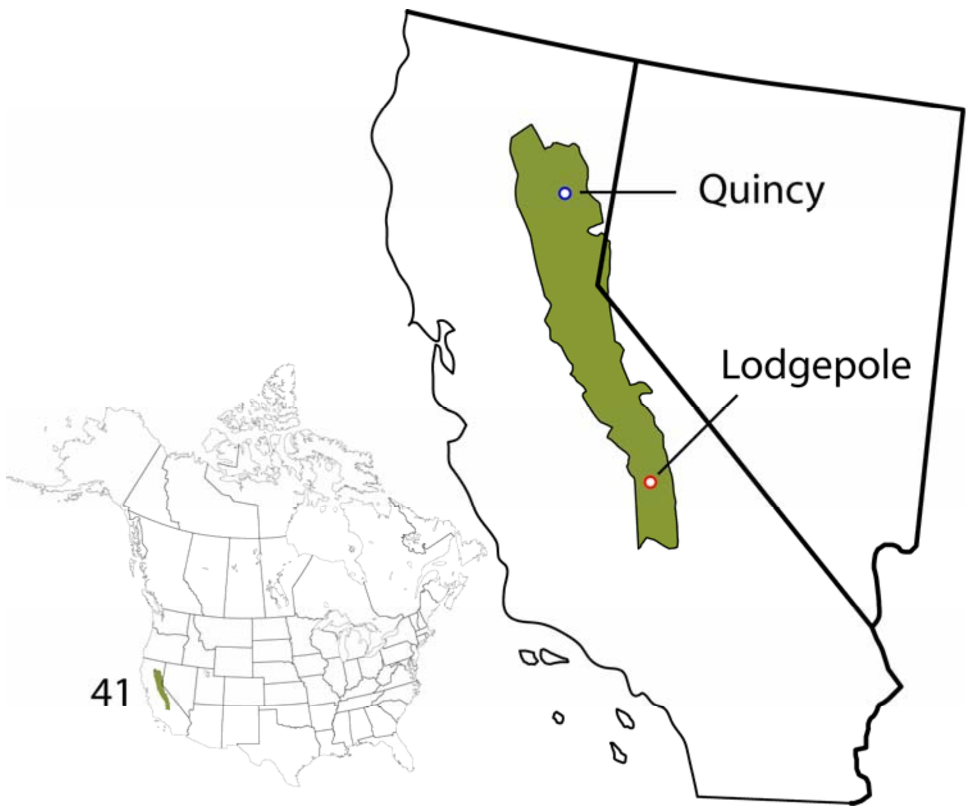


Figure I38. Sierra Nevada Forests.

Quincy, California

Sorex monticolus
Sorex vagrans
Sorex palustris
Sorex trowbridgii
Scapanus latimanus
Myotis lucifugus
Myotis thysanodes
Myotis californicus
Myotis volans
Myotis evotis
Myotis yumanensis
Lasiurus blossevillii
Lasionycteris noctivagans
Eptesicus fuscus
Ochotona princeps
Sylvilagus nuttallii
Lepus americanus
Aplodontia rufa
Neotamias minimus
Neotamias amoenus
Neotamias senex
Neotamias quadrimaculatus
Neotamias speciosus
Marmota flaviventris
Spermophilus beecheyi
Spermophilus lateralis
Sciurus griseus
Tamiasciurus douglasii
Glaucomys sabrinus
Thomomys monticola
Reithrodontomys megalotis
Peromyscus californicus
Peromyscus maniculatus
Peromyscus boylii
Peromyscus truei
Neotoma cinerea
Microtus montanus
Microtus longicaudus
Zapus princeps
Erethizon dorsatum
Canis latrans
Vulpes vulpes
Urocyon cinereoargenteus
Ursus americanus
Martes americana
Martes pennanti
Mustela vison
Mustela frenata
Gulo gulo
Taxidea taxus
Spilogale putorius
Mephitis mephitis
Puma concolor
Lynx rufus
Odocoileus hemionus
Antilocapra americana

Lodgepole, California

Sorex monticolus
Sorex palustris
Scapanus latimanus
Myotis lucifugus
Myotis thysanodes
Myotis californicus
Myotis volans
Myotis evotis
Myotis yumanensis
Lasiurus blossevillii
Lasionycteris noctivagans
Eptesicus fuscus
Ochotona princeps
Sylvilagus nuttallii
Sylvilagus audubonii
Aplodontia rufa
Neotamias alpinus
Neotamias minimus
Neotamias merriami
Neotamias speciosus
Neotamias bottae
Marmota flaviventris
Spermophilus beldingi
Spermophilus beecheyi
Sciurus griseus
Tamiasciurus douglasii
Glaucomys sabrinus
Thomomys bottae
Perognathus longimembris
Perognathus parvus
Reithrodontomys megalotis
Peromyscus maniculatus
Peromyscus boylii
Peromyscus truei
Neotoma macrotis
Neotoma cinerea
Microtus montanus
Erethizon dorsatum
Canis latrans
Urocyon cinereoargenteus
Ursus americanus
Bassariscus astutus
Martes americana
Martes pennanti
Mustela frenata
Taxidea taxus
Puma concolor
Lynx rufus
Odocoileus hemionus
Ovis canadensis

43. South Central Rockies Forests

Stanley, Idaho

44° 13’ N, 114° 56’ W

max. temp. – 11.1 °C

mean temp. – 1.8 °C

min. temp. – -7.6 °C

precipitation – 38.1 cm/yr

Moran, Wyoming

43° 51’ N, 110° 35’ W

max. temp. – 10.8 °C

mean temp. – 2.8 °C

min. temp. – -5.2 °C

precipitation – 63.9 cm/yr

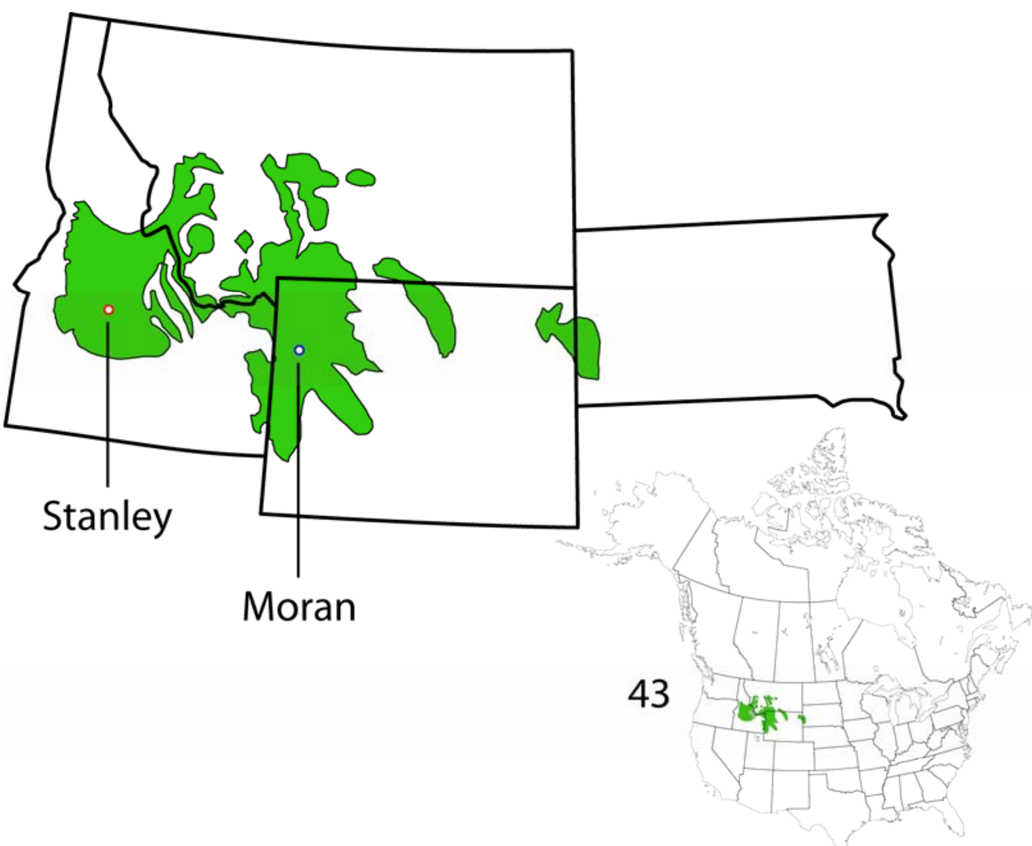


Figure I39. South Central Rockies Forests.

Stanley, Idaho

Sorex vagrans
Sorex monticolus
Sorex palustris
Myotis lucifugus
Myotis yumanensis
Myotis evotis
Myotis thysanodes
Myotis volans
Myotis californicus
Myotis ciliolabrum
Lasiurus cinereus
Lasionycteris noctivagans
Eptesicus fuscus
Euderma maculatum
Corynorhinus townsendii
Ochotona princeps
Sylvilagus nuttallii
Lepus americanus
Lepus townsendii
Neotamias minimus
Neotamias amoenus
Marmota flaviventris
Spermophilus columbianus
Spermophilus lateralis
Tamiasciurus hudsonicus
Glaucomys sabrinus
Thomomys talpoides
Castor canadensis
Peromyscus maniculatus
Neotoma cinerea
Clethrionomys gapperi
Phenacomys intermedius
Microtus pennsylvanicus
Microtus montanus
Microtus longicaudus
Microtus richardsoni
Ondatra zibethicus
Zapus princeps
Canis latrans
Canis lupus
Vulpes vulpes
Ursus americanus
Ursus arctos
Procyon lotor
Martes americanus
Martes pennanti
Mustela frenata
Mustela vison
Gulo gulo
Taxidea taxus
Lontra canadensis
Spilogale gracilis
Puma concolor
Lynx canadensis
Lynx rufus
Cervus canadensis
Odocoileus hemionus
Odocoileus virginianus
Alces alces
Antilocapra americana
Bos bison
Oreamnos americanus
Ovis canadensis

Moran, Wyoming

Sorex cinereus
Sorex monticolus
Sorex nanus
Sorex palustris
Myotis lucifugus
Myotis yumanensis
Myotis evotis
Myotis volans
Lasiurus cinereus
Lasionycteris noctivagans
Eptesicus fuscus
Euderma maculatum
Corynorhinus townsendii
Ochotona princeps
Sylvilagus nuttallii
Sylvilagus audubonii
Lepus americanus
Lepus townsendii
Neotamias minimus
Neotamias amoenus
Neotamias bottae
Marmota flaviventris
Spermophilus elegans
Spermophilus armatus
Spermophilus lateralis
Cynomys leucurus
Tamiasciurus hudsonicus
Glaucomys sabrinus
Thomomys talpoides
Castor canadensis
Peromyscus maniculatus
Neotoma cinerea
Clethrionomys gapperi
Phenacomys intermedius
Microtus pennsylvanicus
Microtus montanus
Microtus longicaudus
Microtus richardsoni
Lemmiscus curtatus
Ondatra zibethicus
Zapus princeps
Erethizon dorsatum
Canis latrans
Canis lupus
Vulpes vulpes
Ursus americanus
Ursus arctos
Martes americana
Mustela erminea
Mustela frenata
Mustela vison
Gulo gulo
Taxidea taxus
Lontra canadensis
Mephitis mephitis
Puma concolor
Lynx canadensis
Lynx rufus
Cervus canadensis
Odocoileus hemionus
Odocoileus virginianus
Alces alces
Antilocapra americana
Bos bison
Ovis canadensis

44. Wasatch and Uinta Montane Forests

Salina, Utah

38° 58’ N, 111° 52’ W

max. temp. – 18.4 °C

mean temp. – 9.3 °C

min. temp. – 0.1 °C

precipitation – 25.1 cm/yr

Kamas, Utah

40° 39’ N, 111° 17’ W

max. temp. – 14.9 °C

mean temp. – 6.7 °C

min. temp. – -1.6 °C

precipitation – 42.9 cm/yr

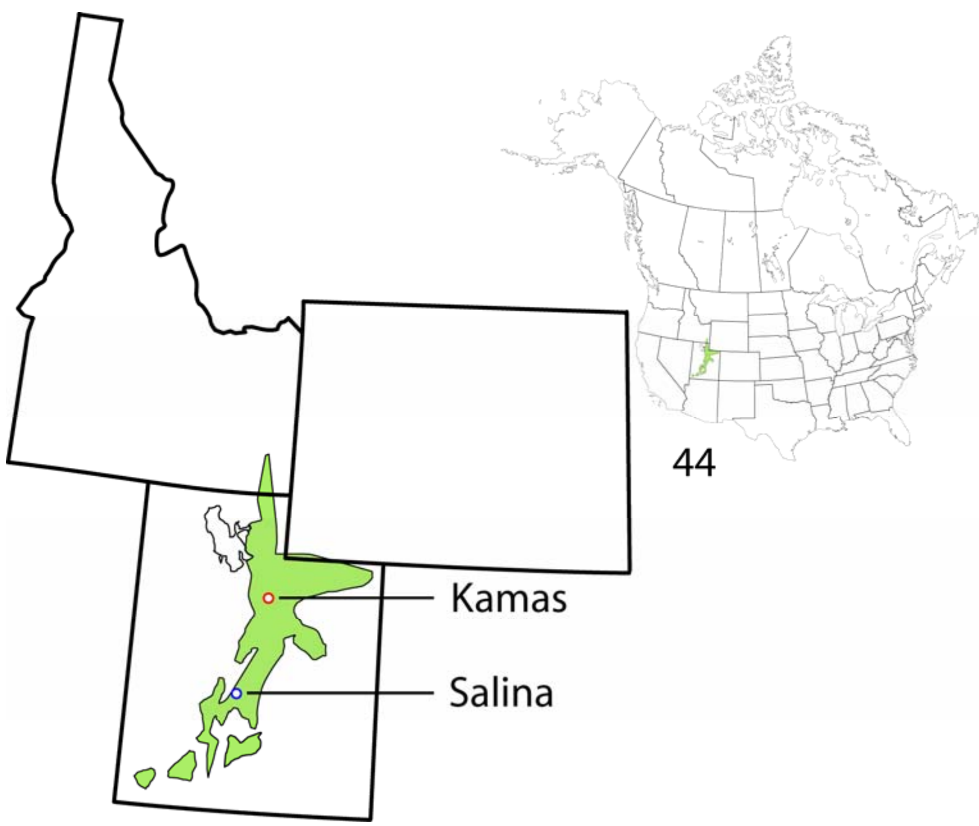


Figure I40. Wasatch and Uinta Montane Forests.

Salina, Utah

Sorex cinereus
Sorex monticolus
Sorex nanus
Sorex palustris
Myotis lucifugus
Myotis evotis
Myotis thysanodes
Myotis volans
Myotis californicus
Myotis ciliolabrum
Lasiurus cinereus
Pipistrellus hesperus
Eptesicus fuscus
Euderma maculatum
Corynorhinus townsendii
Antrozous pallidus
Tadarida brasiliensis
Nyctinomops macrotis
Ochotona princeps
Sylvilagus nuttallii
Lepus americanus
Lepus townsendii
Lepus californicus
Neotamias minimus
Neotamias dorsalis
Neotamias bottae
Marmota flaviventris
Spermophilus armatus
Spermophilus variegatus
Spermophilus lateralis
Cynomys parvidens
Tamiasciurus hudsonicus
Glaucomys sabrinus
Thomomys talpoides
Perognathus parvus
Dipodomys ordii
Castor canadensis
Reithrodontomys megalotis
Peromyscus maniculatus
Peromyscus boylii
Onychomys leucogaster
Neotoma cinerea
Clethrionomys gapperi
Phenacomys intermedius
Microtus montanus
Microtus longicaudus
Microtus richardsoni
Lemmiscus curtatus
Ondatra zibethicus
Zapus princeps
Erethizon dorsatum
Canis latrans
Canis lupus
Vulpes vulpes
Ursus americanus
Ursus arctos
Martes americana
Martes pennanti
Mustela erminea
Mustela frenata
Mustela vison
Gulo gulo
Taxidea taxus
Lontra canadensis
Spilogale gracilis
Mephitis mephitis
Puma concolor
Lynx canadensis
Lynx rufus
Cervus canadensis
Odocoileus hemionus
Antilocapra americana
Bos bison
Ovis canadensis

Kamas, Utah

Sorex cinereus
Sorex vagrans
Sorex monticolus
Sorex nanus
Sorex palustris
Myotis lucifugus
Myotis evotis
Myotis thysanodes
Myotis volans
Myotis californicus
Myotis ciliolabrum
Lasiurus cinereus
Lasionycteris noctivagans
Pipistrellus hesperus
Eptesicus fuscus
Euderma maculatum
Corynorhinus townsendii
Tadarida brasiliensis
Ochotona princeps
Sylvilagus nuttallii
Lepus americanus
Lepus townsendii
Neotamias minimus
Neotamias dorsalis
Neotamias bottae
Marmota flaviventris
Spermophilus elegans
Spermophilus armatus
Spermophilus variegatus
Spermophilus lateralis
Cynomys leucurus
Tamiasciurus hudsonicus
Glaucomys sabrinus
Thomomys talpoides
Castor canadensis
Reithrodontomys megalotis
Peromyscus maniculatus
Peromyscus boylii
Onychomys leucogaster
Neotoma cinerea
Clethrionomys gapperi
Phenacomys intermedius
Microtus pennsylvanicus
Microtus montanus
Microtus longicaudus
Microtus richardsoni
Lemmiscus curtatus
Ondatra zibethicus
Zapus princeps
Erethizon dorsatum
Canis latrans
Canis lupus
Vulpes vulpes
Ursus americanus
Ursus arctos
Martes americana
Martes pennanti
Mustela erminea
Mustela frenata
Mustela vison
Gulo gulo
Taxidea taxus
Lontra canadensis
Spilogale gracilis
Mephitis mephitis
Puma concolor
Lynx canadensis
Lynx rufus
Cervus canadensis
Odocoileus hemionus
Alces alces
Antilocapra americana
Bos bison
Ovis canadensis

45. Colorado Rockies Forests

Pagosa Springs, Colorado

37° 15’ N, 107° 01’ W

max. temp. – 15.8 °C

mean temp. – 6.1 °C

min. temp. – -3.7 °C

precipitation – 52.4 cm/yr

Vail, Colorado

39° 40’ N, 106° 22’ W

max. temp. – 10.0 °C

mean temp. – 2.1 °C

min. temp. – -5.8 °C

precipitation – 51.9 cm/yr

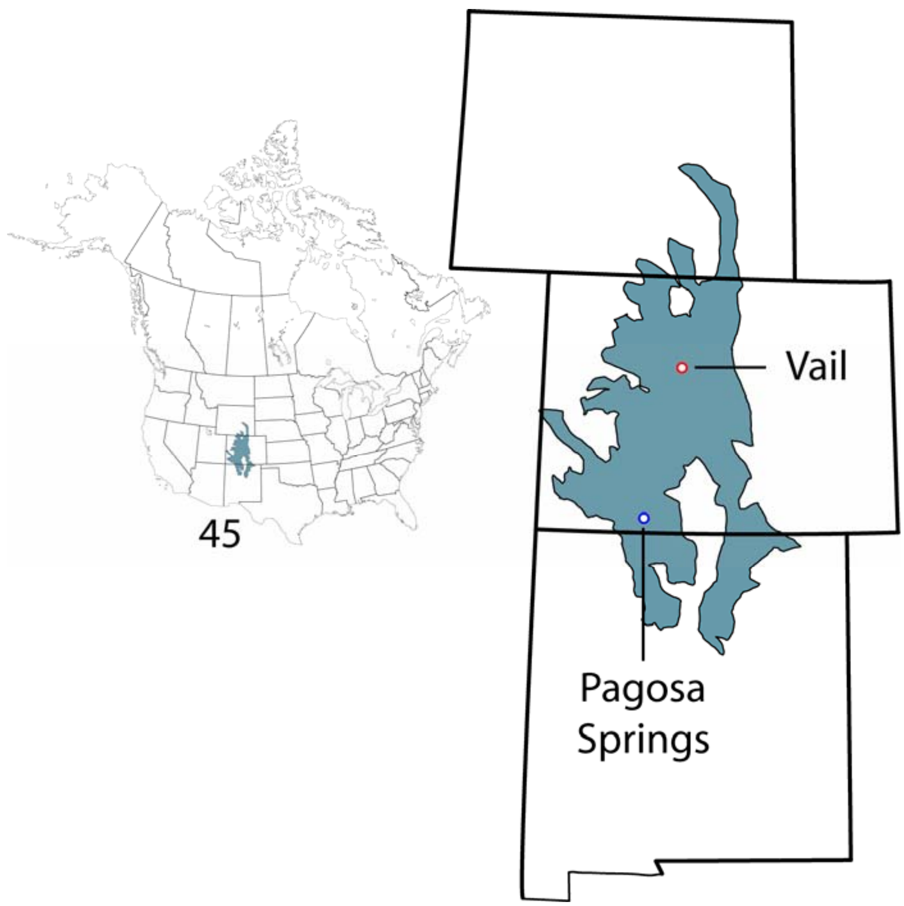


Figure I41. Colorado Rockies Forests.

Pagosa Springs, Colorado

Sorex cinereus
Sorex monticolus
Sorex nanus
Sorex palustris
Myotis lucifugus
Myotis velifer
Myotis evotis
Myotis thysanodes
Myotis volans
Myotis californicus
Myotis ciliolabrum
Lasiurus cinereus
Lasionycteris noctivagans
Eptesicus fuscus
Corynorhinus townsendii
Antrozous pallidus
Tadarida brasiliensis
Nyctinomops macrotis
Ochotona princeps
Sylvilagus nuttallii
Lepus americanus
Lepus townsendii
Lepus californicus
Neotamias minimus
Neotamias quadrivittatus
Marmota flaviventris
Spermophilus tridecemlineatus
Spermophilus variegatus
Spermophilus lateralis
Cynomys gunnisoni
Sciurus aberti
Tamiasciurus hudsonicus
Thomomys talpoides
Castor canadensis
Reithrodontomys megalotis
Peromyscus maniculatus
Peromyscus boylii
Peromyscus nasutus
Neotoma cinerea
Clethrionomys gapperi
Phenacomys intermedius
Microtus pennsylvanicus
Microtus montanus
Microtus longicaudus
Ondatra zibethicus
Zapus princeps
Erethizon dorsatum
Canis latrans
Canis lupus
Vulpes vulpes
Urocyon cinereoargenteus
Ursus americanus
Ursus arctos
Bassaricus astutus
Martes americana
Mustela erminea
Mustela frenata
Mustela nigripes
Mustela vison
Gulo gulo
Taxidea taxus
Lontra canadensis
Spilogale gracilis
Mephitis mephitis
Puma concolor
Lynx canadensis
Lynx rufus
Cervus canadensis
Odocoileus hemionus
Antilocapra americana
Ovis canadensis

Vail, Colorado

Sorex cinereus
Sorex monticolus
Sorex nanus
Sorex palustris
Myotis lucifugus
Myotis evotis
Myotis thysanodes
Myotis volans
Myotis californicus
Myotis ciliolabrum
Lasiurus cinereus
Lasionycteris noctivagans
Eptesicus fuscus
Corynorhinus townsendii
Tadarida brasiliensis
Nyctinomops macrotis
Ochotona princeps
Sylvilagus nuttallii
Lepus americanus
Lepus townsendii
Neotamias minimus
Neotamias bottae
Marmota flaviventris
Spermophilus elegans
Spermophilus tridecemlineatus
Spermophilus variegatus
Spermophilus lateralis
Cynomys leucurus
Sciurus aberti
Tamiasciurus hudsonicus
Thomomys talpoides
Castor canadensis
Peromyscus maniculatus
Peromyscus nasutus
Neotoma cinerea
Clethrionomys gapperi
Phenacomys intermedius
Microtus pennsylvanicus
Microtus montanus
Microtus longicaudus
Ondatra zibethicus
Zapus princeps
Erethizon dorsatum
Canis latrans
Canis lupus
Vulpes vulpes
Urocyon cinereoargenteus
Ursus americanus
Ursus arctos
Bassaricus astutus
Martes americana
Mustela erminea
Mustela frenata
Mustela nigripes
Mustela vison
Gulo gulo
Taxidea taxus
Lontra canadensis
Spilogale gracilis
Mephitis mephitis
Puma concolor
Lynx canadensis
Lynx rufus
Cervus canadensis
Odocoileus hemionus
Antilocapra americana
Bos bison
Ovis canadensis

46. Arizona Mountain Forests

Flagstaff, Arizona

35° 08’ N, 111° 40’ W

max. temp. – 16.3 °C

mean temp. – 7.9 °C

min. temp. – -0.6 °C

precipitation – 58.2 cm/yr

Luna, New Mexico

33° 49’ N, 108° 57’ W

max. temp. – 18.9 °C

mean temp. – 8.0 °C

min. temp. – -2.9 °C

precipitation – 44.6 cm/yr

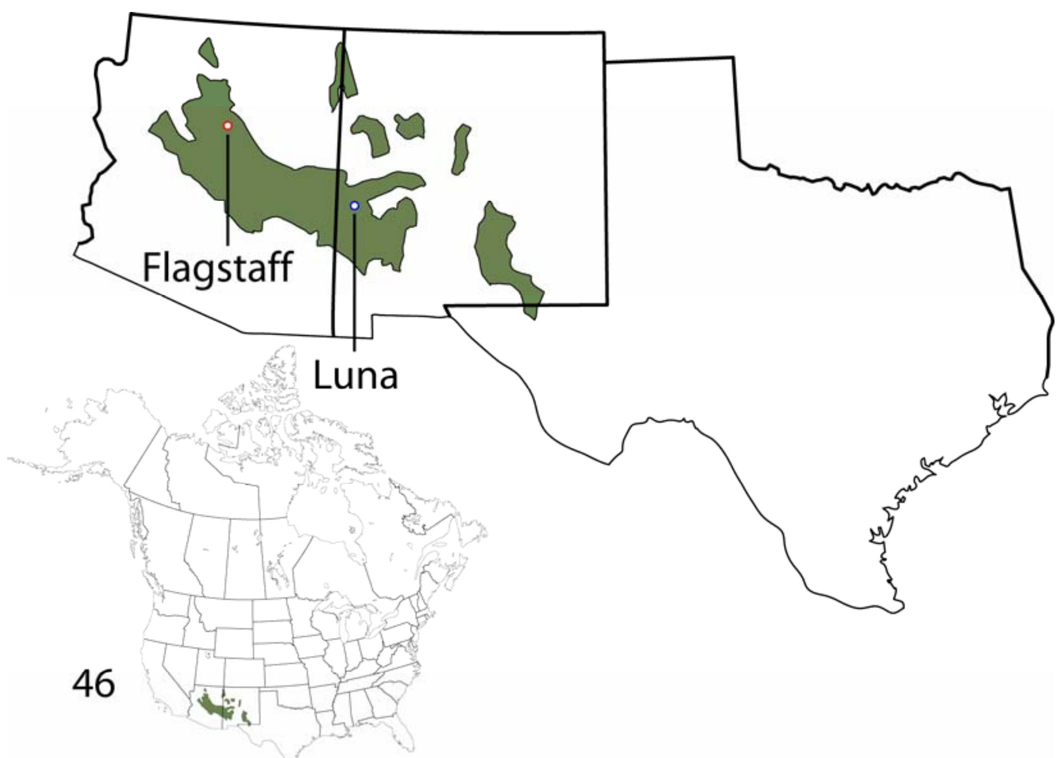


Figure I42. Arizona Mountain Forests.

Flagstaff, Arizona

Sorex monticolus
Notiosorex crawfordi
Myotis yumanensis
Myotis velifer
Myotis occultus
Myotis auriculus
Myotis thysanodes
Myotis volans
Myotis californicus
Myotis ciliolabrum
Lasiurus blossevillii
Lasiurus cinereus
Lasionycteris noctivagans
Pipistrellus hesperus
Eptesicus fuscus
Euderma maculatum
Corynorhinus townsendii
Antrozous pallidus
Tadarida brasiliensis
Nyctinomops macrotis
Sylvilagus nuttallii
Sylvilagus audubonii
Lepus californicus
Neotamias dorsalis
Spermophilus spilosoma
Spermophilus variegatus
Spermophilus lateralis
Cynomys gunnisoni
Sciurus aberti
Sciurus arizonensis
Tamiasciurus hudsonicus
Thomomys bottae
Perognathus flavus
Dipodomys ordii
Castor canadensis
Reithrodontomys megalotis
Peromyscus maniculatus
Peromyscus leucopus
Peromyscus boylii
Peromyscus truei
Onychomys leucogaster
Sigmodon arizonae
Neotoma albigula
Neotoma stephensi
Neotoma mexicana
Microtus mogollonensis
Erethizon dorsatum
Canis latrans
Canis lupus
Urocyon cinereoargenteus
Ursus americanus
Ursus arctos
Bassaricus astutus
Mustela frenata
Mustela nigripes
Taxidea taxus
Lontra canadensis
Spilogale gracilis
Mephitis mephitis
Panthera onca
Puma concolor
Lynx rufus
Cervus canadensis
Odocoileus hemionus
Antilocapra americana
Ovis canadensis

Luna, New Mexico

Sorex monticolus
Notiosorex crawfordi
Myotis yumanensis
Myotis velifer
Myotis occultus
Myotis auriculus
Myotis thysanodes
Myotis volans
Myotis californicus
Myotis ciliolabrum
Lasiurus cinereus
Lasionycteris noctivagans
Pipistrellus hesperus
Eptesicus fuscus
Euderma maculatum
Corynorhinus townsendii
Antrozous pallidus
Tadarida brasiliensis
Nyctinomops macrotis
Sylvilagus audubonii
Lepus californicus
Neotamias dorsalis
Neotamias cinereicollis
Spermophilus spilosoma
Spermophilus variegatus
Spermophilus lateralis
Cynomys gunnisoni
Sciurus aberti
Sciurus arizonensis
Tamiasciurus hudsonicus
Thomomys bottae
Perognathus flavus
Dipodomys ordii
Castor canadensis
Reithrodontomys megalotis
Peromyscus maniculatus
Peromyscus leucopus
Peromyscus boylii
Peromyscus truei
Peromyscus nasutus
Onychomys leucogaster
Onychomys arenicola
Neotoma micropus
Neotoma albigula
Neotoma stephensi
Neotoma mexicana
Clethrionomys gapperi
Microtus longicaudus
Microtus mogollonensis
Zapus princeps
Erethizon dorsatum
Canis latrans
Canis lupus
Urocyon cinereoargenteus
Ursus americanus
Ursus arctos
Bassaricus astutus
Mustela frenata
Mustela nigripes
Taxidea taxus
Lontra canadensis
Spilogale gracilis
Mephitis mephitis
Panthera onca
Puma concolor
Lynx rufus
Cervus canadensis
Odocoileus hemionus
Odocoileus virginianus
Antilocapra americana
Ovis canadensis

47. Madrean Sky Islands Montane Forests

Santa Rita Experimental Range, Arizona

31° 46’ N, 110° 51’ W

max. temp. – 24.9 °C

mean temp. – 17.9 °C

min. temp. – 10.8 °C

precipitation – 59.5 cm/yr

Canelo, Arizona

31° 34’ N, 110° 32’ W

max. temp. – 23.4 °C

mean temp. – 14.6 °C

min. temp. – 5.7 °C

precipitation – 45.8 cm/yr

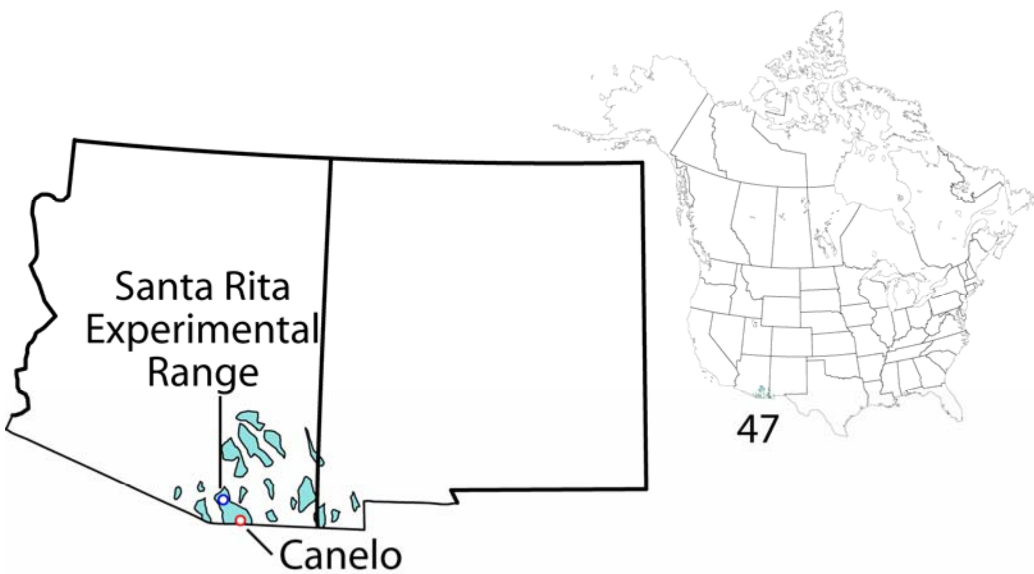


Figure I43. Madrean Sky Islands Montane Forests.

Santa Rita Experimental Range, Arizona

Sorex monticolus
Notiosorex cockrumi
Mormoops megalophylla
Macrotus californicus
Choeronycteris mexicana
Leptonycteris curasoae
Myotis yumanensis
Myotis velifer
Myotis occultus
Myotis auriculus
Myotis thysanodes
Myotis volans
Myotis californicus
Myotis ciliolabrum
Lasiurus blossevillii
Lasiurus cinereus
Pipistrellus hesperus
Eptesicus fuscus
Corynorhinus townsendii
Antrozous pallidus
Tadarida brasiliensis
Nyctinomops femorosaccus
Nyctinomops macrotis
Sylvilagus floridanus
Sylvilagus audubonii
Lepus californicus
Lepus alleni
Ammospermophilus harrisii
Spermophilus spilosoma
Spermophilus variegatus
Speromphilus tereticaudus
Cynomys ludovicianus
Sciurus arizonensis
Thomomys umbrinus
Perognathus flavus
Perognathus amplus
Chaetodipus baileyi
Chaetodipus hispidus
Chaetodipus penicillatus
Dipodomys ordii
Dipodomys spectabilis
Dipodomys merriami
Castor canadensis
Reithrodontomys montanus
Reithrodontomys megalotis
Reithrodontomys fulvescens
Peromyscus eremicus
Peromyscus maniculatus
Peromyscus leucopus
Peromyscus boylii
Peromyscus pectoralis
Onychomys leucogaster
Onychomys torridus
Sigmodon arizonae
Sigmodon fulviventer
Neotoma albigula
Neotoma mexicana
Erethizon dorsatum
Canis latrans
Canis lupus
Vulpes macrotis
Urocyon cinereoargenteus
Ursus americanus
Ursus arctos
Bassaricus astutus
Procyon lotor
Nasua narica
Taxidea taxus
Spilogale gracilis
Mephitis mephitis
Mephitis macroura
Conepatus leuconotus
Panthera onca
Puma concolor
Lynx rufus
Pecari tajacu
Odocoileus hemionus
Odocoileus virginianus

Antilocapra americana *Ovis canadensis*

Canelo, Arizona

Sorex monticolus
Notiosorex cockrumi
Mormoops megalophylla
Macrotus californicus
Choeronycteris mexicana
Leptonycteris curasoae
Myotis yumanensis
Myotis velifer
Myotis occultus
Myotis auriculus
Myotis thysanodes
Myotis volans
Myotis californicus
Myotis ciliolabrum
Lasiurus blossevillii
Lasiurus cinereus
Pipistrellus hesperus
Eptesicus fuscus
Corynorhinus townsendii
Antrozous pallidus
Tadarida brasiliensis
Nyctinomops femorosaccus
Nyctinomops macrotis
Sylvilagus floridanus
Sylvilagus audubonii
Lepus californicus
Lepus alleni
Ammospermophilus harrisii
Spermophilus spilosoma
Spermophilus variegatus
Speromphilus tereticaudus
Cynomys ludovicianus
Sciurus arizonensis
Thomomys umbrinus
Perognathus flavus
Perognathus amplus
Chaetodipus baileyi
Chaetodipus hispidus
Chaetodipus penicillatus
Dipodomys ordii
Dipodomys spectabilis
Dipodomys merriami
Castor canadensis
Reithrodontomys montanus
Reithrodontomys megalotis
Reithrodontomys fulvescens
Peromyscus eremicus
Peromyscus maniculatus
Peromyscus leucopus
Peromyscus boylii
Peromyscus pectoralis
Onychomys leucogaster
Onychomys torridus
Sigmodon arizonae
Sigmodon fulviventer
Neotoma albigula
Neotoma mexicana
Erethizon dorsatum
Canis latrans
Canis lupus
Vulpes macrotis
Urocyon cinereoargenteus
Ursus americanus
Ursus arctos
Bassaricus astutus
Procyon lotor
Nasua narica
Taxidea taxus
Spilogale gracilis
Mephitis mephitis
Mephitis macroura
Conepatus leuconotus
Panthera onca
Puma concolor
Lynx rufus
Pecari tajacu
Odocoileus hemionus
Odocoileus virginianus

Antilocapra americana *Ovis canadensis*

48. Piney Woods Forests

Sam Rayburn Dam, Texas	Shreveport, Louisiana
31° 04' N, 94° 06' W	32° 27' N, 93° 49' W
max. temp. – 25.2 °C	max. temp. – 24.6 °C
mean temp. – 18.6 °C	mean temp. – 18.7 °C
min. temp. – 11.9 °C	min. temp. – 12.8 °C
precipitation – 153.8 cm/yr	precipitation – 130.3 cm/yr

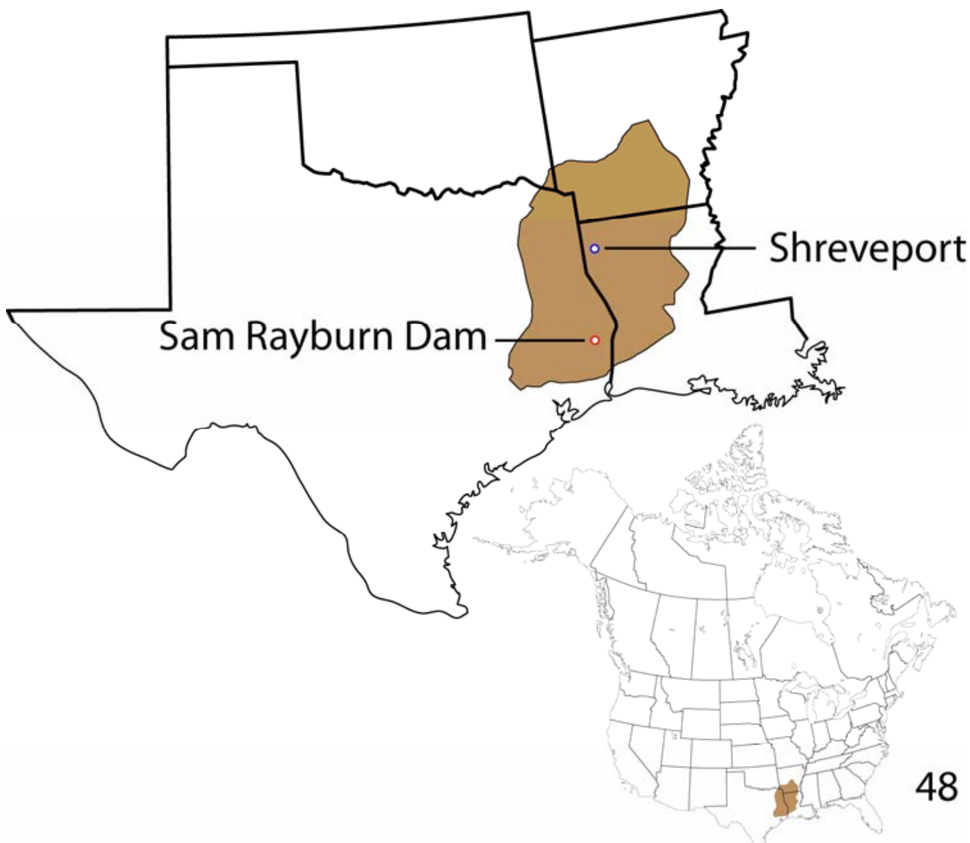


Figure I44. Piney Woods Forests.

Sam Rayburn Dam, Texas

Didelphis virginiana
Blarina carolinensis
Cryptotis parva
Scalopus aquaticus
Myotis austroriparius
Lasiurus borealis
Lasiurus cinereus
Lasiurus intermedius
Lasiurus seminolus
Lasionycteris noctivagans
Pipistrellus subflavus
Eptesicus fuscus
Nycticeius humeralis
Corynorhinus rafinesquii
Tadarida brasiliensis
Sylvilagus aquaticus
Sylvilagus floridanus
Lepus californicus
Sciurus carolinensis
Sciurus niger
Glaucomys volans
Geomys breviceps
Castor canadensis
Oryzomys palustris
Reithrodonotmys fulvescens
Reithrodontomys humulis
Peromyscus gossypinus
Peromyscus leucopus
Peromyscus maniculatus
Ochrotomys nuttalli
Sigmodon hispidus
Neotoma floridana
Microtus pinetorum
Ondatra zibethicus
Canis latrans
Canis rufus
Vulpes vulpes
Urocyon cinereoargenteus
Ursus americanus
Bassariscus astutus
Procyon lotor
Mustela frenata
Mustela vison
Lontra canadensis
Spilogale putorius
Mephitis mephitis
Puma concolor
Panthera onca
Lynx rufus
Odocoileus virginianus

Shreveport, Louisiana

Didelphis virginiana
Blarina brevicauda
Blarina hylophaga
Cryptotis parva
Scalopus aquaticus
Myotis austroriparius
Lasiurus borealis
Lasiurus seminolus
Lasiurus cinereus
Lasionycteris noctivagans
Pipistrellus subflavus
Eptesicus fuscus
Nycticeius humeralis
Sylvilagus palustris
Sylvilagus floridanus
Sciurus carolinensis
Sciurus niger
Glaucomys volans
Geomys breviceps
Castor canadensis
Oryzomys palustris
Reithrodontomys fulvescens
Peromyscus leucopus
Peromyscus gossypinus
Ochrotomys nuttalli
Sigmodon hispidus
Neotoma floridana
Canis latrans
Canis lupus
Canis rufus
Vulpes vulpes
Urocyon cinereoargenteus
Ursus americanus
Procyon lotor
Mustela frenata
Mustela vison
Lontra canadensis
Spilogale putorius
Mephitis mephitis
Puma concolor
Leopardus pardalis
Lynx rufus
Odocoileus virginianus
Bos bison

49. Atlantic Coastal Pine Barrens

Atlantic City, New Jersey

39° 27' N, 74° 34' W

max. temp. – 17.6 °C

mean temp. – 11.9 °C

min. temp. – 6.3 °C

precipitation – 103.1 cm/yr

Chatham, Massachusetts

41° 40' N, 69° 58' W

max. temp. – 13.1 °C

mean temp. – 9.7 °C

min. temp. – 6.2 °C

precipitation – 118.6 cm/yr

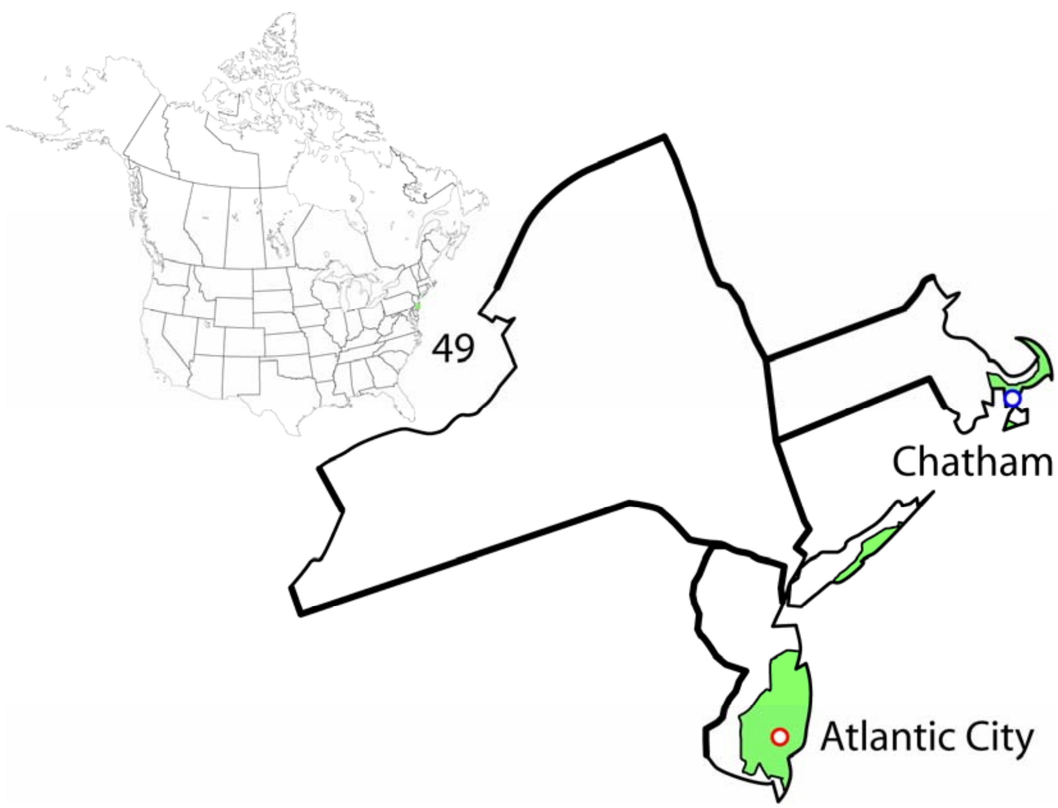


Figure I45. Atlantic Coastal Pine Barrens.

Atlantic City, New Jersey

Didelphis virginiana
Sorex cinereus
Blarina brevicauda
Cryptotis parva
Scalopus aquaticus
Condylura cristata
Myotis lucifugus
Myotis septentrionalis
Lasiurus borealis
Lasiurus cinereus
Lasionycteris noctivagans
Pipistrellus subflavus
Eptesicus fuscus
Sylvilagus floridanus
Sylvilagus obscurus
Tamias striatus
Marmota monax
Sciurus carolinensis
Tamiasciurus hudsonicus
Glaucomys volans
Castor canadensis
Peromyscus leucopus
Clethrionomys gapperi
Microtus pennsylvanicus
Microtus pinetorum
Ondatra zibethicus
Synaptomys cooperi
Zapus hudsonius
Erethizon dorsatum
Canis rufus
Vulpes vulpes
Urocyon cinereoargenteus
Ursus americanus
Procyon lotor
Mustela frenata
Mustela vison
Lontra canadensis
Mephitis mephitis
Puma concolor
Lynx rufus
Odocoileus virginianus

Chatham, Massachusetts

Didelphis virginiana
Sorex cinereus
Sorex fumeus
Blarina brevicauda
Parascalops breweri
Condylura cristata
Myotis lucifugus
Myotis septentrionalis
Lasiurus borealis
Lasiurus cinereus
Lasionycteris noctivagans
Pipistrellus subflavus
Eptesicus fuscus
Sylvilagus floridanus
Sylvilagus transitionalis
Tamias striatus
Marmota monax
Sciurus carolinensis
Tamiasciurus hudsonicus
Glaucomys volans
Castor canadensis
Peromyscus leucopus
Clethrionomys gapperi
Microtus pennsylvanicus
Microtus pinetorum
Ondatra zibethicus
Synaptomys cooperi
Zapus hudsonius
Erethizon dorsatum
Canis rufus
Canis lupus
Vulpes vulpes
Ursus americanus
Procyon lotor
Mustela erminea
Mustela frenata
Mustela vison
Lontra canadensis
Mephitis mephitis
Puma concolor
Lynx canadensis
Lynx rufus
Odocoileus virginianus

50. Middle Atlantic Coastal Forests

Charleston, South Carolina

32° 54’ N, 80° 02’ W

max. temp. – 24.4 °C

mean temp. – 18.5 °C

min. temp. – 12.6 °C

precipitation – 130.9 cm/yr

Williamston, North Carolina

35° 51’ N, 77° 02’ W

max. temp. – 21.8 °C

mean temp. – 15.9 °C

min. temp. – 9.9 °C

precipitation – 125.2 cm/yr

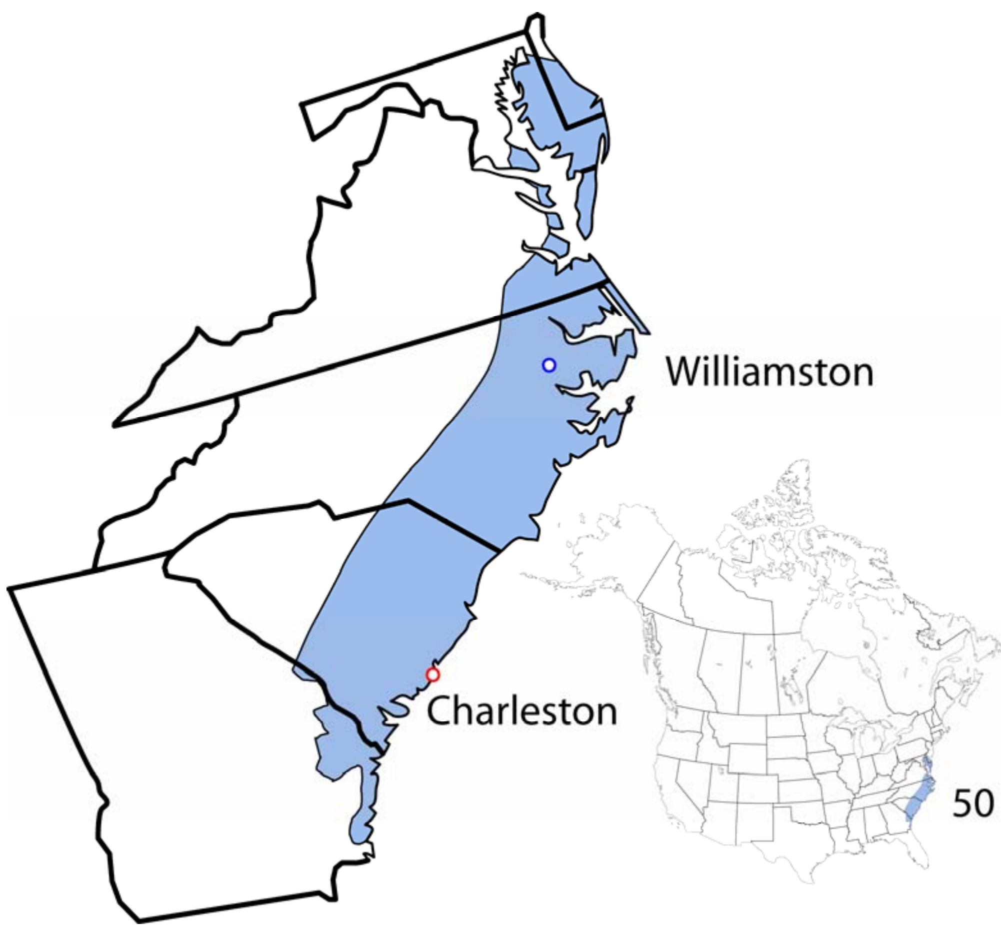


Figure I46. Middle Atlantic Coastal Forests.

Charleston, South Carolina

Didelphis virginiana
Sorex longirostris
Blarina carolinensis
Cryptotis parva
Scalopus aquaticus
Condylura cristata
Lasiurus borealis
Lasiurus cinereus
Lasiurus intermedius
Lasiurus seminolus
Lasionycteris noctivagans
Pipistrellus subflavus
Eptesicus fuscus
Nycticeius humeralis
Corynorhinus rafinesquii
Tadarida brasiliensis
Sylvilagus floridanus
Sylvilagus palustris
Sciurus carolinensis
Sciurus niger
Glaucomys volans
Castor canadensis
Oryzomys palustris
Reithrodontomys humulis
Peromyscus gossypinus
Ochrotomys nuttalli
Sigmodon hispidus
Neotoma floridana
Microtus pinetorum
Canis rufus
Vulpes vulpes
Urocyon cinereoargenteus
Ursus americanus
Procyon lotor
Mustela frenata
Mustela vison
Lontra canadensis
Mephitis mephitis
Puma concolor
Lynx rufus
Odocoileus virginianus

Williamston, North Carolina

Didelphis virginiana
Sorex longirostris
Blarina carolinensis
Cryptotis parva
Scalopus aquaticus
Condylura cristata
Lasiurus borealis
Lasiurus cinereus
Lasiurus seminolus
Lasiurus intermedius
Lasionycteris noctivagans
Pipistrellus subflavus
Eptesicus fuscus
Nycticeius humeralis
Corynorhinus rafinesquii
Sylvilagus floridanus
Sylvilagus palustris
Sciurus carolinensis
Glaucomys volans
Castor canadensis
Oryzomys palustris
Reithrodontomys humulis
Peromyscus gossypinus
Peromyscus leucopus
Ochrotomys nuttalli
Microtus pennsylvanicus
Microtus pinetorum
Ondatra zibethicus
Zapus hudsonius
Canis rufus
Urocyon cinereoargenteus
Ursus americanus
Procyon lotor
Mustela frenata
Mustela vison
Lontra canadensis
Mephitis mephitis
Puma concolor
Lynx rufus
Odocoileus virginianus

51. Southeastern Conifer Forests

Tallahassee, Florida

30° 24’ N, 84° 21’ W

max. temp. – 26.4 °C

mean temp. – 20.0 °C

min. temp. – 13.5 °C

precipitation – 160.6 cm/yr

Orlando, Florida

28° 26’ N, 81° 20’ W

max. temp. – 28.4 °C

mean temp. – 22.7 °C

min. temp. – 16.9 °C

precipitation – 122.8 cm/yr

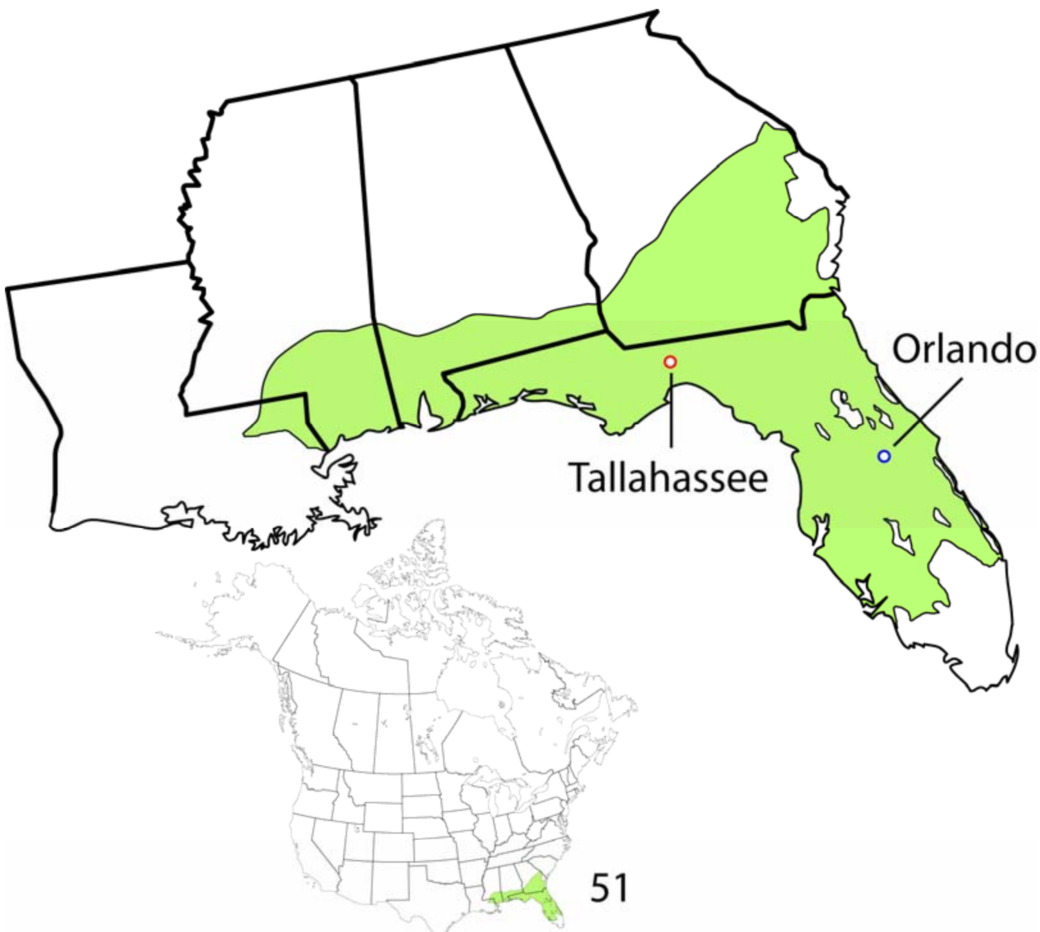


Figure I47. Southeastern Conifer Forests.

Tallahassee, Florida

Didelphis virginiana
Sorex longirostris
Blarina carolinensis
Cryptotis parva
Scalopus aquaticus
Myotis autroriparius
Myotis septentrionalis
Lasiurus borealis
Lasiurus cinereus
Lasiurus intermedius
Lasiurus seminolus
Pipistrellus subflavus
Eptesicus fuscus
Nycticeius humeralis
Corynorhinus rafinesquii
Tadarida brasiliensis
Sylvilagus floridanus
Sylvilagus palustris
Sciurus carolinensis
Sciurus niger
Glaucomys volans
Geomys pinetis
Castor canadensis
Oryzomys palustris
Reithrodontomys humulis
Peromyscus gossypinus
Peromyscus polionotus
Ochrotomys nuttalli
Sigmodon hispidus
Neotoma floridana
Canis rufus
Vulpes vulpes
Urocyon cinereoargenteus
Ursus americanus
Procyon lotor
Mustela frenata
Lontra canadensis
Spilogale putorius
Mephitis mephitis
Puma concolor
Lynx rufus
Odocoileus virginianus
Bos bison

Orlando, Florida

Didelphis virginiana
Sorex longirostris
Blarina carolinensis
Cryptotis parva
Scalopus aquaticus
Myotis autroriparius
Lasiurus cinereus
Lasiurus intermedius
Lasiurus seminolus
Pipistrellus subflavus
Eptesicus fuscus
Nycticeius humeralis
Corynorhinus rafinesquii
Tadarida brasiliensis
Sylvilagus floridanus
Sylvilagus palustris
Sciurus carolinensis
Sciurus niger
Glaucomys volans
Geomys pinetis
Oryzomys palustris
Reithrodontomys humulis
Peromyscus gossypinus
Peromyscus polionotus
Podomys floridanus
Ochrotomys nuttalli
Sigmodon hispidus
Neotoma floridana
Neofiber alleni
Canis rufus
Vulpes vulpes
Urocyon cinereoargenteus
Ursus americanus
Procyon lotor
Mustela frenata
Lontra canadensis
Spilogale putorius
Mephitis mephitis
Puma concolor
Lynx rufus
Odocoileus virginianus
Bos bison

52. Florida Sand Pine Scrub

Yellow Bluff, Florida (climate from Lisbon; 28° 52' N, 81° 47' W)

29° 17' N, 81° 39' W

max. temp. – 27.2 °C

mean temp. – 21.1 °C

min. temp. – 15.0 °C

precipitation – 123.4 cm/yr

Pompano Beach, Florida

26° 14' N, 80° 09' W

max. temp. – 29.2 °C

mean temp. – 24.4 °C

min. temp. – 19.7 °C

precipitation – 145.5 cm/yr

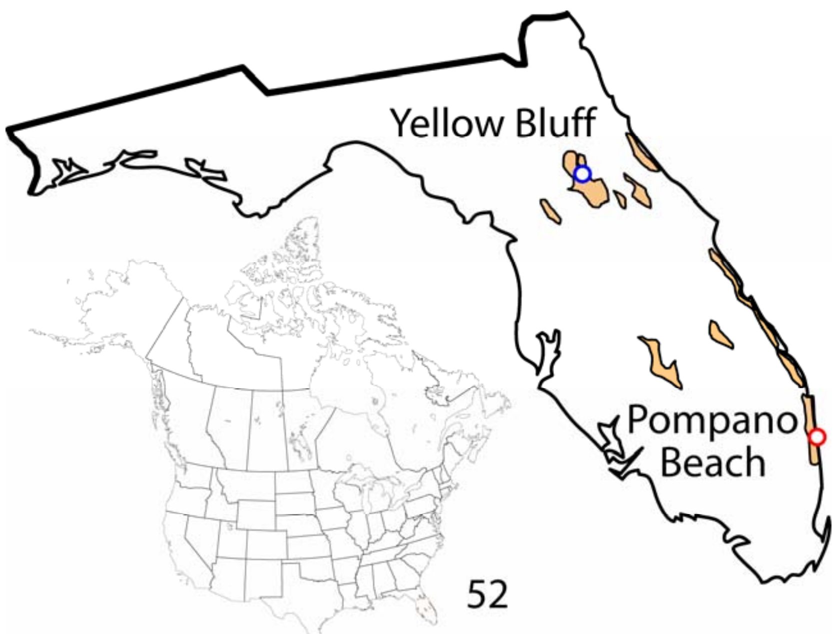


Figure I48. Florida Sand Pine Scrub.

Yellow Bluff, Florida

Didelphis virginiana
Sorex longirostris
Blarina carolinensis
Cryptotis parva
Scalopus aquaticus
Myotis autroriparius
Lasiurus cinereus
Lasiurus intermedius
Lasiurus seminolus
Pipistrellus subflavus
Eptesicus fuscus
Nycticeius humeralis
Corynorhinus rafinesquii
Tadarida brasiliensis
Sylvilagus floridanus
Sylvilagus palustris
Sciurus carolinensis
Sciurus niger
Glaucomys volans
Geomys pinetis
Oryzomys palustris
Reithrodontomys humulis
Peromyscus gossypinus
Podomys floridanus
Ochrotomys nuttalli
Sigmodon hispidus
Neotoma floridana
Microtus pinetorum
Neofiber alleni
Canis rufus
Vulpes vulpes
Urocyon cinereoargenteus
Ursus americanus
Procyon lotor
Mustela frenata
Lontra canadensis
Spilogale putorius
Mephitis mephitis
Puma concolor
Lynx rufus
Odocoileus virginianus
Bos bison

Pompano Beach, Florida

Didelphis virginiana
Blarina carolinensis
Cryptotis parva
Scalopus aquaticus
Lasiurus intermedius
Lasiurus seminolus
Nycticeius humeralis
Tadarida brasiliensis
Sylvilagus floridanus
Sylvilagus palustris
Sciurus carolinensis
Sciurus niger
Glaucomys volans
Oryzomys palustris
Reithrodontomys humulis
Peromyscus gossypinus
Podomys floridanus
Sigmodon hispidus
Neofiber alleni
Canis rufus
Vulpes vulpes
Urocyon cinereoargenteus
Ursus americanus
Procyon lotor
Lontra canadensis
Spilogale putorius
Mephitis mephitis
Puma concolor
Lynx rufus
Odocoileus virginianus

53. Palouse Grasslands

Chelan, Washington	Moscow, Idaho
47° 50’ N, 120° 03’ W	46° 43’ N, 116° 58’ W
max. temp. – 15.3 °C	max. temp. – 14.7 °C
mean temp. – 10.2 °C	mean temp. – 8.5 °C
min. temp. – 5.1 °C	min. temp. – 2.2 °C
precipitation – 28.8 cm/yr	precipitation – 69.5 cm/yr

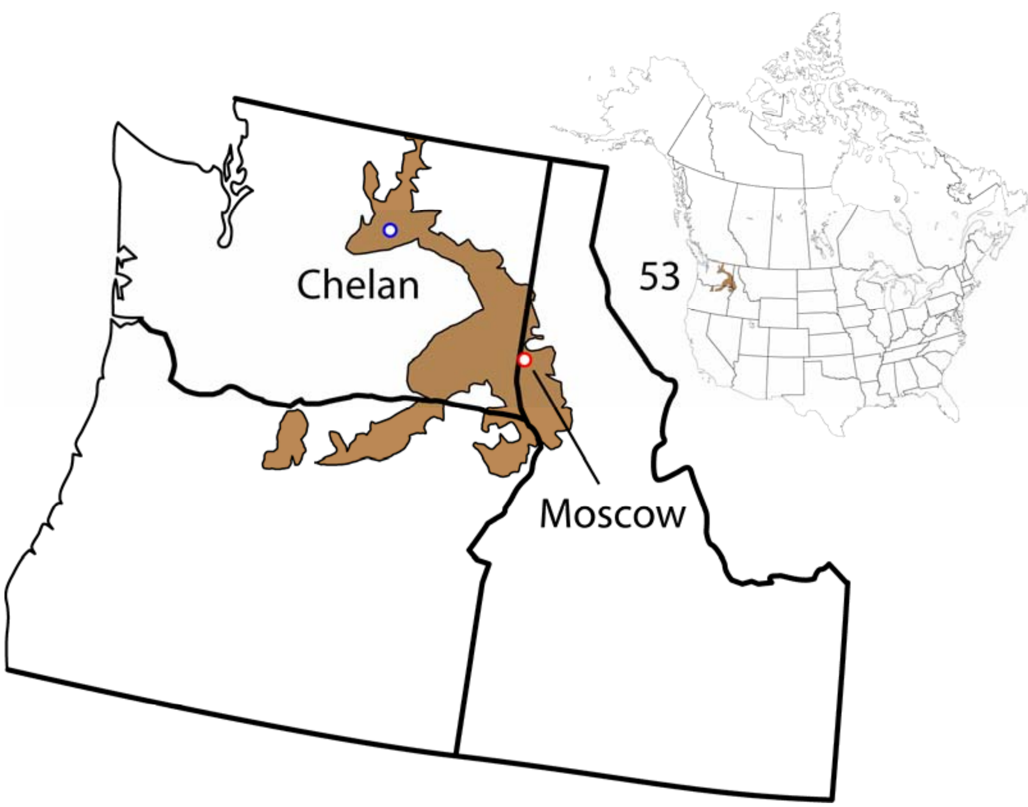


Figure I49. Palouse Grasslands.

Chelan, Washington

Sorex vagrans
Sorex cinereus
Sorex merriami
Scapanus orarius
Myotis lucifugus
Myotis californicus
Myotis ciliolabrum
Myotis yumanensis
Lasionycteris noctivagans
Eptesicus fuscus
Corynorhinus townsendii
Antrozous pallidus
Sylvilagus nuttallii
Lepus townsendii
Neotamias amoenus
Marmota flaviventris
Sciurus griseus
Tamiasciurus hudsonicus
Glaucomys sabrinus
Thomomys talpoides
Perognathus parvus
Castor canadensis
Reithrodontomys megalotis
Peromyscus maniculatus
Neotoma cinerea
Clethrionomys gapperi
Phenacomys intermedius
Microtus pennsylvanicus
Microtus montanus
Microtus longicaudus
Lemmiscus curtatus
Ondatra zibethicus
Erethizon dorsatum
Canis latrans
Ursus americanus
Procyon lotor
Mustela frenata
Mustela erminea
Taxidea taxus
Lontra canadensis
Mephitis mephitis
Puma concolor
Lynx rufus
Odocoileus hemionus

Moscow, Idaho

Sorex cinereus
Sorex vagrans
Sorex palustris
Myotis lucifugus
Myotis yumanensis
Myotis evotis
Myotis volans
Myotis californicus
Lasiurus cinereus
Lasionycteris noctivagans
Eptesicus fuscus
Corynorhinus townsendii
Sylvilagus nuttallii
Lepus americanus
Lepus townsendii
Neotamias amoenus
Marmota flaviventris
Spermophilus columbianus
Tamiasciurus hudsonicus
Glaucomys sabrinus
Thomomys talpoides
Perognathus parvus
Castor canadensis
Peromyscus maniculatus
Neotoma cinerea
Clethrionomys gapperi
Phenacomys intermedius
Microtus montanus
Microtus longicaudus
Microtus richardsoni
Ondatra zibethicus
Zapus princeps
Canis latrans
Canis lupus
Vulpes vulpes
Ursus americanus
Ursus arctos
Procyon lotor
Martes americanus
Martes pennanti
Mustela frenata
Mustela vison
Gulo gulo
Taxidea taxus
Lontra canadensis
Spilogale gracilis
Puma concolor
Lynx canadensis
Lynx rufus
Cervus canadensis
Odocoileus hemionus
Odocoileus virginianus
Alces alces
Rangifer tarandus
Oreamnos americanus
Ovis canadensis

54. California Central Valley Grasslands

Chico, California

39° 41’ N, 121° 49’ W

max. temp. – 23.3 °C

mean temp. – 15.8 °C

min. temp. – 8.4 °C

precipitation – 66.6 cm/yr

Fresno, California

36° 47’ N, 119° 43’ W

max. temp. – 24.1 °C

mean temp. – 17.3 °C

min. temp. – 10.6 °C

precipitation – 28.5 cm/yr

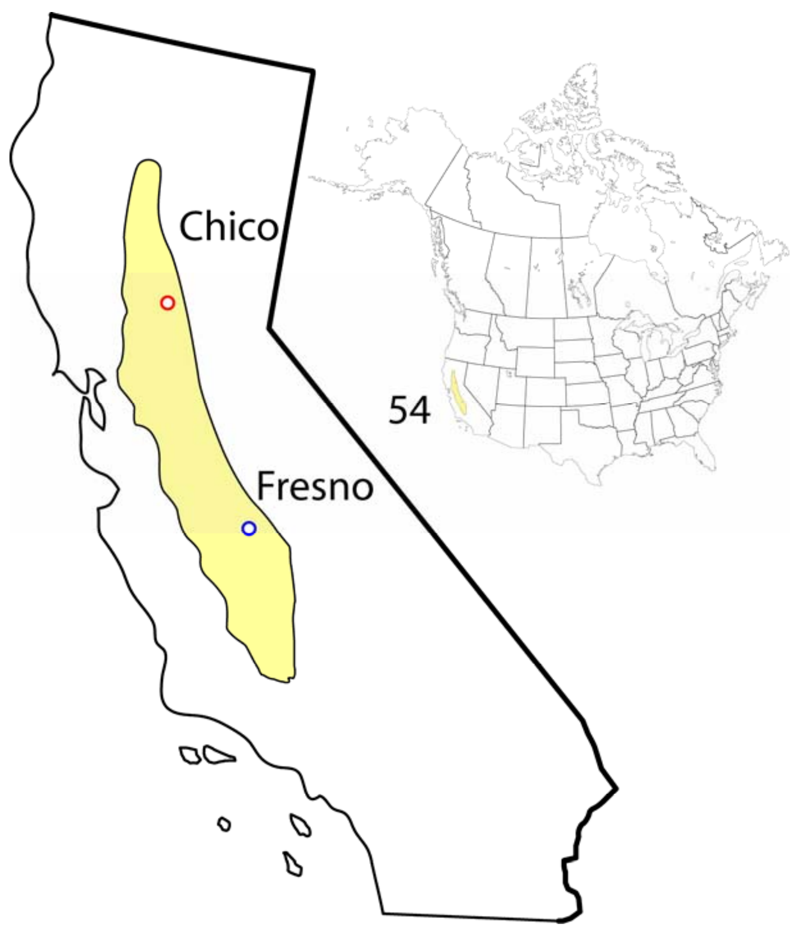


Figure I50. California Central Valley Grasslands.

Chico, California

Myotis californicus
Myotis ciliolabrum
Myotis yumanensis
Lasiurus cinereus
Lasiurus blossevillii
Eptesicus fuscus
Pipistrellus hesperus
Corynorhinus townsendii
Antrozous pallidus
Tadarida brasiliensis
Sylvilagus audubonii
Lepus californicus
Spermophilus beecheyi
Tamiasciurus douglasii
Thomomys bottae
Perognathus inornatus
Dipodomys californicus
Castor canadensis
Reithrodontomys megalotis
Peromyscus maniculatus
Microtus californicus
Erethizon dorsatum
Canis latrans
Vulpes vulpes
Urocyon cinereoargenteus
Procyon lotor
Mustela vison
Mustela frenata
Taxidea taxus
Lontra canadensis
Spilogale putorius
Mephitis mephitis
Puma concolor
Lynx rufus
Antilocapra americana

Fresno, California

Sorex ornatus
Myotis californicus
Myotis ciliolabrum
Myotis yumanensis
Lasiurus cinereus
Lasiurus blossevillii
Eptesicus fuscus
Pipistrellus hesperus
Corynorhinus townsendii
Antrozous pallidus
Tadarida brasiliensis
Sylvilagus audubonii
Lepus californicus
Ammospermophilus nelsoni
Spermophilus beecheyi
Thomomys bottae
Perognathus longimembris
Perognathus inornatus
Dipodomys heermanni
Dipodomys nitratoides
Castor canadensis
Reithrodontomys megalotis
Peromyscus maniculatus
Microtus californicus
Erethizon dorsatum
Canis latrans
Urocyon cinereoargenteus
Procyon lotor
Mustela vison
Mustela frenata
Taxidea taxus
Lontra canadensis
Spilogale putorius
Mephitis mephitis
Puma concolor
Lynx rufus
Antilocapra americana

55. Canadian Aspen Forests and Parklands

Edmonton, Alberta

53° 34’ N, 113° 31’ W

max. temp. – 9.0 °C

mean temp. – 3.9 °C

min. temp. – -1.2 °C

precipitation – 47.7 cm/yr

Moosomin, Saskatchewan

50° 07’ N, 101° 40’ W

max. temp. – 8.1 °C

mean temp. – 2.6 °C

min. temp. – -2.9 °C

precipitation – 51.1 cm/yr

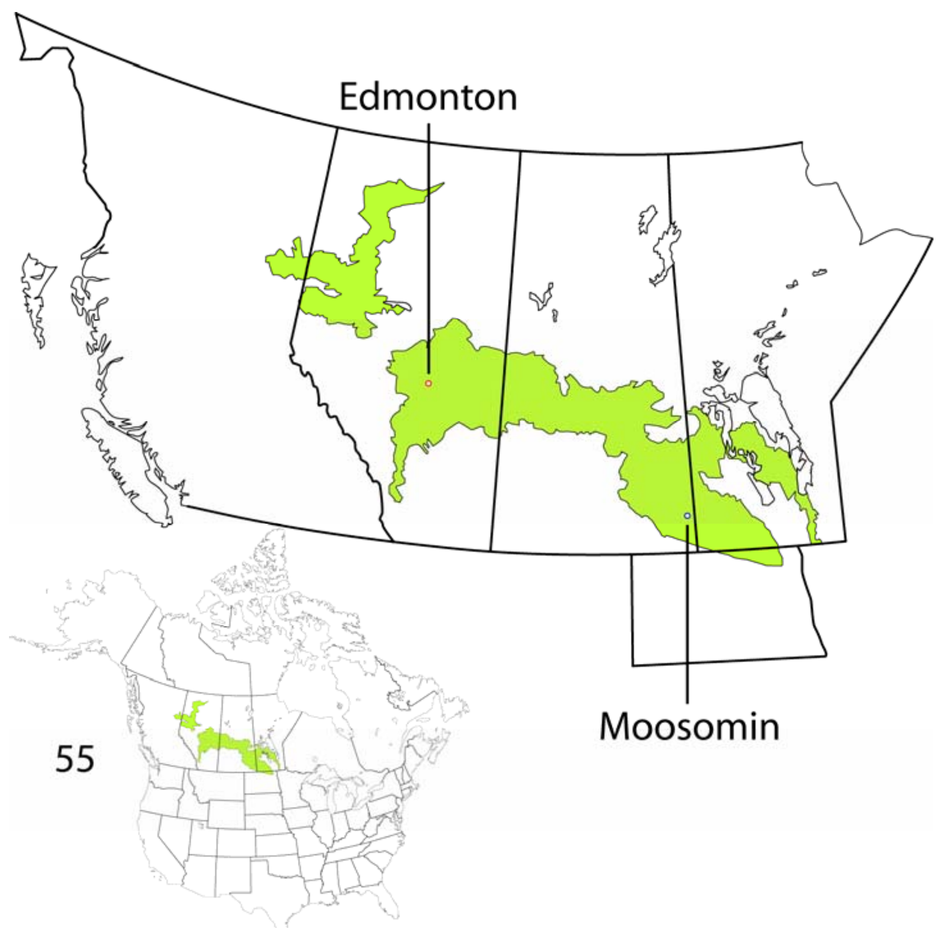


Figure I51. Canadian Aspen Forests and Parklands.

Edmonton, Alberta

Sorex cinereus
Sorex monticolus
Sorex arcticus
Myotis lucifugus
Myotis volans
Myotis septentrionalis
Lasiurus cinereus
Lasionycteris noctivagans
Eptesicus fuscus
Lepus americanus
Lepus townsendii
Neotamias minimus
Marmota monax
Spermophilus richardsonii
Spermophilus tridecemlineatus
Spermophilus franklinii
Glaucomys sabrinus
Thomomys talpoides
Castor canadensis
Peromyscus maniculatus
Clethrionomys gapperi
Phenacomys ungava
Microtus pennsylvanicus
Microtus ochrogaster
Ondatra zibethicus
Synaptomys borealis
Zapus hudsonius
Zapus princeps
Erethizon dorsatum
Canis latrans
Canis lupus
Ursus americanus
Ursus arctos
Procyon lotor
Mustela erminea
Mustela nivalis
Mustela frenata
Mustela vison
Gulo gulo
Taxidea taxus
Lontra canadensis
Mephitis mephitis
Lynx canadensis
Cervus canadensis
Odocoileus hemionus
Alces alces
Bos bison

Moosomin, Saskatchewan

Sorex cinereus
Sorex haydeni
Sorex arcticus
Blarina brevicauda
Myotis lucifugus
Myotis septentrionalis
Lasiurus borealis
Lasiurus cinereus
Lasionycteris noctivagans
Lepus americanus
Lepus townsendii
Neotamias minimus
Marmota monax
Spermophilus richardsonii
Spermophilus tridecemlineatus
Spermophilus franklinii
Thomomys talpoides
Castor canadensis
Peromyscus maniculatus
Onychomys leucogaster
Clethrionomys gapperi
Microtus pennsylvanicus
Microtus ochrogaster
Ondatra zibethicus
Zapus hudsonius
Zapus princeps
Erethizon dorsatum
Canis latrans
Canis lupus
Vulpes vulpes
Ursus americanus
Ursus arctos
Procyon lotor
Mustela erminea
Mustela nivalis
Mustela frenata
Mustela vison
Gulo gulo
Taxidea taxus
Lontra canadensis
Mephitis mephitis
Lynx canadensis
Cervus canadensis
Odocoileus hemionus
Odocoileus virginianus
Alces alces
Antilocapra americana
Bos bison

56. Northern Mixed Grasslands

Saskatoon, Saskatchewan

52° 10’ N, 106° 43’ W

max. temp. – 8.2 °C

mean temp. – 2.2 °C

min. temp. – -3.8 °C

precipitation – 35.0 cm/yr

Mohall, North Dakota

48° 46’ N, 101° 31’ W

max. temp. – 10.5 °C

mean temp. – 3.6 °C

min. temp. – -3.4 °C

precipitation – 44.3 cm/yr

Figure I52. Northern Mixed Grasslands.

Saskatoon, Saskatchewan

Sorex cinereus
Sorex haydeni
Sorex arcticus
Myotis lucifugus
Myotis septentrionalis
Lasiurus borealis
Lasiurus cinereus
Lasionycteris noctivagans
Eptesicus fuscus
Lepus americanus
Lepus townsendii
Neotamias minimus
Marmota monax
Spermophilus richardsonii
Spermophilus tridecemlineatus
Spermophilus franklinii
Thomomys talpoides
Castor canadensis
Peromyscus maniculatus
Onychomys leucogaster
Clethrionomys gapperi
Microtus pennsylvanicus
Microtus ochrogaster
Ondatra zibethicus
Zapus princeps
Erethizon dorsatum
Canis latrans
Canis lupus
Ursus americanus
Ursus arctos
Procyon lotor
Mustela nivalis
Mustela frenata
Mustela vison
Gulo gulo
Taxidea taxus
Lontra canadensis
Mephitis mephitis
Lynx canadensis
Cervus canadensis
Odocoileus hemionus
Odocoileus virginianus
Antilocapra americana
Bos bison

Mohall, North Dakota

Sorex cinereus
Sorex haydeni
Sorex arcticus
Blarina brevicauda
Myotis lucifugus
Myotis septentrionalis
Lasiurus borealis
Lasiurus cinereus
Lasionycteris noctivagans
Eptesicus fuscus
Sylvilagus floridanus
Lepus americanus
Lepus townsendii
Spermophilus richardsonii
Spermophilus tridecemlineatus
Spermophilus franklinii
Thomomys talpoides
Perognathus fasciatus
Castor canadensis
Peromyscus maniculatus
Peromyscus leucopus
Onychomys leucogaster
Clethrionomys gapperi
Microtus pennsylvanicus
Microtus ochrogaster
Ondatra zibethicus
Zapus hudsonius
Zapus princeps
Erethizon dorsatum
Canis latrans
Canis lupus
Vulpes vulpes
Vulpes velox
Urocyon cinereoargenteus
Ursus americanus
Ursus arctos
Procyon lotor
Mustela nivalis
Mustela frenata
Mustela vison
Gulo gulo
Taxidea taxus
Lontra canadensis
Mephitis mephitis
Lynx canadensis
Lynx rufus
Cervus canadensis
Odocoileus hemionus
Odocoileus virginianus
Alces alces
Antilocapra americana
Bos bison

57. Montane Valley and Foothills Grasslands

Dillon, Montana	Great Falls, Montana
45° 13' N, 112° 39' W	47° 28' N, 111° 23' W
max. temp. – 13.4 °C	max. temp. – 13.6 °C
mean temp. – 10.8 °C	mean temp. – 6.5 °C
min. temp. – 5.7 °C	min. temp. – -0.5 °C
precipitation – 100.5 cm/yr	precipitation – 37.8 cm/yr

Figure I53. Montane Valley and Foothills Grasslands.

Dillon, Montana

Sorex cinereus
Sorex monticolus
Sorex palustris
Myotis lucifugus
Myotis yumanensis
Myotis evotis
Myotis volans
Lasiurus cinereus
Lasionycteris noctivagans
Eptesicus fuscus
Euderma maculatum
Sylvilagus idahoensis
Sylvilagus nuttallii
Lepus americanus
Neotamias minimus
Neotamias amoenus
Marmota flaviventris
Spermophilus elegans
Spermophilus armatus
Spermophilus lateralis
Tamiasciurus hudsonicus
Glaucomys sabrinus
Thomomys talpoides
Castor canadensis
Peromyscus maniculatus
Neotoma cinerea
Clethrionomys gapperi
Phenacomys intermedius
Microtus pennsylvanicus
Microtus montanus
Microtus longicaudus
Microtus richardsoni
Lemmiscus curtatus
Ondatra zibethicus
Zapus princeps
Erethizon dorsatum
Canis latrans
Canis lupus
Vulpes vulpes
Ursus americanus
Ursus arctos
Martes americana
Martes pennanti
Mustela erminea
Mustela frenata
Mustela vison
Gulo gulo
Taxidea taxus
Lontra canadensis
Mephitis mephitis
Puma concolor
Lynx canadensis
Lynx rufus
Cervus canadensis
Odocoileus hemionus
Odocoileus virginianus
Alces alces
Antilocapra americana
Bos bison
Ovis canadensis

Great Falls, Montana

Lasiurus cinereus
Eptesicus fuscus
Ochotona princeps
Sylvilagus nuttallii
Sylvilagus audubonii
Lepus americanus
Lepus townsendii
Neotamias minimus
Neotamias amoenus
Marmota flaviventris
Spermophilus richardsonii
Spermophilus columbianus
Cynomys ludovicianus
Tamiasciurus hudsonicus
Thomomys talpoides
Castor canadensis
Peromyscus maniculatus
Onychomys leucogaster
Neotoma cinerea
Clethrionomys gapperi
Phenacomys intermedius
Microtus pennsylvanicus
Microtus longicaudus
Lemmiscus curtatus
Ondatra zibethicus
Zapus princeps
Erethizon dorsatum
Canis latrans
Canis lupus
Vulpes velox
Ursus americanus
Ursus arctos
Mustela erminea
Mustela frenata
Mustela nigripes
Mustela vison
Gulo gulo
Taxidea taxus
Lontra canadensis
Mephitis mephitis
Puma concolor
Lynx canadensis
Lynx rufus
Cervus canadensis
Odocoileus hemionus
Odocoileus virginianus
Alces alces
Antilocapra americana
Bos bison
Ovis canadensis

58. Northwestern Mixed Grasslands

Wolf Point, Montana

48° 06’ N, 105° 39’ W

max. temp. – 14.4 °C

mean temp. – 6.7 °C

min. temp. – -1.1 °C

precipitation – 28.2 cm/yr

Pierre, South Dakota

44° 23’ N, 100° 17’ W

max. temp. – 15.2 °C

mean temp. – 8.6 °C

min. temp. – 1.9 °C

precipitation – 50.5 cm/yr

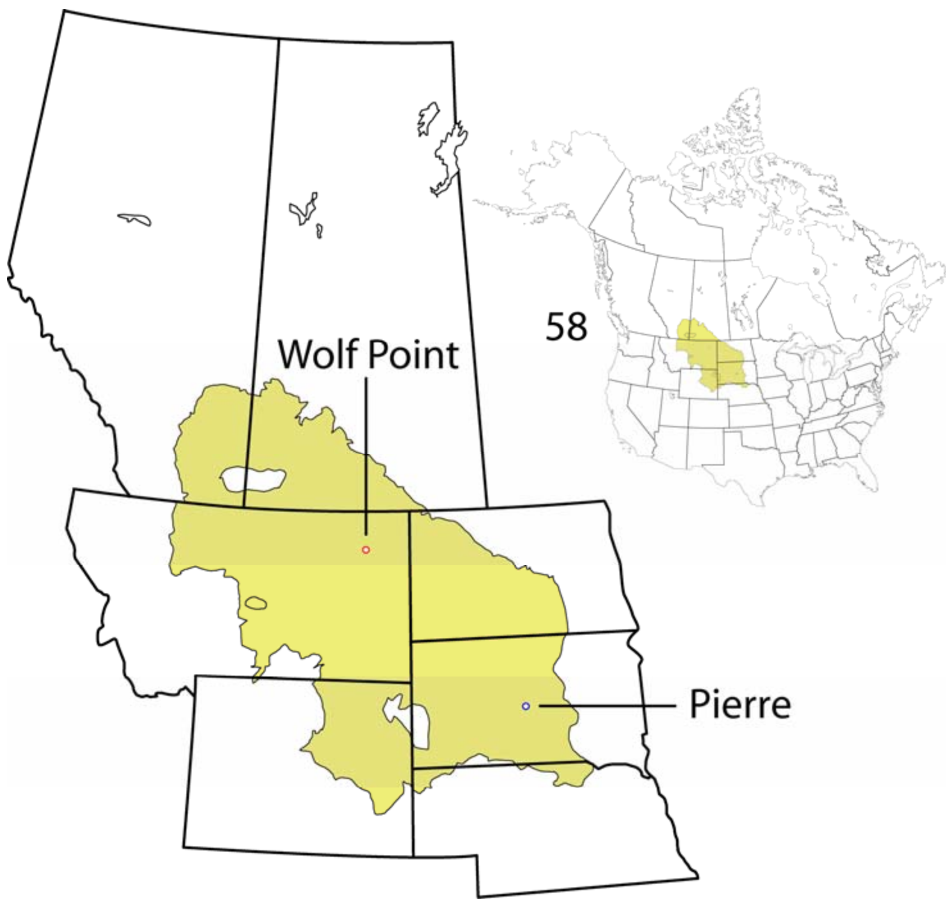


Figure I54. Northwestern Mixed Grasslands.

Wolf Point, Montana

Sorex cinereus
Sorex haydeni
Myotis lucifugus
Myotis evotis
Lasiurus borealis
Lasiurus cinereus
Lasionycteris noctivagans
Eptesicus fuscus
Sylvilagus nuttallii
Sylvilagus audubonii
Lepus americanus
Lepus townsendii
Neotamias minimus
Spermophilus richardsonii
Spermophilus tridecemlineatus
Cynomys ludovicianus
Thomomys talpoides
Perognathus fasciatus
Dipodomys ordii
Castor canadensis
Reithrodontomys megalotis
Peromyscus maniculatus
Peromyscus leucopus
Onychomys leucogaster
Neotoma cinerea
Clethrionomys gapperi
Microtus pennsylvanicus
Microtus ochrogaster
Lemmiscus curtatus
Ondatra zibethicus
Zapus princeps
Erethizon dorsatum
Canis latrans
Canis lupus
Vulpes velox
Ursus americanus
Ursus arctos
Mustela nivalis
Mustela frenata
Mustela nigripes
Mustela vison
Gulo gulo
Taxidea taxus
Lontra canadensis
Mephitis mephitis
Puma concolor
Lynx canadensis
Lynx rufus
Cervus canadensis
Odocoileus hemionus
Odocoileus virginianus
Antilocapra americana
Bos bison
Ovis canadensis

Pierre, South Dakota

Sorex cinereus
Sorex haydeni
Blarina brevicauda
Cryptotis parva
Myotis lucifugus
Lasiurus borealis
Lasiurus cinereus
Lasionycteris noctivagans
Eptesicus fuscus
Sylvilagus floridanus
Lepus townsendii
Spermophilus tridecemlineatus
Cynomys ludovicianus
Thomomys talpoides
Perognathus fasciatus
Perognatus flavescens
Chaetodipus hispidus
Castor canadensis
Reithrodontomys megalotis
Peromyscus maniculatus
Peromyscus leucopus
Onychomys leucogaster
Microtus pennsylvanicus
Microtus ochrogaster
Ondatra zibethicus
Erethizon dorsatum
Canis latrans
Canis lupus
Vulpes vulpes
Vulpes velox
Ursus americanus
Ursus arctos
Procyon lotor
Mustela nivalis
Mustela frenata
Mustela nigripes
Mustela vison
Taxidea taxus
Lontra canadensis
Spilogale putorius
Mephitis mephitis
Puma concolor
Lynx rufus
Cervus canadensis
Odocoileus hemionus
Odocoileus virginianus
Antilocapra americana
Bos bison

59. Northern Tall Grasslands

Winnipeg, Manitoba

49° 55’ N, 97° 13’ W

max. temp. – 8.3 °C

mean temp. – 2.6 °C

min. temp. – -3.1 °C

precipitation – 51.4 cm/yr

Grand Forks, North Dakota

47° 57’ N, 97° 11’ W

max. temp. – 10.7 °C

mean temp. – 4.6 °C

min. temp. – -1.4 °C

precipitation – 49.8 cm/yr

Figure I55. Northern Tall Grasslands.

Winnipeg, Manitoba

Sorex cinereus
Sorex palustris
Sorex arcticus
Blarina brevicauda
Condylura cristata
Myotis lucifugus
Myotis septentrionalis
Lasiurus borealis
Lasiurus cinereus
Lasionycteris noctivagans
Eptesicus fuscus
Lepus americanus
Lepus townsendii
Tamias striatus
Neotamias minimus
Marmota monax
Spermophilus franklinii
Sciurus carolinensis
Tamiasciurus hudsonicus
Glaucomys sabrinus
Thomomys talpoides
Castor canadensis
Peromyscus maniculatus
Clethrionomys gapperi
Microtus pennsylvanicus
Microtus ochrogaster
Ondatra zibethicus
Synaptomys borealis
Zapus hudsonius
Napaeozapus insignis
Erethizon dorsatum
Canis latrans
Canis lupus
Vulpes vulpes
Ursus americanus
Ursus arctos
Procyon lotor
Martes americana
Martes pennanti
Mustela erminea
Mustela nivalis
Mustela vison
Gulo gulo
Taxidea taxus
Lontra canadensis
Mephitis mephitis
Lynx canadensis
Lynx rufus
Cervus canadensis
Odocoileus hemionus
Odocoileus virginianus
Alces alces
Rangifer tarandus
Bos bison

Grand Forks, North Dakota

Sorex cinereus
Sorex haydeni
Sorex palustris
Sorex arcticus
Blarina brevicauda
Condylura cristata
Myotis septentrionalis
Myotis lucifugus
Lasiurus borealis
Lasiurus cinereus
Lasionycteris noctivagans
Eptesicus fuscus
Sylvilagus floridanus
Lepus americanus
Lepus townsendii
Tamias striatus
Marmota monax
Spermophilus richardsonii
Spermophilus tridecemlineatus
Spermophilus franklinii
Sciurus carolinensis
Sciurus niger
Tamiasciurus hudsonicus
Glaucomys sabrinus
Thomomys talpoides
Geomys bursarius
Castor canadensis
Peromyscus maniculatus
Peromyscus leucopus
Onychomys leucogaster
Clethrionomys gapperi
Microtus pennsylvanicus
Microtus ochrogaster
Ondatra zibethicus
Synaptomys cooperi
Zapus hudsonius
Zapus princeps
Erethizon dorsatum
Canis latrans
Canis lupus
Vulpes vulpes
Vulpes velox
Urocyon cinereoargenteus
Ursus americanus
Ursus arctos
Procyon lotor
Martes americana
Martes pennanti
Mustela erminea
Mustela nivalis
Mustela frenata
Mustela vison
Gulo gulo
Taxidea taxus
Lontra canadensis
Mephitis mephitis
Lynx canadensis
Lynx rufus
Cervus canadensis
Odocoileus hemionus
Odocoileus virginianus
Alces alces
Rangifer tarandus
Antilocapra americana
Bos bison

60. Central Tall Grasslands

Marshall, Minnesota

44° 28’ N, 95° 47’ W

max. temp. – 13.7 °C

mean temp. – 7.9 °C

min. temp. – 2.1 °C

precipitation – 65.4 cm/yr

Iowa Falls, Iowa

42° 31’ N, 93° 15’ W

max. temp. – 13.9 °C

mean temp. – 7.9 °C

min. temp. – 1.9 °C

precipitation – 88.7 cm/yr

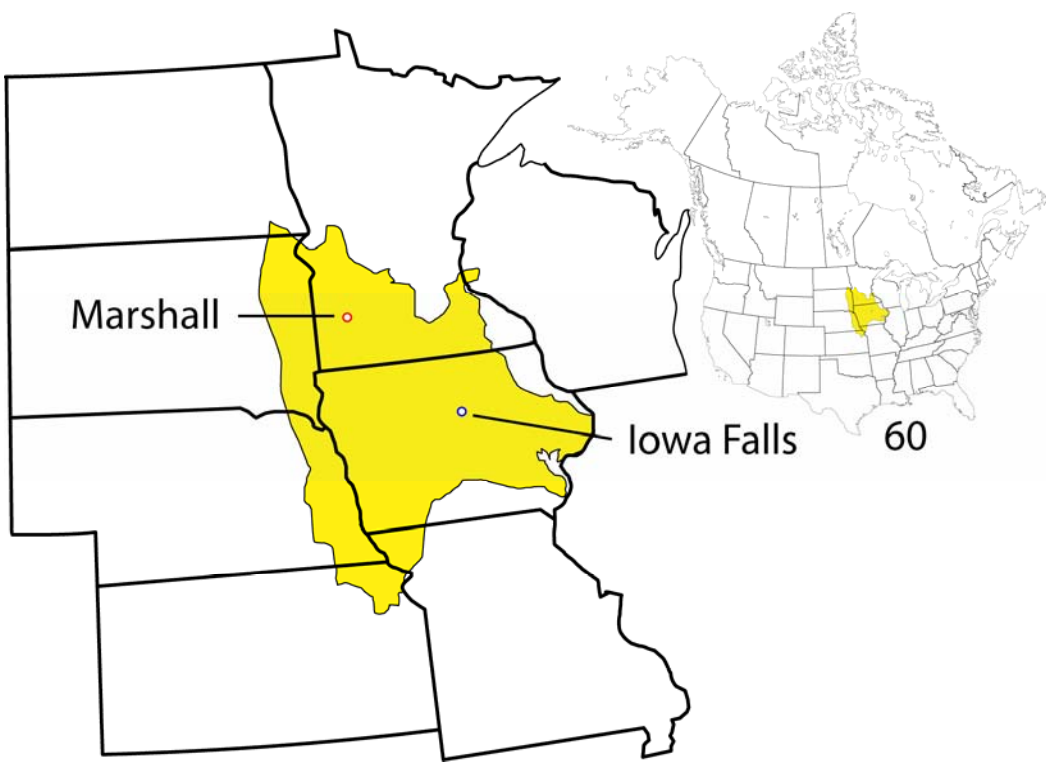


Figure I56. Central Tall Grasslands.

Marshall, Minnesota

Didelphis virginiana
Sorex cinereus
Sorex haydeni
Sorex arcticus
Blarina brevicauda
Myotis lucifugus
Myotis septentrionalis
Lasiurus borealis
Lasiurus cinereus
Lasionycteris noctivagans
Eptesicus fuscus
Sylvilagus floridanus
Lepus townsendii
Marmota monax
Spermophilus tridecemlineatus
Spermophilus franklinii
Sciurus niger
Tamiasciurus hudsonicus
Geomys bursarius
Perognatus flavescens
Castor canadensis
Reithrodontomys megalotis
Peromyscus maniculatus
Peromyscus leucopus
Onychomys leucogaster
Clethrionomys gapperi
Microtus pennsylvanicus
Microtus ochrogaster
Ondatra zibethicus
Synaptomys cooperi
Zapus hudsonius
Erethizon dorsatum
Canis latrans
Canis lupus
Vulpes vulpes
Urocyon cinereoargenteus
Ursus americanus
Procyon lotor
Mustela erminea
Mustela nivalis
Mustela frenata
Mustela vison
Taxidea taxus
Lontra canadensis
Spilogale putorius
Mephitis mephitis
Puma concolor
Lynx canadensis
Lynx rufus
Cervus canadensis
Odocoileus hemionus
Odocoileus virginianus
Antilocapra americanua
Bos bison

Iowa Falls, Iowa

Didelphis virginiana
Sorex cinereus
Blarina brevicauda
Cryptotis parva
Scalopus aquaticus
Myotis lucifugus
Myotis septentrionalis
Myotis ciliolabrum
Lasiurus cinereus
Lasiurus borealis
Lasionycteris noctivagans
Pipistrellus sublflavus
Eptesicus fuscus
Sylvilagus floridanus
Lepus townsendii
Marmota monax
Spermophilus tridecemlineatus
Spermophilus franklinii
Sciurus carolinensis
Sciurus niger
Tamiasciurus hudsonicus
Glaucomys volans
Geomys bursarius
Perognatus flavescens
Castor canadensis
Reithrodontomys megalotis
Peromyscus maniculatus
Peromyscus leucopus
Microtus pennsylvanicus
Microtus ochrogaster
Microtus pinetorum
Ondatra zibethicus
Synaptomys cooperi
Zapus hudsonius
Erethizon dorsatum
Canis latrans
Canis lupus
Vulpes vulpes
Urocyon cinereoargenteus
Ursus americanus
Procyon lotor
Mustela nivalis
Mustela frenata
Mustela vison
Taxidea taxus
Lontra canadensis
Spilogale putorius
Mephitis mephitis
Puma concolor
Lynx canadensis
Lynx rufus
Cervus canadensis
Odocoileus virginianus
Bos bison

61. Flint Hills Tall Grasslands

El Dorado, Kansas

37° 49’ N, 96° 51’ W

max. temp. – 19.6 °C

mean temp. – 13.1 °C

min. temp. – 6.5 °C

precipitation – 90.2 cm/yr

Manhattan, Kansas

39° 13’ N, 96° 36’ W

max. temp. – 19.7 °C

mean temp. – 12.7 °C

min. temp. – 5.7 °C

precipitation – 88.4 cm/yr

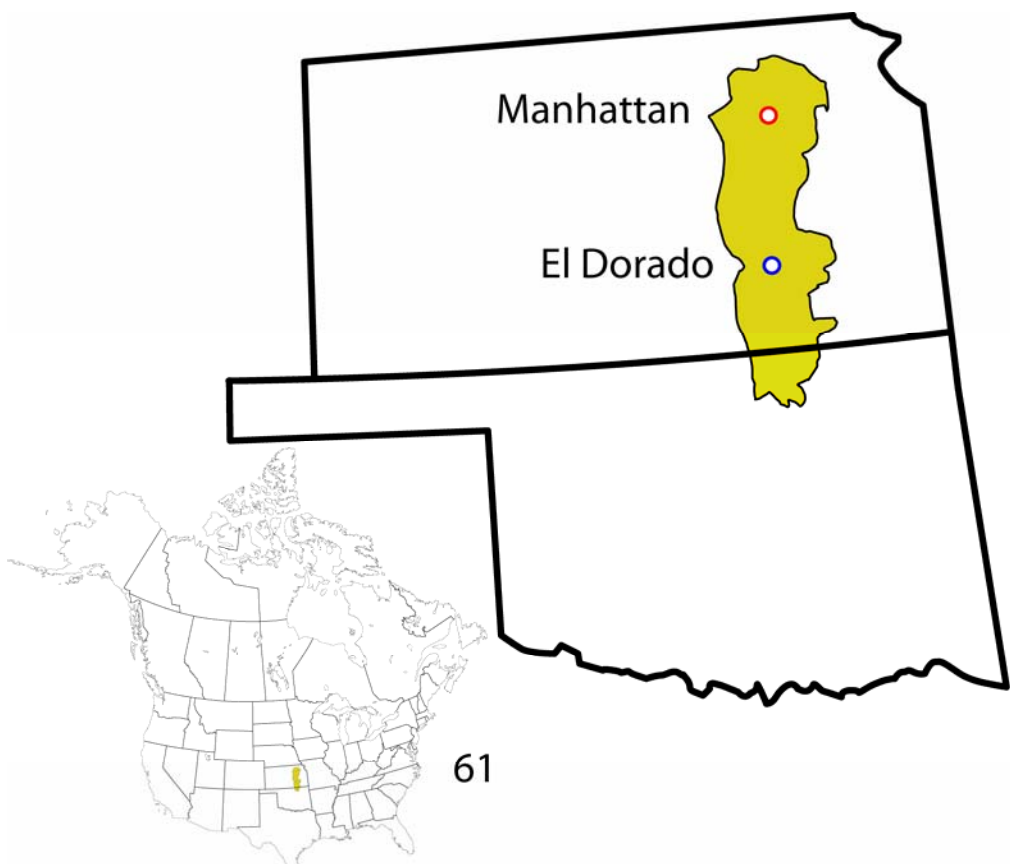


Figure I57. Flint Hills Tall Grasslands.

El Dorado, Kansas

Didelphis virginiana
Blarina hylophaga
Cryptotis parva
Scalopus aquaticus
Myotis lucifugus
Myotis septentrionalis
Myotis ciliolabrum
Lasiurus borealis
Lasiurus cinereus
Lasionycteris noctivagans
Pipistrellus subflavus
Eptesicus fuscus
Nycticeius humeralis
Tadarida brasiliensis
Sylvilagus floridanus
Lepus californicus
Marmota monax
Spermophilus tridecemlineatus
Spermophilus franklinii
Sciurus carolinensis
Sciurus niger
Geomys bursarius
Chaetodipus hispidus
Castor canadensis
Reithrodontomys montanus
Reithrodontomys megalotis
Peromyscus maniculatus
Peromyscus leucopus
Onychomys leucogaster
Sigmodon hispidus
Microtus ochrogaster
Microtus pinetorum
Ondatra zibethicus
Synaptomys cooperi
Zapus hudsonius
Erethizon dorsatum
Canis latrans
Canis lupus
Vulpes vulpes
Urocyon cinereoargenteus
Ursus americanus
Ursus arctos
Bassariscus astutus
Procyon lotor
Mustela frenata
Mustela vison
Taxidea taxus
Lontra canadensis
Spilogale putorius
Mephitis mephitis
Puma concolor
Lynx rufus
Cervus canadensis
Odocoileus virginianus
Bos bison

Manhattan, Kansas

Didelphis virginiana
Blarina hylophaga
Cryptotis parva
Scalopus aquaticus
Myotis lucifugus
Myotis ciliolabrum
Lasiurus borealis
Lasiurus cinereus
Lasionycteris noctivagans
Pipistrellus subflavus
Eptesicus fuscus
Tadarida brasiliensis
Sylvilagus floridanus
Lepus californicus
Marmota monax
Spermophilus tridecemlineatus
Spermophilus franklinii
Sciurus carolinensis
Sciurus niger
Geomys bursarius
Chaetodipus hispidus
Castor canadensis
Reithrodontomys montanus
Reithrodontomys megalotis
Peromyscus maniculatus
Peromyscus leucopus
Onychomys leucogaster
Sigmodon hispidus
Microtus ochrogaster
Microtus pinetorum
Ondatra zibethicus
Synaptomys cooperi
Zapus hudsonius
Erethizon dorsatum
Canis latrans
Canis lupus
Vulpes vulpes
Urocyon cinereoargenteus
Ursus americanus
Ursus arctos
Procyon lotor
Mustela frenata
Mustela vison
Taxidea taxus
Lontra canadensis
Spilogale putorius
Mephitis mephitis
Puma concolor
Lynx rufus
Cervus canadensis
Odocoileus virginianus
Bos bison

62. Nebraska Sand Hills Mixed Grasslands

Mullen, Nebraska

42° 03’ N, 101° 03’ W

max. temp. – 17.0 °C

mean temp. – 9.4 °C

min. temp. – 1.8 °C

precipitation – 54.4 cm/yr

Burwell, Nebraska

41° 47’ N, 99° 09’ W

max. temp. – 16.1 °C

mean temp. – 8.7 °C

min. temp. – 1.3 °C

precipitation – 60.1 cm/yr

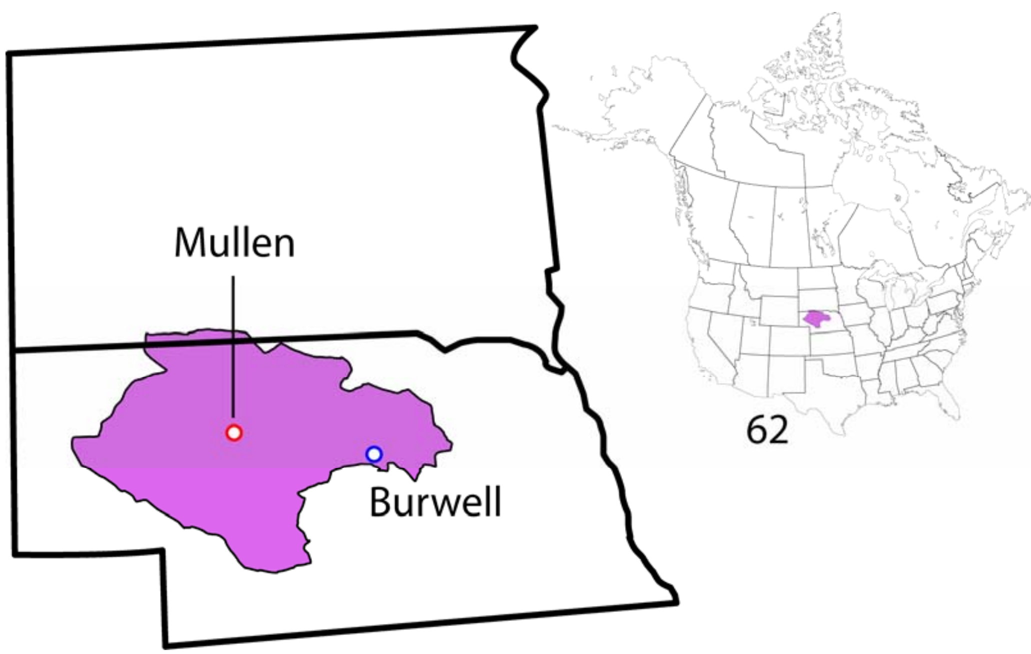


Figure I58. Nebraska Sand Hills Mixed Grasslands.

Mullen, Nebraska

Didelphis virginiana
Sorex cinereus
Sorex haydeni
Blarina brevicauda
Cryptotis parva
Scalopus aquaticus
Myotis lucifugus
Myotis ciliolabrum
Lasiurus borealis
Lasiurus cinereus
Lasionycteris noctivagans
Eptesicus fuscus
Sylvilagus floridanus
Lepus townsendii
Lepus californicus
Spermophilus tridecemlineatus
Spermophilus spilosoma
Cynomys ludovicianus
Sciurus niger
Geomys bursarius
Perognatus flavescens
Perognathus flavus
Chaetodipus hispidus
Dipodomys ordii
Castor canadensis
Reithrodontomys montanus
Reithrodontomys megalotis
Peromyscus maniculatus
Peromyscus leucopus
Onychomys leucogaster
Microtus pennsylvanicus
Microtus ochrogaster
Ondatra zibethicus
Synaptomys cooperi
Zapus hudsonius
Erethizon dorsatum
Canis latrans
Canis lupus
Vulpes velox
Ursus americanus
Ursus arctos
Procyon lotor
Mustela nivalis
Mustela frenata
Mustela nigripes
Mustela vison
Taxidea taxus
Lontra canadensis
Spilogale putorius
Mephitis mephitis
Puma concolor
Lynx rufus
Cervus canadensis
Odocoileus hemionus
Odocoileus virginianus
Antilocapra americana
Bos bison

Burwell, Nebraska

Didelphis virginiana
Sorex cinereus
Sorex haydeni
Blarina brevicauda
Cryptotis parva
Scalopus aquaticus
Myotis lucifugus
Myotis ciliolabrum
Lasiurus borealis
Lasiurus cinereus
Lasionycteris noctivagans
Eptesicus fuscus
Sylvilagus floridanus
Lepus townsendii
Lepus californicus
Spermophilus tridecemlineatus
Spermophilus spilosoma
Spermophilus franklinii
Cynomys ludovicianus
Sciurus niger
Geomys bursarius
Perognatus flavescens
Chaetodipus hispidus
Dipodomys ordii
Castor canadensis
Reithrodontomys montanus
Reithrodontomys megalotis
Peromyscus maniculatus
Peromyscus leucopus
Onychomys leucogaster
Microtus pennsylvanicus
Microtus ochrogaster
Ondatra zibethicus
Synaptomys cooperi
Zapus hudsonius
Erethizon dorsatum
Canis latrans
Canis lupus
Vulpes vulpes
Vulpes velox
Ursus americanus
Ursus arctos
Procyon lotor
Mustela nivalis
Mustela frenata
Mustela nigripes
Mustela vison
Taxidea taxus
Lontra canadensis
Spilogale putorius
Mephitis mephitis
Puma concolor
Lynx rufus
Cervus canadensis
Odocoileus hemionus
Odocoileus virginianus
Antilocapra americana
Bos bison

63. Western Short Grasslands

Sterling, Colorado

40° 37’ N, 103° 13’ W

max. temp. – 18.0 °C

mean temp. – 9.9 °C

min. temp. – 1.8 °C

precipitation – 41.4 cm/yr

Amarillo, Texas

35° 13’ N, 101° 42’ W

max. temp. – 21.3 °C

mean temp. – 13.9 °C

min. temp. – 6.4 °C

precipitation – 50.1 cm/yr

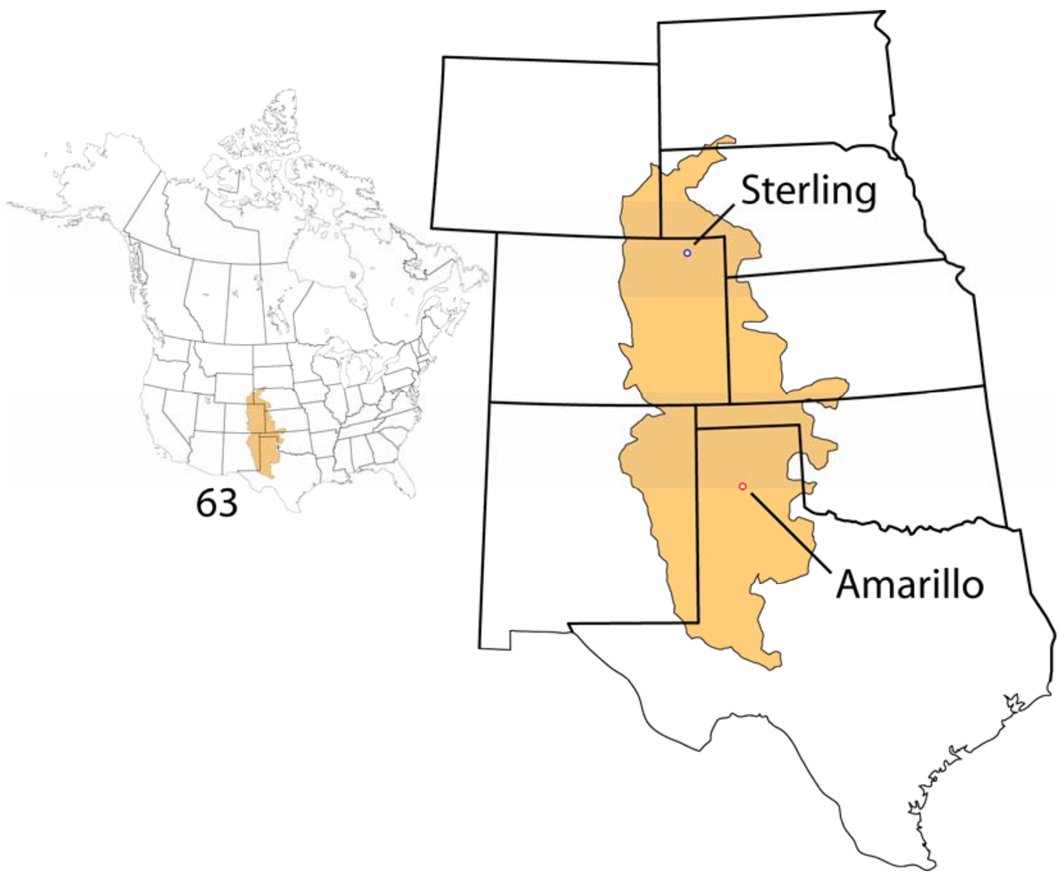


Figure I59. Western Short Grasslands.

Sterling, Colorado

Didelphis virginiana
Scalopus aquaticus
Myotis lucifugus
Myotis ciliolabrum
Lasiurus borealis
Lasiurus cinereus
Lasionycteris noctivagans
Eptesicus fuscus
Sylvilagus floridanus
Sylvilagus audubonii
Lepus townsendii
Lepus californicus
Spermophilus tridecemlineatus
Spermophilus spilosoma
Cynomys ludovicianus
Sciurus niger
Geomys bursarius
Perognatus flavescens
Perognathus flavus
Chaetodipus hispidus
Dipodomys ordii
Castor canadensis
Reithrodontomys montanus
Reithrodontomys megalotis
Peromyscus maniculatus
Onychomys leucogaster
Microtus pennsylvanicus
Microtus ochrogaster
Ondatra zibethicus
Erethizon dorsatum
Canis latrans
Canis lupus
Vulpes velox
Ursus americanus
Ursus arctos
Procyon lotor
Mustela frenata
Mustela nigripes
Mustela vison
Taxidea taxus
Lontra canadensis
Spilogale putorius
Mephitis mephitis
Puma concolor
Lynx rufus
Cervus canadensis
Odocoileus hemionus
Odocoileus virginianus
Antilocapra americana
Bos bison

Amarillo, Texas

Didelphis virginiana
Cryptotis parva
Notiosorex crawfordi
Scalopus aquaticus
Myotis velifer
Lasiurus borealis
Lasiurus cinereus
Lasionycteris noctivagans
Pipistrellus hesperus
Eptesicus fuscus
Corynorhinus townsendii
Antrozous pallidus
Tadarida brasiliensis
Nyctinomops macrotis
Sylvilagus floridanus
Lepus californicus
Spermophilus spilosoma
Spermophilus tridecemlineatus
Cynomys ludovicianus
Sciurus niger
Geomys bursarius
Cratogeomys castanops
Perognathus flavescens
Perognathus merriami
Chaetodipus hispidus
Dipodomys ordii
Castor canadensis
Reithrodontomys megalotis
Reithrodontomys montanus
Peromyscus boylii
Peromyscus leucopus
Peromyscus maniculatus
Baiomys taylori
Onychomys leucogaster
Sigmodon hispidus
Neotoma leucodon
Neotoma micropus
Erethizon dorsatum
Canis latrans
Canis lupus
Vulpes velox
Vulpes vulpes
Urocyon cinereoargenteus
Ursus americanus
Bassariscus astutus
Procyon lotor
Mustela nigripes
Taxidea taxus
Spilogale putorius
Mephitis mephitis
Puma concolor
Lynx rufus
Odocoileus hemionus
Odocoileus virginianus
Antilocapra americana
Bos bison

64. Central and Southern Mixed Grasslands

Hays, Kansas

38° 52' N, 99° 20' W

max. temp. – 19.1 °C

mean temp. – 11.9 °C

min. temp. – 4.4 °C

precipitation – 57.5 cm/yr

Altus, Oklahoma

34° 35' N, 99° 20' W

max. temp. – 23.7 °C

mean temp. – 16.2 °C

min. temp. – 8.7 °C

precipitation – 74.1 cm/yr

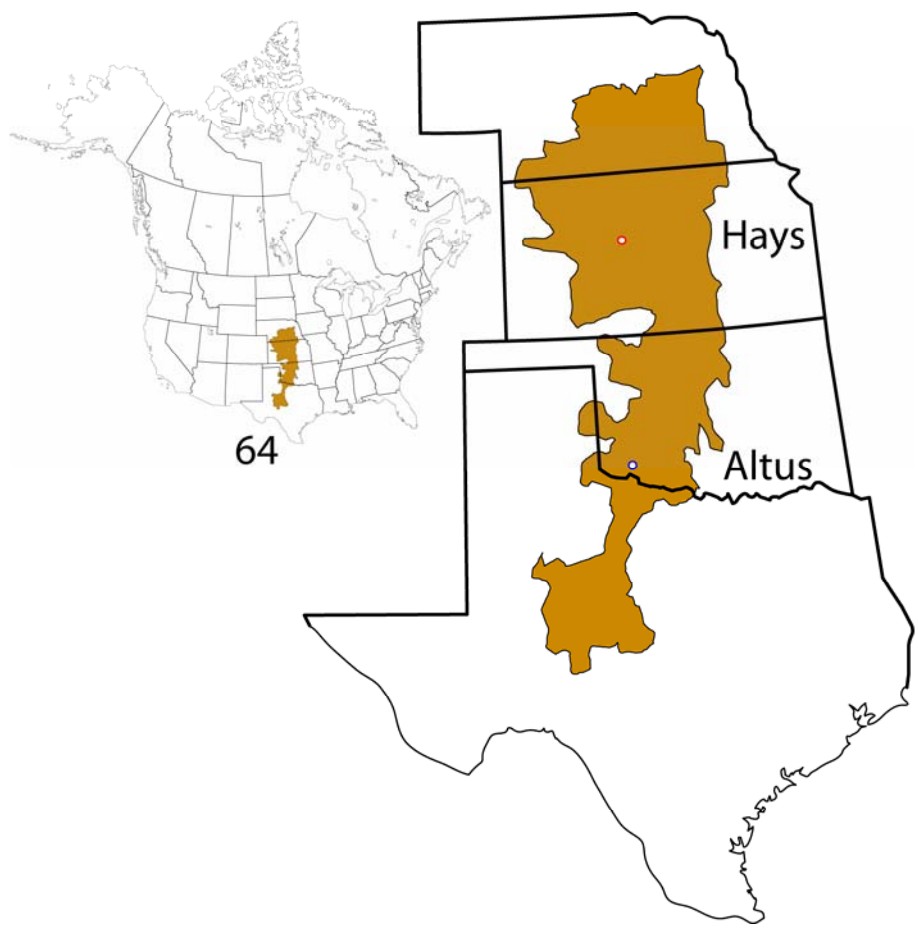


Figure I60. Central and Southern Mixed Grasslands.

Hays, Kansas

Didelphis virginiana
Blarina hylophaga
Cryptotis parva
Scalopus aquaticus
Myotis lucifugus
Myotis ciliolabrum
Lasiurus borealis
Lasiurus cinereus
Lasionycteris noctivagans
Pipistrellus subflavus
Eptesicus fuscus
Tadarida brasiliensis
Sylvilagus floridanus
Lepus townsendii
Lepus californicus
Spermophilus tridecemlineatus
Spermophilus franklinii
Cynomys ludovicianus
Sciurus niger
Geomys bursarius
Perognatus flavescens
Perognathus flavus
Chaetodipus hispidus
Castor canadensis
Reithrodontomys montanus
Reithrodontomys megalotis
Peromyscus maniculatus
Peromyscus leucopus
Onychomys leucogaster
Sigmodon hispidus
Neotoma floridana
Microtus ochrogaster
Ondatra zibethicus
Synaptomys cooperi
Zapus hudsonius
Erethizon dorsatum
Canis latrans
Canis lupus
Vulpes velox
Ursus americanus
Ursus arctos
Bassariscus astutus
Procyon lotor
Mustela frenata
Mustela nigripes
Mustela vison
Taxidea taxus
Lontra canadensis
Spilogale putorius
Mephitis mephitis
Puma concolor
Lynx rufus
Cervus canadensis
Odocoileus hemionus
Odocoileus virginianus
Antilocapra americana
Bos bison

Altus, Oklahoma

Didelphis virginiana
Cryptotis parva
Notiosorex crawfordi
Scalopus aquaticus
Myotis velifer
Myotis ciliolabrum
Lasiurus borealis
Lasiurus cinereus
Lasionycteris noctivagans
Pipistrellus subflavus
Eptesicus fuscus
Corynorhinus townsendii
Tadarida brasiliensis
Sylvilagus floridanus
Lepus californicus
Spermophilus tridecemlineatus
Cynomys ludovicianus
Sciurus niger
Geomys bursarius
Perognathus merriami
Perognathus flavus
Chaetodipus hispidus
Dipodomys ordii
Castor canadensis
Reithrodontomys montanus
Reithrodontomys fulvescens
Peromyscus maniculatus
Peromyscus leucopus
Peromyscus attwateri
Onychomys leucogaster
Sigmodon hispidus
Neotoma micropus
Microtus pinetorum
Erethizon dorsatum
Canis latrans
Canis lupus
Canis rufus
Ursus americanus
Bassariscus astutus
Procyon lotor
Mustela frenata
Mustela nigripes
Mustela vison
Taxidea taxus
Lontra canadensis
Spilogale putorius
Mephitis mephitis
Puma concolor
Lynx rufus
Cervus canadensis
Odocoileus virginianus
Antilocapra americana
Bos bison

65. Central Forest/Grassland Tranisition Zone

Tulsa, Oklahoma

36° 12’ N, 95° 53’ W

max. temp. – 21.9 °C

mean temp. – 16.0 °C

min. temp. – 10.1 °C

precipitation – 107.7 cm/yr

Springfield, Illinois

39° 51’ N, 89° 41’ W

max. temp. – 16.9 °C

mean temp. – 11.5 °C

min. temp. – 6.1 °C

precipitation – 90.3 cm/yr

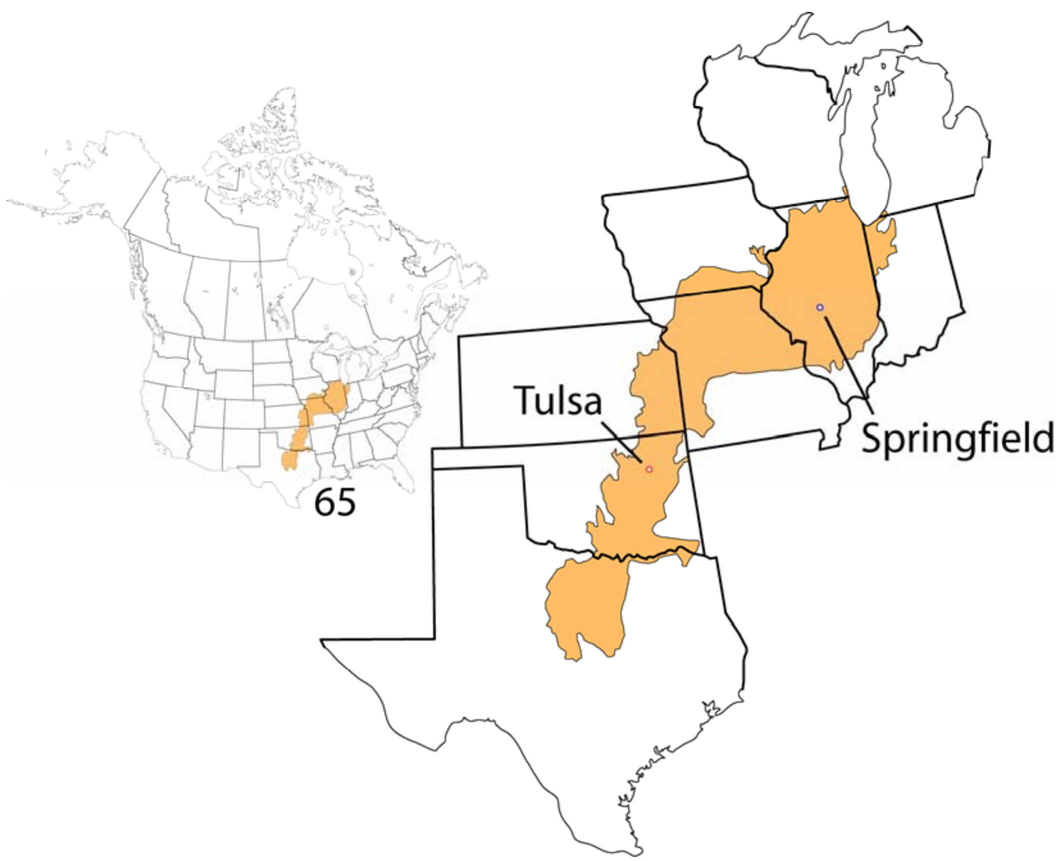


Figure I61. Central Forest/Grassland Tranisition Zone

Tulsa, Oklahoma

Didelphis virginiana
Blarina hylophaga
Cryptotis parva
Notiosorex crawfordi
Scalopus aquaticus
Myotis lucifugus
Myotis ciliolabrum
Lasiurus borealis
Lasiurus cinereus
Lasionycteris noctivagans
Pipistrellus subflavus
Eptesicus fuscus
Corynorhinus townsendii
Sylvilagus palustris
Sylvilagus floridanus
Lepus californicus
Spermophilus tridecemlineatus
Sciurus carolinensis
Sciurus niger
Glaucomys volans
Geomys bursarius
Chaetodipus hispidus
Castor canadensis
Oryzomys palustris
Reithrodontomys montanus
Reithrodontomys fulvescens
Peromyscus maniculatus
Peromyscus leucopus
Peromyscus attwateri
Sigmodon hispidus
Neotoma floridana
Microtus pinetorum
Ondatra zibethicus
Zapus hudsonius
Canis latrans
Canis lupus
Canis rufus
Vulpes vulpes
Urocyon cinereoargenteus
Ursus americanus
Procyon lotor
Mustela frenata
Mustela vison
Taxidea taxus
Lontra canadensis
Spilogale putorius
Mephitis mephitis
Puma concolor
Lynx rufus
Cervus canadensis
Odocoileus virginianus
Bos bison

Springfield, Illinois

Didelphis virginiana
Blarina brevicauda
Blarina hylophaga
Cryptotis parva
Scalopus aquaticus
Myotis lucifugus
Myotis septentrionalis
Myotis sodalis
Lasiurus borealis
Lasiurus cinereus
Lasionycteris noctivagans
Pipistrellus subflavus
Eptesicus fuscus
Nycticeius humeralis
Sylvilagus floridanus
Tamias striatus
Marmota monax
Spermophilus franklinii
Spermophilus tricedemlineatus
Sciurus carolinensis
Sciurus niger
Glaucomys volans
Geomys bursarius
Peromyscus leucopus
Peromyscus maniculatus
Microtus ochrogaster
Microtus pinetorum
Ondatra zibethicus
Synaptomys cooperi
Zapus hudsonius
Erethizon dorsatum
Canis latrans
Canis lupus
Canis rufus
Vulpes vulpes
Urocyon cinereoargenteus
Ursus americanus
Procyon lotor
Mustela frenata
Mustela vison
Taxidea taxus
Gulo gulo
Lontra canadensis
Mephitis mephitis
Puma concolor
Lynx rufus
Cervus elephus
Odocoileus virginianus
Bos bison

66. Edwards Plateau Savannas

Fredericksburg, Texas

30° 14’ N, 98° 55’ W

max. temp. – 25.7 °C

mean temp. – 19.0 °C

min. temp. – 12.2 °C

precipitation – 80.4 cm/yr

Kileen, Texas

31° 04’ N, 97° 44’ W

max. temp. – 25.4 °C

mean temp. – 18.7 °C

min. temp. – 12.1 °C

precipitation – 83.5 cm/yr

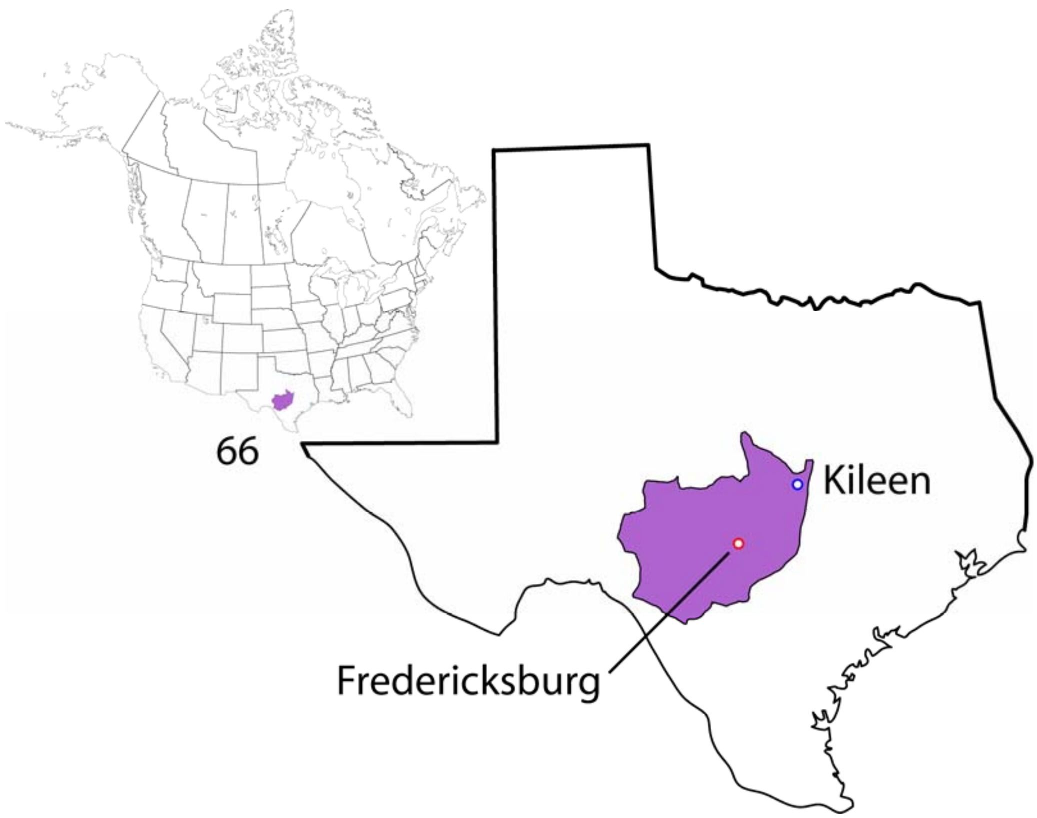


Figure I62. Edwards Plateau Savannas.

Fredericksburg, Texas

Didelphis virginiana
Scalopus aquaticus
Myotis velifer
Lasiurus borealis
Lasiurus cinereus
Lasionycteris noctivagans
Pipistrellus subflavus
Nycticeius humeralis
Tadarida brasiliensis
Sylvilagus floridanus
Lepus californicus
Spermophilus mexicanus
Spermophilus variegatus
Cynomys ludovicianus
Sciurus niger
Geomys texensis
Perognathus merriami
Chaetodipus hispidus
Castor canadensis
Reithrodontomys montanus
Peromyscus attwateri
Peromyscus leucopus
Peromyscus maniculatus
Peromyscus pectoralis
Baiomys taylori
Sigmodon hispidus
Neotoma albigula
Neotoma floridana
Microtus pinetorum
Erethizon dorsatum
Canis latrans
Canis lupus
Canis rufus
Vulpes vulpes
Urocyon cinereoargenteus
Ursus americanus
Bassariscus astutus
Procyon lotor
Mustela frenata
Mustela nigripes
Mustela vison
Taxidea taxus
Spilogale gracilis
Spilogale putorius
Mephitis mephitis
Conepatus leuconotus
Puma concolor
Leopardus pardalis
Lynx rufus
Pecari tajacu
Odocoileus virginianus
Antilocapra americana
Bos bison

Kileen, Texas

Didelphis virginiana
Cryptotis parva
Scalopus aquaticus
Myotis velifer
Lasiurus borealis
Lasiurus cinereus
Lasionycteris noctivagans
Pipistrellus subflavus
Eptesicus fuscus
Nycticeius humeralis
Tadarida brasiliensis
Sylvilagus floridanus
Lepus californicus
Spermophilus mexicanus
Spermophilus variegatus
Sciurus carolinensis
Sciurus niger
Perognathus merriami
Chaetodipus hispidus
Castor canadensis
Reithrodonotmys fulvescens
Reithrodontomys montanus
Peromyscus attwateri
Peromyscus leucopus
Peromyscus maniculatus
Peromyscus pectoralis
Baiomys taylori
Sigmodon hispidus
Neotoma floridana
Microtus pinetorum
Erethizon dorsatum
Canis latrans
Canis lupus
Canis rufus
Vulpes vulpes
Urocyon cinereoargenteus
Ursus americanus
Bassariscus astutus
Procyon lotor
Mustela frenata
Mustela vison
Taxidea taxus
Lontra canadensis
Spilogale putorius
Mephitis mephitis
Conepatus leuconotus
Puma concolor
Lynx rufus
Odocoileus virginianus
Antilocapra americana
Bos bison

67. Texas Blackland Prairies

Dallas, Texas

32° 54' N, 97° 01' W

max. temp. – 24.3 °C

mean temp. – 18.6 °C

min. temp. – 12.8 °C

precipitation – 88.2 cm/yr

Paris, Texas

33° 40' N, 95° 34' W

max. temp. – 23.4 °C

mean temp. – 17.1 °C

min. temp. – 10.8 °C

precipitation – 121.5 cm/yr

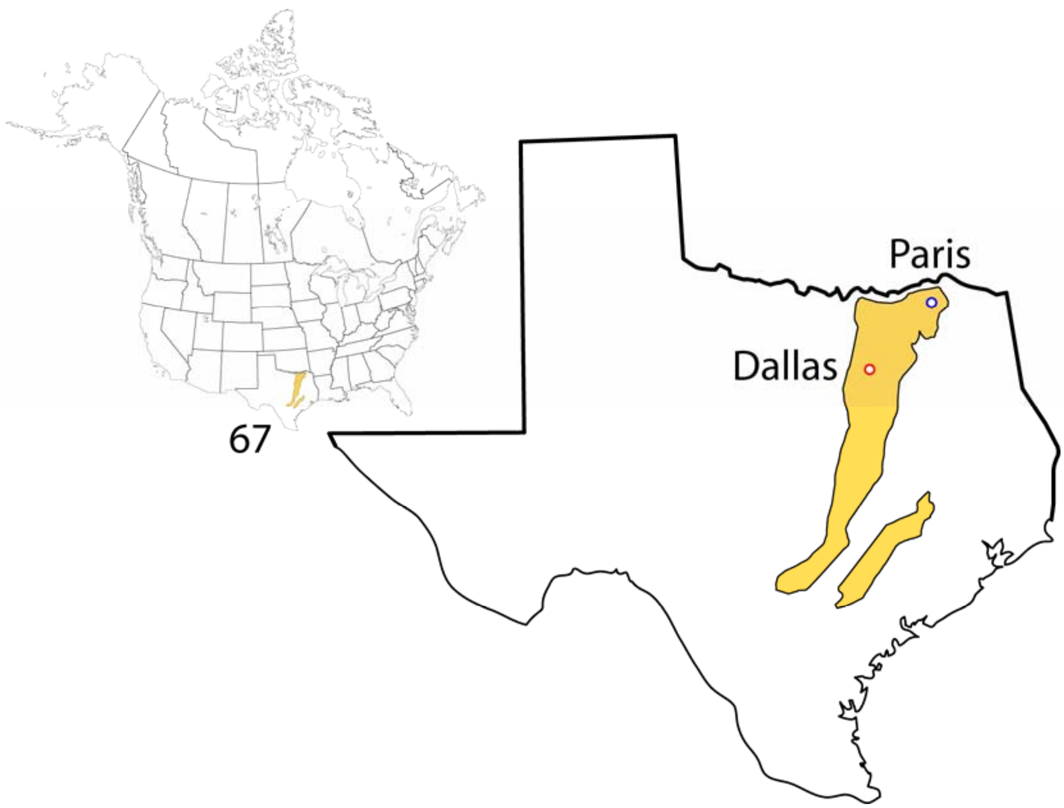


Figure I63. Texas Blackland Prairies.

Dallas, Texas

Didelphis virginiana
Blarina carolinensis
Cryptotis parva
Scalopus aquaticus
Myotis velifer
Lasiurus borealis
Lasiurus cinereus
Lasionycteris noctivagans
Pipistrellus subflavus
Eptesicus fuscus
Nycticeius humeralis
Tadarida brasiliensis
Sylvilagus aquaticus
Sylvilagus floridanus
Lepus californicus
Spermophilus tridecemlineatus
Sciurus niger
Glaucomys volans
Geomys bursarius
Chaetodipus hispidus
Castor canadensis
Reithrodonotmys fulvescens
Reithrodontomys montanus
Peromyscus leucopus
Peromyscus maniculatus
Baiomys taylori
Sigmodon hispidus
Neotoma floridana
Microtus pinetorum
Ondatra zibethicus
Canis latrans
Canis rufus
Vulpes vulpes
Urocyon cinereoargenteus
Ursus americanus
Bassariscus astutus
Procyon lotor
Mustela frenata
Mustela vison
Taxidea taxus
Lontra canadensis
Spilogale putorius
Mephitis mephitis
Conepatus leuconotus
Puma concolor
Lynx rufus
Odocoileus virginianus
Antilocapra americana
Bos bison

Paris, Texas

Didelphis virginiana
Blarina carolinensis
Blarina hylophaga
Cryptotis parva
Scalopus aquaticus
Lasiurus borealis
Lasiurus cinereus
Lasionycteris noctivagans
Pipistrellus subflavus
Eptesicus fuscus
Nycticeius humeralis
Tadarida brasiliensis
Sylvilagus aquaticus
Sylvilagus floridanus
Lepus californicus
Spermophilus tridecemlineatus
Sciurus carolinensis
Sciurus niger
Glaucomys volans
Geomys breviceps
Chaetodipus hispidus
Castor canadensis
Oryzomys palustris
Reithrodonotmys fulvescens
Reithrodontomys humulis
Peromyscus gossypinus
Peromyscus leucopus
Peromyscus maniculatus
Sigmodon hispidus
Neotoma floridana
Microtus pinetorum
Ondatra zibethicus
Canis latrans
Canis rufus
Vulpes vulpes
Urocyon cinereoargenteus
Ursus americanus
Bassariscus astutus
Procyon lotor
Mustela frenata
Mustela vison
Taxidea taxus
Lontra canadensis
Spilogale putorius
Mephitis mephitis
Puma concolor
Lynx rufus
Odocoileus virginianus
Bos bison

68. Western Gulf Coastal Grasslands

Corpus Christi, Texas

27° 46’ N, 97° 31’ W

max. temp. – 27.2 °C

mean temp. – 21.9 °C

min. temp. – 16.7 °C

precipitation – 82.2 cm/yr

Galveston, Texas

29° 20’ N, 94° 47’ W

max. temp. – 24.8 °C

mean temp. – 21.8 °C

min. temp. – 18.7 °C

precipitation – 111.4 cm/yr

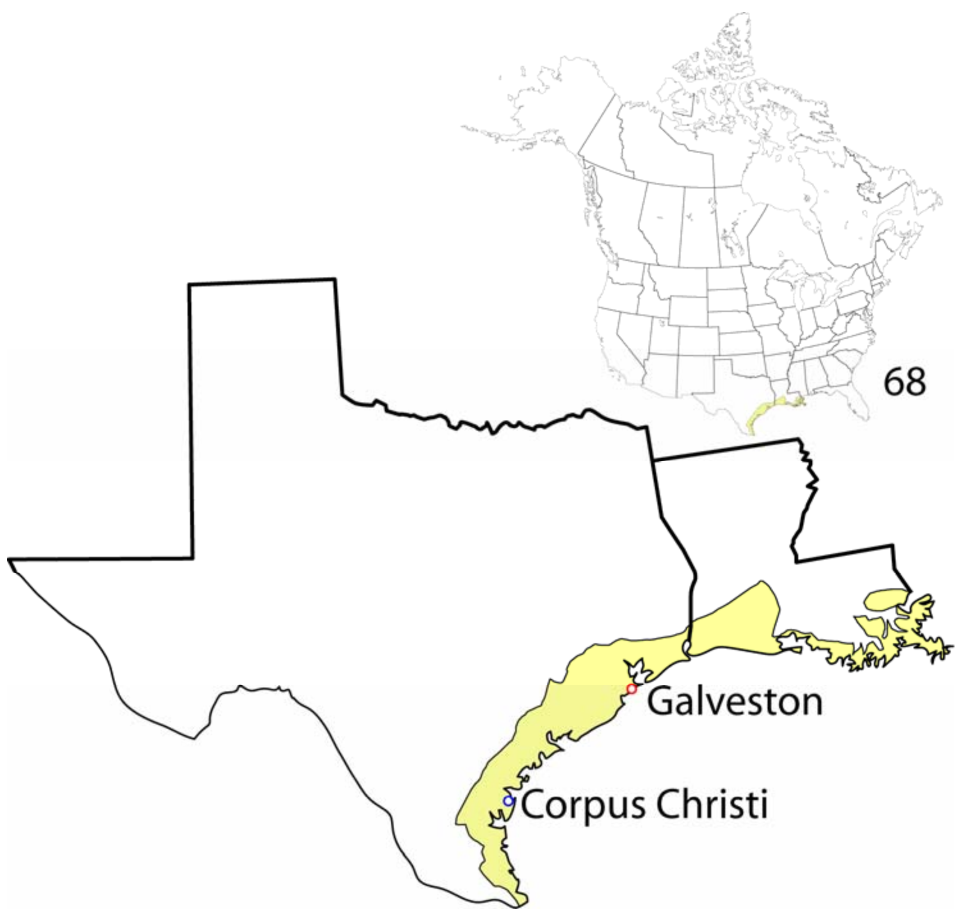


Figure I64. Western Gulf Coastal Grasslands.

Corpus Christi, Texas

Didelphis virginiana
Cryptotis parva
Notiosorex crawfordi
Scalopus aquaticus
Lasiurus borealis
Lasiurus cinereus
Lasiurus ega
Lasiurus intermedius
Pipistrellus subflavus
Nycticeius humeralis
Tadarida brasiliensi
Nyctinomops macrotis
Sylvilagus floridanus
Lepus californicus
Spermophilus mexicanus
Spermophilus spilosoma
Sciurus niger
Geomys personatus
Perognathus merriami
Chaetodipus hispidus
Dipodomys compactus
Castor canadensis
Oryzomys palustris
Reithrodonotmys fulvescens
Peromyscus leucopus
Peromyscus maniculatus
Baiomys taylori
Onychomys leucogaster
Sigmodon hispidus
Neotoma micropus
Canis latrans
Canis rufus
Urocyon cinereoargenteus
Ursus americanus
Bassariscus astutus
Procyon lotor
Nasua narica
Mustela frenata
Taxidea taxus
Lontra canadensis
Spilogale putorius
Mephitis mephitis
Conepatus leuconotus
Puma concolor
Leopardus pardalis
Panthera onca
Lynx rufus
Odocoileus virginianus

Galveston, Texas

Didelphis virginiana
Blarina carolinensis
Cryptotis parva
Scalopus aquaticus
Lasiurus borealis
Lasiurus cinereus
Lasiurus intermedius
Lasiurus seminolus
Pipistrellus subflavus
Eptesicus fuscus
Nycticeius humeralis
Tadarida brasiliensis
Nyctinomops macrotis
Sylvilagus aquaticus
Sylvilagus floridanus
Lepus californicus
Sciurus carolinensis
Sciurus niger
Glaucomys volans
Geomys breviceps
Castor canadensis
Oryzomys palustris
Reithrodonotmys fulvescens
Reithrodontomys humulis
Peromyscus leucopus
Peromyscus maniculatus
Baiomys taylori
Sigmodon hispidus
Neotoma floridana
Ondatra zibethicus
Canis latrans
Canis rufus
Vulpes vulpes
Urocyon cinereoargenteus
Ursus americanus
Bassariscus astutus
Procyon lotor
Mustela frenata
Mustela vison
Taxidea taxus
Lontra canadensis
Spilogale putorius
Mephitis mephitis
Puma concolor
Leopardus pardalis
Panthera onca
Lynx rufus
Odocoileus virginianus

69. Everglades

Everglades City, Florida

25° 51’ N, 81° 23’ W

max. temp. – 28.5 °C

mean temp. – 23.4 °C

min. temp. – 18.2 °C

precipitation – 132.3 cm/yr

Belle Glade, Florida

26° 39’ N, 80° 38’ W

max. temp. – 29.5 °C

mean temp. – 23.2 °C

min. temp. – 16.8 °C

precipitation – 131.0 cm/yr

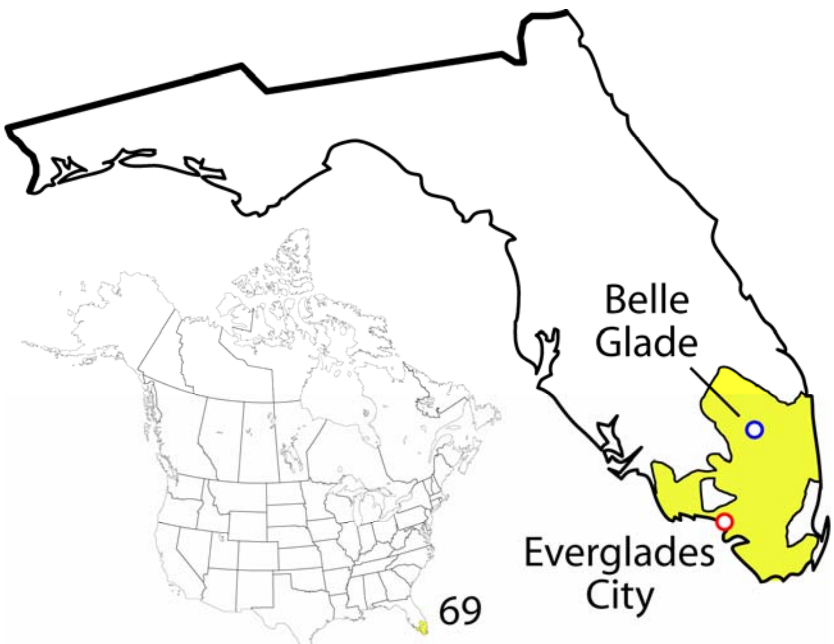


Figure I65. Everglades.

Everglades City, Florida

Didelphis virginiana
Blarina carolinensis
Cryptotis parva
Scalopus aquaticus
Nycticeius humeralis
Tadarida brasiliensis
Sylvilagus floridanus
Sylvilagus palustris
Sciurus carolinensis
Sciurus niger
Oryzomys palustris
Reithrodontomys humulis
Peromyscus gossypinus
Sigmodon hispidus
Neofiber alleni
Canis rufus
Vulpes vulpes
Urocyon cinereoargenteus
Ursus americanus
Procyon lotor
Mustela vison
Lontra canadensis
Spilogale putorius
Mephitis mephitis
Puma concolor
Lynx rufus
Odocoileus virginianus

Belle Glade, Florida

Didelphis virginiana
Blarina carolinensis
Cryptotis parva
Scalopus aquaticus
Lasiurus intermedius
Lasiurus seminolus
Nycticeius humeralis
Tadarida brasiliensis
Sylvilagus floridanus
Sylvilagus palustris
Sciurus carolinensis
Sciurus niger
Glaucomys volans
Oryzomys palustris
Reithrodontomys humulis
Peromyscus gossypinus
Sigmodon hispidus
Neofiber alleni
Canis rufus
Vulpes vulpes
Urocyon cinereoargenteus
Ursus americanus
Procyon lotor
Lontra canadensis
Spilogale putorius
Mephitis mephitis
Puma concolor
Lynx rufus
Odocoileus virginianus

70. California Interior Chaparral and Woodlands

Berkeley, California

37° 52’ N, 122° 16’ W

max. temp. – 18.3 °C

mean temp. – 14.2 °C

min. temp. – 10.1 °C

precipitation – 64.5 cm/yr

Santa Maria, California

34° 55’ N, 120° 28’ W

max. temp. – 20.7 °C

mean temp. – 14.3 °C

min. temp. – 7.8 °C

precipitation – 35.6 cm/yr

Figure I66. California Interior Chaparral and Woodlands.

Berkeley, California

Sorex sonomae
Sorex ornatus
Sorex trowbridgii
Scapanus latimanus
Myotis californicus
Myotis evotis
Myotis yumanensis
Lasiurus cinereus
Lasiurus blossevillii
Eptesicus fuscus
Pipistrellus hesperus
Antrozous pallidus
Corynorhinus townsendii
Tadarida brasiliensis
Eumops perotis
Sylvilagus bachmani
Sylvilagus audubonii
Lepus californicus
Spermophilus beecheyi
Sciurus griseus
Thomomys bottae
Perognathus inornatus
Chaetodipus californicus
Dipodomys heermanni
Reithrodontomys megalotis
Reithrodontomys raviventris
Peromyscus californicus
Peromyscus maniculatus
Peromyscus boylii
Peromyscus truei
Neotoma macrotis
Microtus californicus
Canis latrans
Urocyon cinereoargenteus
Bassariscus astutus
Procyon lotor
Mustela vison
Mustela frenata
Taxidea taxus
Spilogale putorius
Mephitis mephitis
Lynx rufus
Odocoileus hemionus

Santa Maria, California

Sorex ornatus
Sorex trowbridgii
Scapanus latimanus
Myotis thysanodes
Myotis californicus
Myotis ciliolabrum
Myotis volans
Myotis evotis
Myotis yumanensis
Lasiurus cinereus
Lasiurus blossevillii
Eptesicus fuscus
Pipistrellus hesperus
Corynorhinus townsendii
Antrozous pallidus
Tadarida brasiliensis
Sylvilagus bachmani
Sylvilagus audubonii
Lepus californicus
Spermophilus beecheyi
Sciurus griseus
Thomomys bottae
Chaetodipus californicus
Dipodomys heermanni
Reithrodontomys megalotis
Peromyscus californicus
Peromyscus maniculatus
Peromyscus boylii
Peromyscus truei
Neotoma lepida
Neotoma macrotis
Microtus californicus
Canis latrans
Urocyon cinereoargenteus
Bassariscus astutus
Procyon lotor
Mustela frenata
Taxidea taxus
Spilogale putorius
Mephitis mephitis
Puma concolor
Lynx rufus
Odocoileus hemionus

71. California Montane Chaparral and Woodlands

Santa Barbara, California

34° 26’ N, 119° 51’ W

max. temp. – 22.1 °C

mean temp. – 15.8 °C

min. temp. – 9.6 °C

precipitation – 43.0 cm/yr

Lake Arrowhead, California

34° 15’ N, 117° 11’ W

max. temp. – 16.8 °C

mean temp. – 10.7 °C

min. temp. – 4.6 °C

precipitation – 105.8 cm/yr

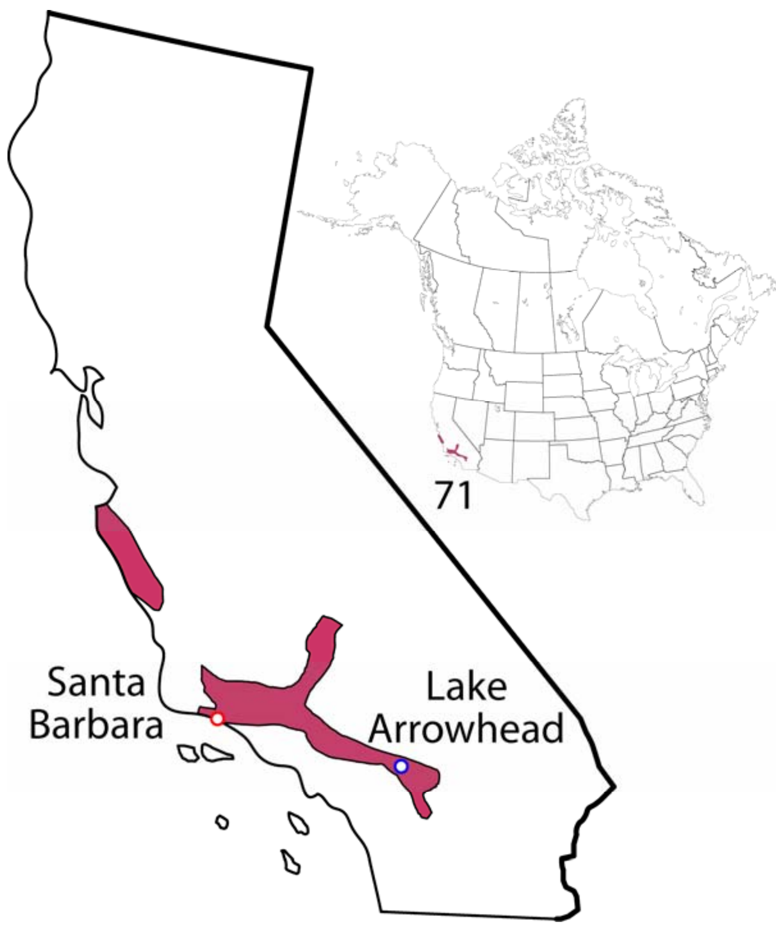


Figure I67. California Montane Chaparral and Woodlands.

Santa Barbara, California

Sorex ornatus
Sorex trowbridgii
Scapanus latimanus
Myotis thysanodes
Myotis californicus
Myotis ciliolabrum
Myotis volans
Myotis evotis
Myotis yumanensis
Lasiurus cinereus
Lasiurus blossevillii
Eptesicus fuscus
Pipistrellus hesperus
Corynorhinus townsendii
Antrozous pallidus
Tadarida brasiliensis
Eumops perotis
Sylvilagus bachmani
Sylvilagus audubonii
Lepus californicus
Neotamias merriami
Spermophilus beecheyi
Sciurus griseus
Thomomys bottae
Chaetodipus californicus
Dipodomys agilis
Reithrodontomys megalotis
Peromyscus californicus
Peromyscus fraterculus
Peromyscus maniculatus
Peromyscus boylii
Peromyscus truei
Neotoma lepida
Neotoma macrotis
Microtus californicus
Canis latrans
Urocyon cinereoargenteus
Bassariscus astutus
Procyon lotor
Mustela frenata
Taxidea taxus
Spilogale putorius
Mephitis mephitis
Puma concolor
Lynx rufus
Odocoileus hemionus

Lake Arrowhead, California

Sorex monticolus
Sorex ornatus
Notiosorex crawfordi
Macrotus californicus
Myotis thysanodes
Myotis californicus
Myotis ciliolabrum
Myotis volans
Myotis evotis
Myotis yumanensis
Lasiurus cinereus
Lasiurus blossevillii
Eptesicus fuscus
Pipistrellus hesperus
Euderma maculata
Antrozous pallidus
Tadarida brasiliensis
Sylvilagus bachmani
Sylvilagus audubonii
Lepus californicus
Neotamias obscurus
Neotamias speciosus
Ammospermophilus leucurus
Spermophilus beecheyi
Spermophilus lateralis
Sciurus griseus
Glaucomys sabrinus
Thomomys bottae
Chaetodipus californicus
Dipodomys merriami
Reithrodontomys megalotis
Peromyscus crinitus
Peromyscus californicus
Peromyscus eremicus
Peromyscus maniculatus
Peromyscus boylii
Peromyscus truei
Onychomys torridus
Neotoma lepida
Neotoma macrotis
Microtus californicus
Microtus longicaudus
Canis latrans
Vulpes macrotis
Urocyon cinereoargenteus
Ursus americanus
Bassariscus astutus
Mustela frenata
Taxidea taxus
Lynx rufus
Odocoileus hemionus
Ovis canadensis

72. California Coastal Sage and Chaparral

Los Angeles, California

33° 56’ N, 118° 24’ W

max. temp. – 21.4 °C

mean temp. – 17.4 °C

min. temp. – 13.4 °C

precipitation – 33.4 cm/yr

San Diego, California

32° 44’ N, 117° 10’ W

max. temp. – 21.6 °C

mean temp. – 18.0 °C

min. temp. – 14.5 °C

precipitation – 27.4 cm/yr

Figure I68. California Coastal Sage and Chaparral.

Los Angeles, California

Sorex ornatus
Notiosorex crawfordi
Scapanus latimanus
Macrotus californicus
Myotis thysanodes
Myotis californicus
Myotis ciliolabrum
Myotis volans
Myotis evotis
Myotis yumanensis
Lasiurus cinereus
Lasiurus blossevillii
Eptesicus fuscus
Pipistrellus hesperus
Corynorhinus townsendii
Antrozous pallidus
Tadarida brasiliensis
Eumops perotis
Sylvilagus bachmani
Sylvilagus audubonii
Lepus californicus
Spermophilus beecheyi
Thomomys bottae
Perognathus longimembris
Chaetodipus californicus
Dipodomys simulans
Reithrodontomys megalotis
Peromyscus californicus
Peromyscus fraterculus
Peromyscus maniculatus
Peromyscus boylii
Neotoma lepida
Neotoma macrotis
Microtus californicus
Canis latrans
Urocyon cinereoargenteus
Bassariscus astutus
Procyon lotor
Mustela frenata
Taxidea taxus
Spilogale putorius
Mephitis mephitis
Puma concolor
Lynx rufus
Odocoileus hemionus

San Diego, California

Sorex ornatus
Notiosorex crawfordi
Scapanus latimanus
Macrotus californicus
Choeronycteris mexicana
Myotis thysanodes
Myotis californicus
Myotis ciliolabrum
Myotis volans
Myotis evotis
Myotis yumanensis
Lasiurus cinereus
Lasiurus blossevillii
Eptesicus fuscus
Pipistrellus hesperus
Corynorhinus townsendii
Antrozous pallidus
Tadarida brasiliensis
Nyctinomops femorosaccus
Nyctinomops macrotis
Eumops perotis
Sylvilagus bachmani
Sylvilagus audubonii
Lepus californicus
Spermophilus beecheyi
Thomomys bottae
Perognathus longimembris
Chaetodipus fallax
Chaetodipus californicus
Dipodomys simulans
Reithrodontomys megalotis
Peromyscus californicus
Peromyscus fraterculus
Peromyscus maniculatus
Peromyscus boylii
Onychomys torridus
Neotoma lepida
Neotoma macrotis
Microtus californicus
Canis latrans
Urocyon cinereoargenteus
Bassariscus astutus
Procyon lotor
Mustela frenata
Taxidea taxus
Spilogale putorius
Mephitis mephitis
Puma concolor
Lynx rufus
Odocoileus hemionus

75. Snake/Columbia Shrub Steppe

Burns Junction, Oregon

42° 47’ N, 117° 51’ W

max. temp. – 19.1 °C

mean temp. – 10.3 °C

min. temp. – 1.4 °C

precipitation – 22.0 cm/yr

Hagerman, Idaho

42° 48’ N, 114° 55’ W

max. temp. – 19.9 °C

mean temp. – 10.9 °C

min. temp. – 1.9 °C

precipitation – 24.8 cm/yr

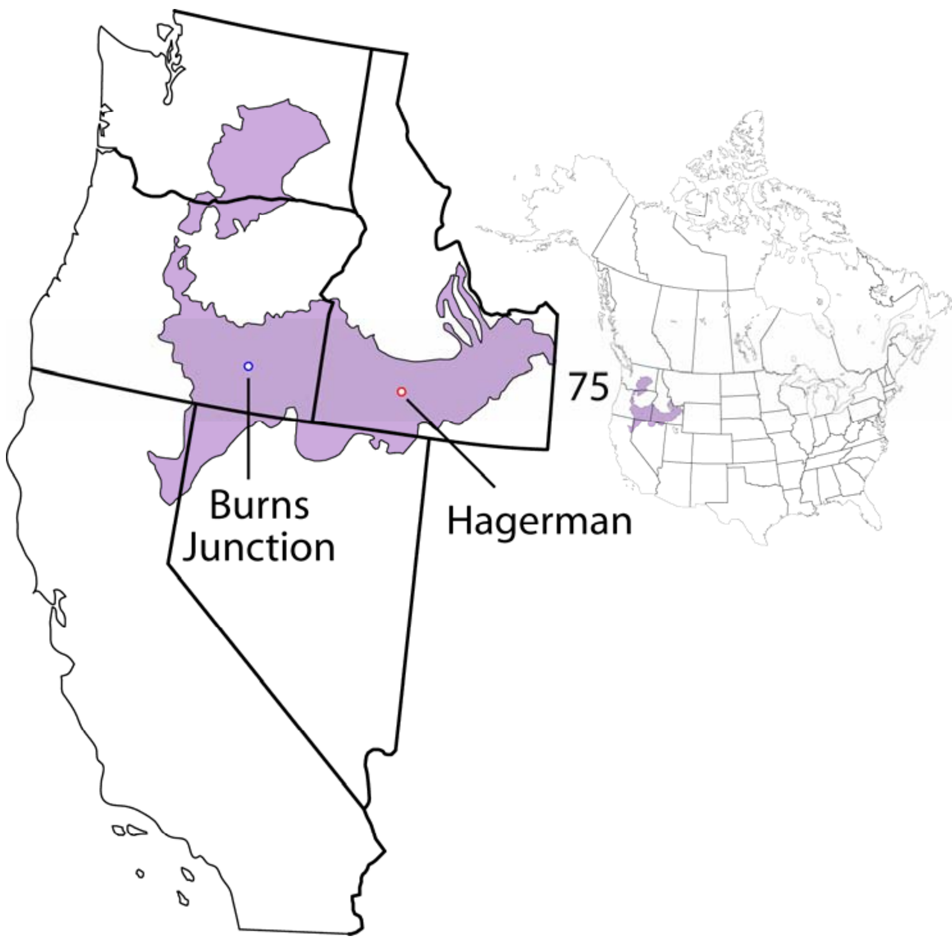


Figure I69. Snake/Columbia Shrub Steppe.

Burns Junction, Oregon

Sorex vagrans
Sorex preblei
Sorex merriami
Myotis lucifugus
Myotis thysanodes
Myotis californicus
Myotis ciliolabrum
Myotis volans
Myotis evotis
Myotis yumanensis
Lasiurus cinereus
Eptesicus fuscus
Pipistrellus hesperus
Corynorhinus townsendii
Antrozous pallidus
Sylvilagus idahoensis
Sylvilagus nuttallii
Lepus americanus
Lepus townsendii
Lepus californicus
Neotamias minimus
Neotamias amoenus
Marmota flaviventris
Spermophilus canus
Spermophilus beldingi
Thomomys townsendii
Thomomys talpoides
Perognathus parvus
Microdipodomys megacephalus
Dipodomys ordii
Dipodomys microps
Castor canadensis
Reithrodontomys megalotis
Peromyscus crinitus
Peromyscus maniculatus
Onychomys leucogaster
Neotoma lepida
Neotoma cinerea
Microtus montanus
Microtus longicaudus
Lemmiscus curtatus
Ondatra zibethicus
Zapus princeps
Erethizon dorsatum
Canis latrans
Procyon lotor
Mustela frenata
Taxidea taxus
Lontra canadensis
Spilogale putorius
Mephitis mephitis
Lynx rufus
Odocoileus hemionus
Antilocapra americana

Hagerman, Idaho

Sorex cinereus
Sorex vagrans
Myotis lucifugus
Myotis yumanensis
Myotis evotis
Myotis thysanodes
Myotis volans
Myotis californicus
Myotis ciliolabrum
Lasiurus cinereus
Lasionycteris noctivagans
Eptesicus fuscus
Euderma maculatum
Corynorhinus townsendii
Sylvilagus idahoensis
Sylvilagus nuttallii
Lepus americanus
Lepus townsendii
Lepus californicus
Neotamias minimus
Neotamias amoenus
Marmota flaviventris
Spermophilus mollis
Spermophilus beldingi
Thomomys talpoides
Perognathus parvus
Dipodomys ordii
Castor canadensis
Reithrodontomys megalotis
Peromyscus crinitus
Peromyscus maniculatus
Onychomys leucogaster
Neotoma cinerea
Microtus montanus
Microtus longicaudus
Lemmiscus curtatus
Ondatra zibethicus
Zapus princeps
Canis latrans
Canis lupus
Vulpes vulpes
Ursus americanus
Procyon lotor
Mustela erminea
Mustela frenata
Mustela vison
Taxidea taxus
Lontra canadensis
Spilogale gracilis
Puma concolor
Lynx canadensis
Lynx rufus
Cervus canadensis
Odocoileus hemionus
Antilocapra americana
Bos bison
Ovis canadensis

76. Great Basin Shrub Steppe

Fallon, Nevada

39° 27' N, 118° 47' W

max. temp. – 20.0 °C

mean temp. – 10.8 °C

min. temp. – 1.4 °C

precipitation – 13.5 cm/yr

Wendover, Utah

40° 43' N, 114° 02' W

max. temp. – 16.7 °C

mean temp. – 10.8 °C

min. temp. – 4.9 °C

precipitation – 12.1 cm/yr

Figure I70. Great Basin Shrub Steppe.

Fallon, Nevada

Myotis lucifugus
Myotis evotis
Myotis thysanodes
Myotis volans
Myotis californicus
Myotis ciliolabrum
Lasiurus blossevillii
Lasiurus cinereus
Lasionycteris noctivagans
Pipistrellus hesperus
Eptesicus fuscus
Euderma maculatum
Corynorhinus townsendii
Antrozous pallidus
Tadarida brasiliensis
Sylvilagus idahoensis
Sylvilagus nuttallii
Lepus californicus
Neotamias minimus
Marmota flaviventris
Ammospermophilus leucurus
Spermophilus mollis
Thomomys bottae
Perognathus longimembris
Perognathus parvus
Chaetodipus formosus
Microdipodomys megacephalus
Dipodomys ordii
Dipodomys microps
Dipodomys merriami
Reithrodontomys megalotis
Peromyscus crinitus
Peromyscus maniculatus
Peromyscus truei
Onychomys leucogaster
Neotoma lepida
Neotoma cinerea
Microtus montanus
Microtus longicaudus
Lemmiscus curtatus
Ondatra zibethicus
Erethizon dorsatum
Canis latrans
Canis lupus
Vulpes macrotis
Ursus arctos
Procyon lotor
Mustela erminea
Mustela frenata
Mustela vison
Taxidea taxus
Spilogale gracilis
Mephitis mephitis
Puma concolor
Lynx rufus
Odocoileus hemionus
Antilocapra americana
Ovis canadensis

Wendover, Utah

Sorex vagrans
Myotis lucifugus
Myotis evotis
Myotis thysanodes
Myotis volans
Myotis californicus
Myotis ciliolabrum
Lasiurus cinereus
Lasionycteris noctivagans
Eptesicus fuscus
Euderma maculatum
Corynorhinus townsendii
Sylvilagus idahoensis
Sylvilagus nuttallii
Lepus townsendii
Lepus californicus
Ammospermophilus leucurus
Spermophilus mollis
Spermophilus lateralis
Thomomys bottae
Perognathus longimembris
Perognathus parvus
Chaetodipus formosus
Dipodomys ordii
Dipodomys microps
Reithrodontomys megalotis
Peromyscus crinitus
Peromyscus maniculatus
Peromyscus truei
Onychomys leucogaster
Neotoma lepida
Neotoma cinerea
Microtus montanus
Microtus longicaudus
Lemmiscus curtatus
Ondatra zibethicus
Erethizon dorsatum
Canis latrans
Canis lupus
Vulpes macrotis
Ursus arctos
Mustela erminea
Mustela frenata
Taxidea taxus
Spilogale gracilis
Mephitis mephitis
Puma concolor
Lynx rufus
Cervus canadensis
Odocoileus hemionus
Antilocapra americana
Ovis canadensis

77. Wyoming Basin Shrub Steppe

Rock Springs, Wyoming

41° 36' N, 109° 04' W

max. temp. – 11.8 °C

mean temp. – 5.4 °C

min. temp. – -0.9 °C

precipitation – 24.0 cm/yr

Thermopolis, Wyoming

43° 39' N, 108° 12' W

max. temp. – 17.3 °C

mean temp. – 8.8 °C

min. temp. – 0.4 °C

precipitation – 30.4 cm/yr

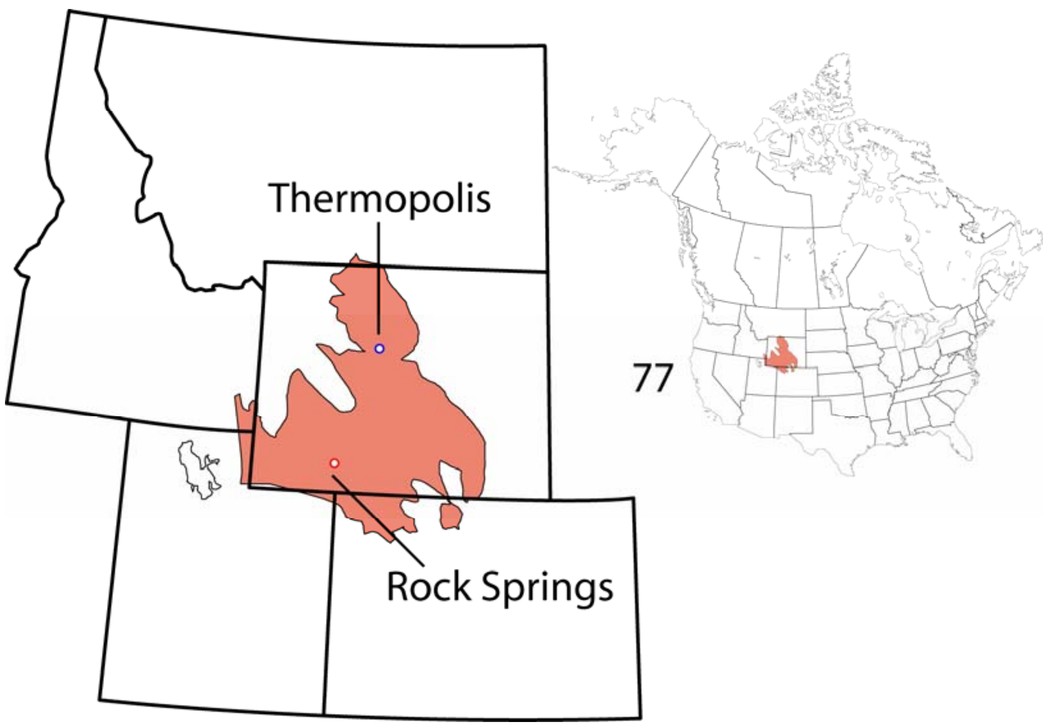


Figure I71. Wyoming Basin Shrub Steppe.

Rock Springs, Wyoming

Sorex nanus
Myotis lucifugus
Myotis evotis
Myotis thysanodes
Myotis volans
Myotis ciliolabrum
Lasiurus cinereus
Lasionycteris noctivagans
Eptesicus fuscus
Euderma maculatum
Corynorhinus townsendii
Sylvilagus nuttallii
Sylvilagus audubonii
Lepus americanus
Lepus townsendii
Neotamias minimus
Spermophilus elegans
Spermophilus tridecemlineatus
Spermophilus lateralis
Cynomys leucurus
Thomomys talpoides
Perognathus fasciatus
Dipodomys ordii
Castor canadensis
Peromyscus maniculatus
Onychomys leucogaster
Neotoma cinerea
Clethrionomys gapperi
Phenacomys intermedius
Microtus montanus
Microtus longicaudus
Lemmiscus curtatus
Ondatra zibethicus
Zapus princeps
Erethizon dorsatum
Canis latrans
Canis lupus
Vulpes velox
Ursus americanus
Ursus arctos
Mustela erminea
Mustela frenata
Mustela vison
Taxidea taxus
Lontra canadensis
Spilogale putorius
Mephitis mephitis
Puma concolor
Lynx canadensis
Lynx rufus
Cervus canadensis
Odocoileus hemionus
Odocoileus virginianus
Alces alces
Antilocapra americana
Bos bison
Ovis canadensis

Thermopolis, Wyoming

Sorex cinereus
Sorex nanus
Myotis lucifugus
Myotis yumanensis
Myotis evotis
Myotis volans
Myotis ciliolabrum
Lasiurus cinereus
Lasionycteris noctivagans
Eptesicus fuscus
Euderma maculatum
Corynorhinus townsendii
Sylvilagus nuttallii
Sylvilagus audubonii
Lepus townsendii
Neotamias minimus
Neotamias bottae
Marmota flaviventris
Spermophilus elegans
Spermophilus tridecemlineatus
Spermophilus lateralis
Cynomys leucurus
Glaucomys sabrinus
Thomomys talpoides
Perognathus fasciatus
Dipodomys ordii
Castor canadensis
Reithrodontomys megalotis
Peromyscus maniculatus
Onychomys leucogaster
Neotoma cinerea
Clethrionomys gapperi
Phenacomys intermedius
Microtus pennsylvanicus
Microtus montanus
Microtus longicaudus
Microtus ochrogaster
Lemmiscus curtatus
Ondatra zibethicus
Zapus princeps
Erethizon dorsatum
Canis latrans
Canis lupus
Vulpes vulpes
Ursus americanus
Ursus arctos
Mustela erminea
Mustela frenata
Mustela vison
Taxidea taxus
Lontra canadensis
Mephitis mephitis
Puma concolor
Lynx canadensis
Lynx rufus
Cervus canadensis
Odocoileus hemionus
Odocoileus virginianus
Alces alces
Antilocapra americana
Bos bison
Ovis canadensis

78. Colorado Plateau Shrublands

Monument Valley, Arizona	Corrales, New Mexico
36° 59’ N, 110° 07’ W	35° 14’ N, 106° 36’ W
max. temp. – 19.1 °C	max. temp. – 21.0 °C
mean temp. – 12.9 °C	mean temp. – 11.9 °C
min. temp. – 6.7 °C	min. temp. – 2.8 °C
precipitation – 10.4 cm/yr	precipitation – 23.6 cm/yr

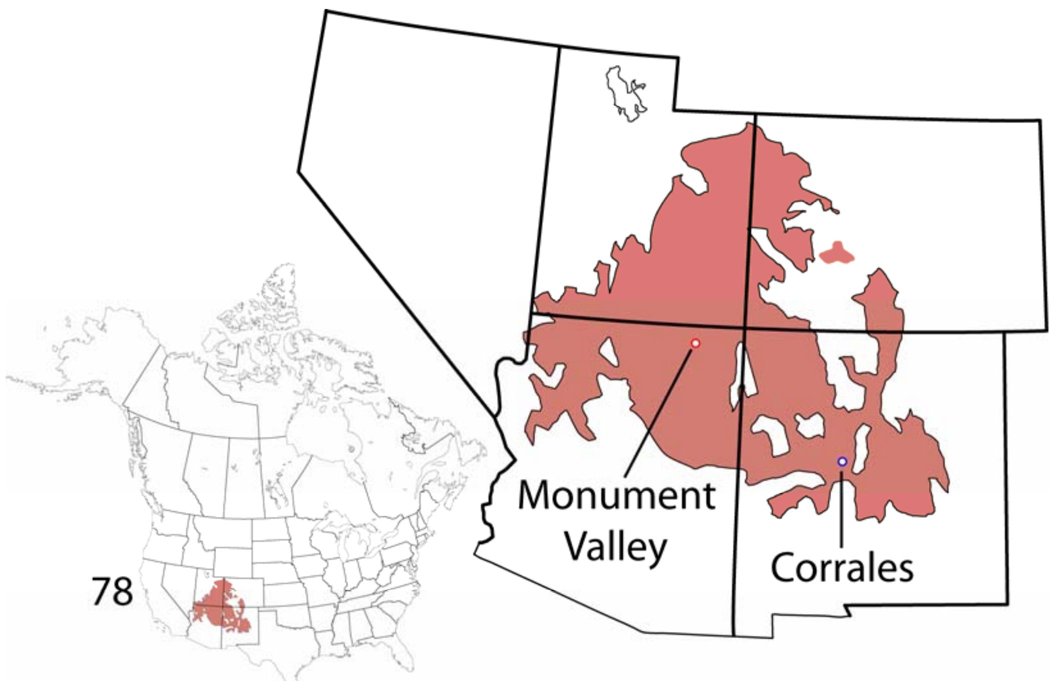


Figure I72. Colorado Plateau Shrublands.

Monument Valley, Arizona

Sorex monticolus
Myotis yumanensis
Myotis occultus
Myotis evotis
Myotis thysanodes
Myotis volans
Myotis californicus
Myotis ciliolabrum
Lasiurus blossevillii
Lasiurus cinereus
Lasionycteris noctivagans
Pipistrellus hesperus
Eptesicus fuscus
Euderma maculatum
Corynorhinus townsendii
Antrozous pallidus
Tadarida brasiliensis
Nyctinomops macrotis
Sylvilagus nuttallii
Sylvilagus audubonii
Lepus californicus
Neotamias rufus
Ammospermophilus leucurus
Spermophilus spilosoma
Spermophilus variegatus
Cynomys gunnisoni
Thomomys bottae
Perognathus flavus
Perognathus flavescens
Dipodomys ordii
Castor canadensis
Reithrodontomys megalotis
Peromyscus crinitus
Peromyscus maniculatus
Peromyscus boylii
Peromyscus truei
Peromyscus nasutus
Onychomys leucogaster
Neotoma albigula
Neotoma stephensi
Neotoma mexicana
Neotoma cinerea
Microtus longicaudus
Microtus mogollonensis
Ondatra zibethicus
Erethizon dorsatum
Canis latrans
Canis lupus
Urocyon cinereoargenteus
Ursus americanus
Ursus arctos
Bassaricus astutus
Mustela nigripes
Taxidea taxus
Lontra canadensis
Spilogale gracilis
Mephitis mephitis
Puma concolor
Lynx rufus
Odocoileus hemionus
Antilocapra americana
Ovis canadensis

Corrales, New Mexico

Sorex monticolus
Notiosorex crawfordi
Myotis yumanensis
Myotis velifer
Myotis occultus
Myotis thysanodes
Myotis volans
Myotis californicus
Myotis ciliolabrum
Lasiurus cinereus
Lasionycteris noctivagans
Pipistrellus hesperus
Eptesicus fuscus
Euderma maculatum
Corynorhinus townsendii
Antrozous pallidus
Tadarida brasiliensis
Nyctinomops macrotis
Sylvilagus audubonii
Lepus californicus
Ammospermophilus interpres
Spermophilus tridecemlineatus
Spermophilus spilosoma
Spermophilus variegatus
Cynomys ludovicianus
Cynomys gunnisoni
Tamiasciurus hudsonicus
Thomomys bottae
Cratogeomys castanops
Perognathus flavus
Perognathus flavescens
Dipodomys ordii
Dipodomys spectabilis
Castor canadensis
Reithrodontomys montanus
Reithrodontomys megalotis
Peromyscus crinitus
Peromyscus maniculatus
Peromyscus leucopus
Peromyscus boylii
Peromyscus truei
Peromyscus nasutus
Onychomys leucogaster
Sigmodon fulviventer
Neotoma micropus
Neotoma albigula
Neotoma mexicana
Clethrionomys gapperi
Microtus longicaudus
Microtus mogollonensis
Ondatra zibethicus
Zapus princeps
Erethizon dorsatum
Canis latrans
Canis lupus
Vulpes vulpes
Vulpes macrotis
Urocyon cinereoargenteus
Ursus americanus
Ursus arctos
Bassaricus astutus
Procyon lotor
Mustela frenata
Mustela nigripes
Taxidea taxus
Lontra canadensis
Spilogale gracilis
Mephitis mephitis
Conepatus leuconotus
Panthera onca
Puma concolor
Lynx rufus
Cervus canadensis
Odocoileus hemionus
Odocoileus virginianus
Antilocapra americana
Bos bison

79. Mojave Desert

Barstow, California

34° 53’ N, 117° 01’ W

max. temp. – 27.4 °C

mean temp. – 18.7 °C

min. temp. – 10.0 °C

precipitation – 11.0 cm/yr

Searchlight, Nevada

35° 28’ N, 114° 55’ W

max. temp. – 23.2 °C

mean temp. – 17.1 °C

min. temp. – 10.8 °C

precipitation – 21.1 cm/yr

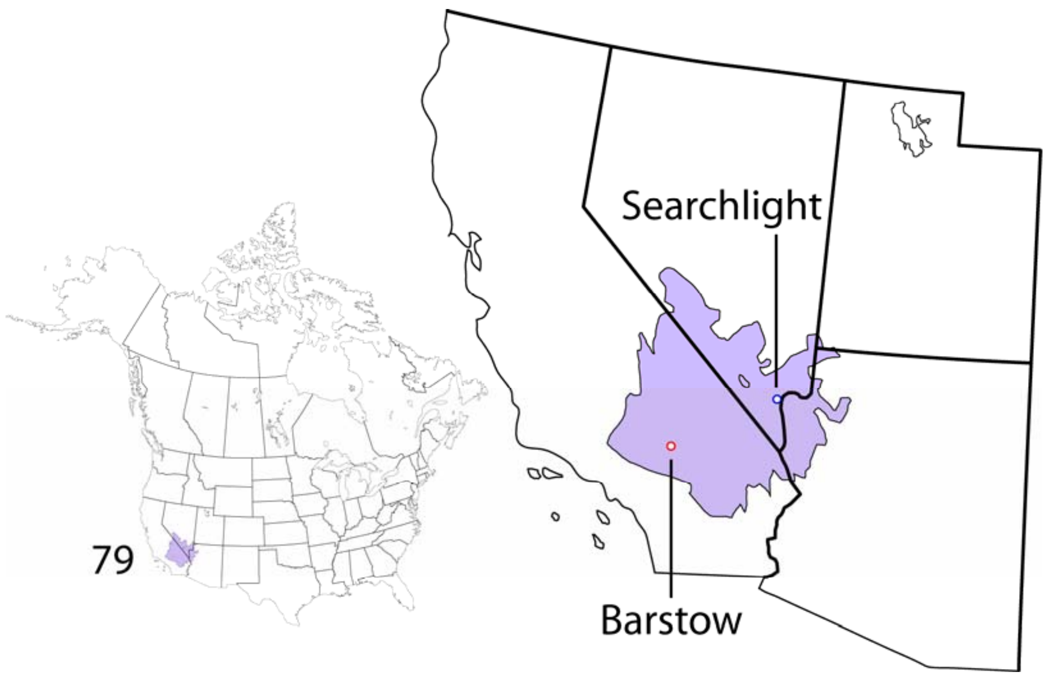


Figure I73. Mojave Desert.

Barstow, California

Notiosorex crawfordi
Myotis yumanensis
Myotis evotis
Myotis thysanodes
Myotis volans
Myotis californicus
Myotis ciliolabrum
Lasiurus blossevillii
Lasiurus cinereus
Lasiurus xanthinus
Pipistrellus hesperus
Eptesicus fuscus
Euderma maculatum
Corynorhinus townsendii
Antrozous pallidus
Tadarida brasiliensis
Nyctinomops macrotis
Sylvilagus audubonii
Lepus californicus
Ammospermophilus leucurus
Speromphilus beecheyi
Spermophilus tereticaudus
Spermophilus lateralis
Sciurus griseus
Glaucomys sabrinus
Thomomys bottae
Perognathus longimembris
Chaetodipus formosus
Perognathus penicillatus
Dipodomys merriami
Dipodomys deserti
Reithrodontomys megalotis
Peromyscus crinitus
Peromyscus californicus
Peromyscus eremicus
Peromyscus maniculatus
Peromyscus boylii
Peromsycus truei
Onychomys torridus
Neotoma lepida
Neotoma macrotis
Canis latrans
Vulpes macrotis
Urocyon cinereoargenteus
Ursus arctos
Bassariscus astutus
Procyon lotor
Spilogale gracilis
Mephitis mephitis
Panthera onca
Puma concolor
Lynx rufus
Antilocapra americana
Ovis canadensis

Searchlight, Nevada

Notiosorex crawfordi
Macrotus californicus
Myotis yumanensis
Myotis evotis
Myotis thysanodes
Myotis volans
Myotis californicus
Myotis ciliolabrum
Lasiurus blossevillii
Lasiurus cinereus
Lasionycteris noctivagans
Pipistrellus hesperus
Eptesicus fuscus
Euderma maculatum
Corynorhinus townsendii
Tadarida brasiliensis
Nyctinomops macrotis
Sylvilagus audubonii
Lepus californicus
Ammospermophilus leucurus
Spermophilus variegatus
Speromphilus tereticaudus
Thomomys bottae
Perognathus longimembris
Chaetodipus formosus
Chaetodipus penicillatus
Dipodomys merriami
Dipodomys deserti
Castor canadensis
Reithrodontomys megalotis
Peromyscus crinitus
Peromyscus eremicus
Peromyscus maniculatus
Peromyscus boylii
Peromyscus truei
Onychomys torridus
Neotoma lepida
Ondatra zibethicus
Erethizon dorsatum
Canis latrans
Canis lupus
Vulpes macrotis
Urocyon cinereoargenteus
Ursus arctos
Bassaricus astutus
Procyon lotor
Taxidea taxus
Lontra canadensis
Spilogale gracilis
Mephitis mephitis
Puma concolor
Lynx rufus
Odocoileus hemionus
Antilocapra americana
Ovis canadensis

80. Sonoran Desert

Yuma, Arizona

32° 40’ N, 114° 36’ W

max. temp. – 31.4 °C

mean temp. – 24.1 °C

min. temp. – 16.6 °C

precipitation – 7.6 cm/yr

Phoenix, Arizona

33° 26’ N, 111° 24’ W

max. temp. – 29.2 °C

mean temp. – 22.7 °C

min. temp. – 16.2 °C

precipitation – 21.1 cm/yr

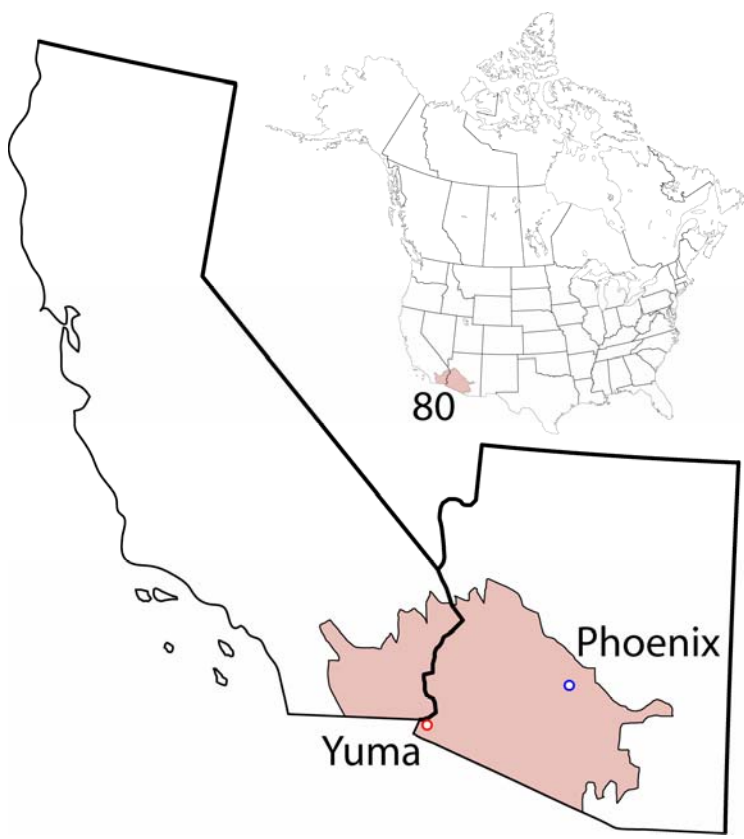


Figure I74. Sonoran Desert.

Yuma, Arizona

Sorex monticolus
Notiosorex crawfordi
Macrotus californicus
Choeronycteris mexicana
Myotis yumanensis
Myotis occultus
Myotis evotis
Myotis thysanodes
Myotis volans
Myotis californicus
Myotis ciliolabrum
Lasiurus blossevillii
Lasiurus cinereus
Pipistrellus hesperus
Eptesicus fuscus
Euderma maculatum
Corynorhinus townsendii
Antrozous pallidus
Tadarida brasiliensis
Nyctinomops femorosaccus
Nyctinomops macrotis
Sylvilagus audubonii
Lepus californicus
Ammospermophilus harrisii
Speromphilus tereticaudus
Thomomys bottae
Perognathus longimembris
Chaetodipus baileyi
Chaetodipus penicillatus
Dipodomys merriami
Dipodomys deserti
Castor canadensis
Reithrodontomys megalotis
Peromyscus crinitus
Peromyscus eremicus
Peromyscus maniculatus
Onychomys torridus
Sigmodon arizonae
Neotoma albigula
Neotoma devia
Ondatra zibethicus
Canis latrans
Vulpes macrotis
Urocyon cinereoargenteus
Ursus arctos
Bassaricus astutus
Procyon lotor
Taxidea taxus
Spilogale gracilis
Mephitis mephitis
Panthera onca
Puma concolor
Lynx rufus
Odocoileus hemionus
Odocoileus virginianus
Antilocapra americana
Ovis canadensis

Phoenix, Arizona

Sorex monticolus
Notiosorex crawfordi
Macrotus californicus
Myotis yumanensis
Myotis velifer
Myotis occultus
Myotis evotis
Myotis thysanodes
Myotis volans
Myotis californicus
Myotis ciliolabrum
Lasiurus blossevillii
Lasiurus cinereus
Pipistrellus hesperus
Eptesicus fuscus
Euderma maculatum
Corynorhinus townsendii
Antrozous pallidus
Tadarida brasiliensis
Nyctinomops macrotis
Sylvilagus floridanus
Sylvilagus audubonii
Lepus californicus
Neotamias cinereicollis
Ammospermophilus harrisii
Spermophilus variegatus
Speromphilus tereticaudus
Thomomys bottae
Perognathus longimembris
Chaetodipus baileyi
Chaetodipus penicillatus
Chaetodipus intermedius
Dipodomys merriami
Reithrodontomys megalotis
Peromyscus eremicus
Peromyscus maniculatus
Onychomys torridus
Sigmodon arizonae
Neotoma albigula
Neotoma lepida
Ondatra zibethicus
Erethizon dorsatum
Canis latrans
Canis lupus
Vulpes macrotis
Urocyon cinereoargenteus
Ursus arctos
Bassaricus astutus
Procyon lotor
Nasua narica
Taxidea taxus
Lontra canadensis
Spilogale gracilis
Mephitis mephitis
Mephitis macroura
Conepatus leuconotus
Panthera onca
Puma concolor
Lynx rufus
Pecari tajacu
Odocoileus hemionus
Odocoileus virginianus
Antilocapra americana
Ovis canadensis

81. Chihuahuan Desert

Columbus, New Mexico

31° 50’ N, 107° 38’ W

max. temp. – 25.4 °C

mean temp. – 17.1 °C

min. temp. – 8.8 °C

precipitation – 26.1 cm/yr

Fort Stockton, Texas

30° 54’ N, 102° 55’ W

max. temp. – 26.7 °C

mean temp. – 18.6 °C

min. temp. – 10.4 °C

precipitation – 35.7 cm/yr

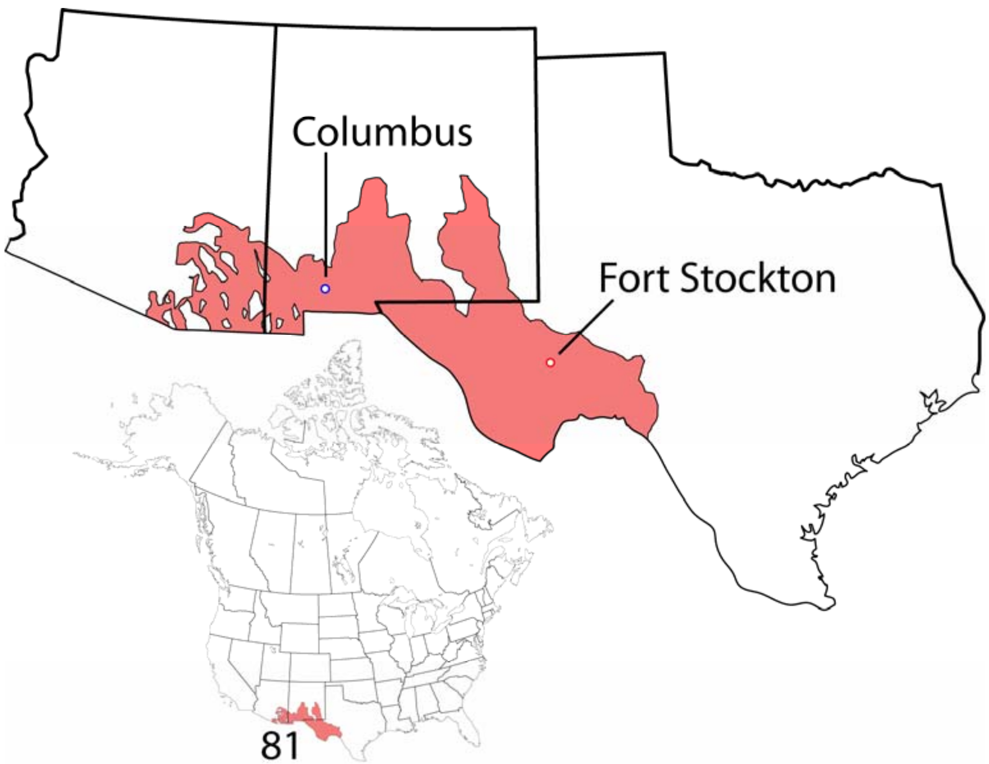


Figure I75. Chihuahuan Desert.

Columbus, New Mexico

Notiosorex crawfordi
Macrotus californicus
Myotis yumanensis
Myotis velifer
Myotis thysanodes
Myotis volans
Myotis californicus
Myotis ciliolabrum
Lasiurus cinereus
Lasionycteris noctivagans
Pipistrellus hesperus
Eptesicus fuscus
Euderma maculatum
Corynorhinus townsendii
Antrozous pallidus
Tadarida brasiliensis
Nyctinomops macrotis
Sylvilagus audubonii
Lepus californicus
Spermophilus spilosoma
Spermophilus variegatus
Cynomys ludovicianus
Geomys arenarius
Perognathus flavescens
Chaetodipus hispidus
Chaetodipus eremicus
Chaetodipus intermedius
Dipodomys ordii
Dipodomys spectabilis
Dipodomys merriami
Castor canadensis
Reithrodontomys montanus
Reithrodontomys megalotis
Peromyscus eremicus
Peromyscus maniculatus
Peromyscus leucopus
Peromyscus boylii
Peromyscus nasutus
Onychomys leucogaster
Onychomys arenicola
Sigmodon hispidus
Sigmodon fulviventer
Neotoma micropus
Neotoma albigula
Neotoma mexicana
Microtus mogollonensis
Erethizon dorsatum
Canis latrans
Canis lupus
Vulpes macrotis
Urocyon cinereoargenteus
Ursus americanus
Ursus arctos
Bassaricus astutus
Procyon lotor
Nasua narica
Mustela frenata
Taxidea taxus
Spilogale gracilis
Mephitis mephitis
Mephitis macroura
Conepatus leuconotus
Panthera onca
Puma concolor
Lynx rufus
Cervus canadensis
Odocoileus hemionus
Odocoileus virginianus
Antilocapra americana
Bos bison
Ovis canadensis

Fort Stockton, Texas

Notiosorex crawfordi
Myotis velifer
Myoits yumanensis
Lasiurus borealis
Lasiurus cinereus
Lasionycteris noctivagans
Pipistrellus hesperus
Corynorhinus townsendii
Antrozous pallidus
Tadarida brasiliensis
Nyctinomops macrotis
Sylvilagus robustus
Lepus californicus
Ammospermophilus interpres
Spermophilus mexicanus
Spermophilus spilosoma
Spermophilus variegatus
Cynomys ludovicianus
Thomomys bottae
Cratogeomys castanops
Perognathus flavus
Perognathus merriami
Chaetodipus hispidus
Chaetodipus intermedius
Chaetodipus nelsoni
Chaetodipus eremicus
Dipodomys spectabilis
Dipodomys merriami
Dipodomys ordii
Reithrodonotmys fulvescens
Reithrodontomys megalotis
Reithrodontomys montanus
Peromyscus eremicus
Peromyscus leucopus
Peromyscus maniculatus
Peromyscus pectoralis
Onychomys arenicola
Onychomys leucogaster
Sigmodon hispidus
Neotoma leucodon
Neotoma micropus
Erethizon dorsatum
Canis latrans
Canis lupus
Vulpes velox
Vulpes vulpes
Urocyon cinereoargenteus
Bassariscus astutus
Procyon lotor
Mustela frenata
Mustela nigripes
Taxidea taxus
Spilogale gracilis
Mephitis mephitis
Conepatus leuconotus
Puma concolor
Lynx rufus
Pecari tajacu
Odocoileus hemionus
Odocoileus virginianus
Antilocapra americana
Bos bison

82. Tamaulipan Mezquital

Eagle Pass, Texas

28° 43’ N, 100° 29’ W

max. temp. – 28.2 °C

mean temp. – 21.6 °C

min. temp. – 14.9 °C

precipitation – 54.6 cm/yr

McAllen, Texas

26° 11’ N, 98° 14’ W

max. temp. – 28.9 °C

mean temp. – 23.2 °C

min. temp. – 17.4 °C

precipitation – 58.3 cm/yr

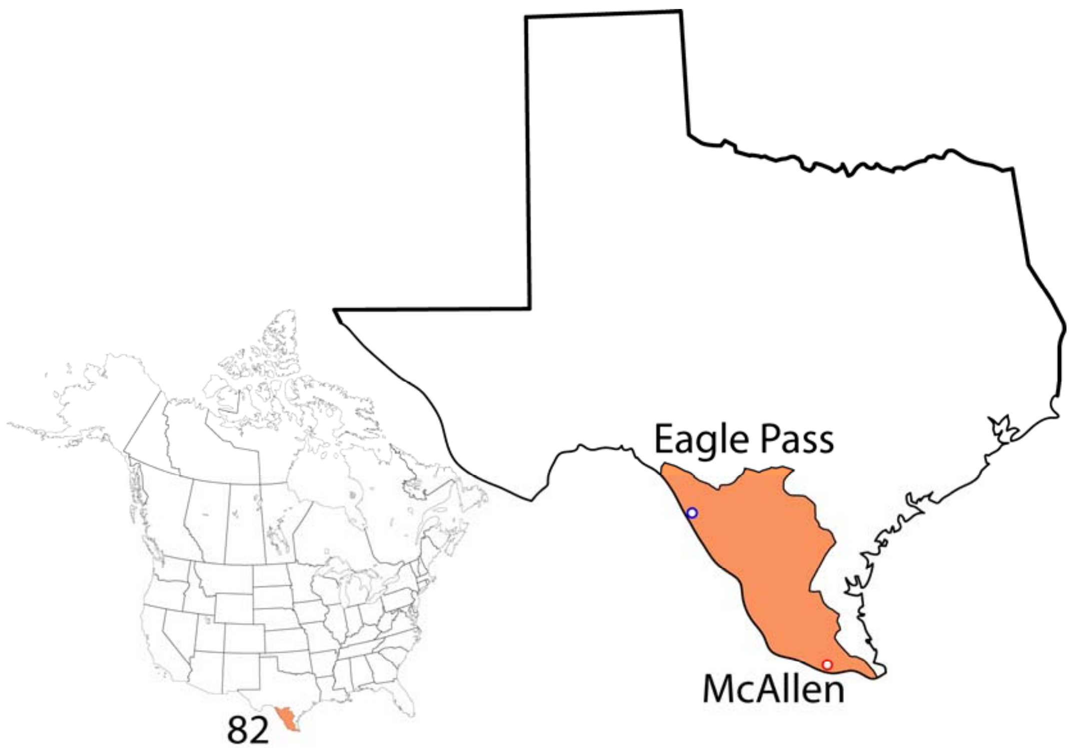


Figure I76. Tamaulipan Mezquital.

Eagle Pass, Texas

Didelphis virginiana
Cryptotis parva
Notiosorex crawfordi
Mormoops megalophylla
Myotis velifer
Myoits yumanensis
Lasiurus borealis
Lasiurus cinereus
Lasionycteris noctivagans
Pipistrellus subflavus
Nycticeius humeralis
Antrozous pallidus
Tadarida brasiliensis
Nyctinomops macrotis
Sylvilagus floridanus
Lepus californicus
Spermophilus mexicanus
Spermophilus spilosoma
Sciurus niger
Geomys personatus
Cratogeomys castanops
Perognathus merriami
Chaetodipus hispidus
Chaetodipus nelsoni
Dipodomys compactus
Dipodomys merriami
Dipodomys ordii
Castor canadensis
Reithrodonotmys fulvescens
Peromyscus eremicus
Peromyscus leucopus
Peromyscus maniculatus
Peromyscus pectoralis
Baiomys taylori
Onychomys leucogaster
Sigmodon hispidus
Neotoma micropus
Canis latrans
Urocyon cinereoargenteus
Ursus americanus
Bassariscus astutus
Procyon lotor
Nasua narica
Mustela frenata
Taxidea taxus
Spilogale gracilis
Mephitis mephitis
Conepatus leuconotus
Puma concolor
Leopardus pardalis
Leopardus wiedii
Lynx rufus
Pecari tajacu
Odocoileus virginianus
Bos bison

McAllen, Texas

Didelphis virginiana
Cryptotis parva
Notiosorex crawfordi
Scalopus aquaticus
Mormoops megalophylla
Choeronycteris mexicana
Myotis velifer
Myoits yumanensis
Lasiurus borealis
Lasiurus cinereus
Lasiurus intermedius
Lasionycteris noctivagans
Pipistrellus subflavus
Nycticeius humeralis
Antrozous pallidus
Tadarida brasiliensis
Nyctinomops macrotis
Sylvilagus floridanus
Lepus californicus
Spermophilus mexicanus
Spermophilus spilosoma
Sciurus niger
Geomys personatus
Cratogeomys castanops
Perognathus merriami
Chaetodipus hispidus
Dipodomys compactus
Dipodomys ordii
Liomys irroratus
Castor canadensis
Reithrodonotmys fulvescens
Peromyscus leucopus
Peromyscus maniculatus
Baiomys taylori
Onychomys leucogaster
Sigmodon hispidus
Neotoma micropus
Canis latrans
Urocyon cinereoargenteus
Ursus americanus
Bassariscus astutus
Procyon lotor
Nasua narica
Mustela frenata
Taxidea taxus
Spilogale putorius
Mephitis mephitis
Conepatus leuconotus
Puma concolor
Leopardus pardalis
Herpailurus yagouaroundi
Panthera onca
Lynx rufus
Pecari tajacu
Odocoileus virginianus
Bos bison

83. Interior Alaska/Yukon Lowland Taiga

Galena, Alaska

64° 44’ N, 156° 56’ W

max. temp. – 0.7 °C

mean temp. – -3.9 °C

min. temp. – -8.4 °C

precipitation – 33.1 cm/yr

Fort Yukon, Alaska

66° 33’ N, 145° 12’ W

max. temp. – -0.9 °C

mean temp. – -6.4 °C

min. temp. – -12.6 °C

precipitation – 19.5 cm/yr

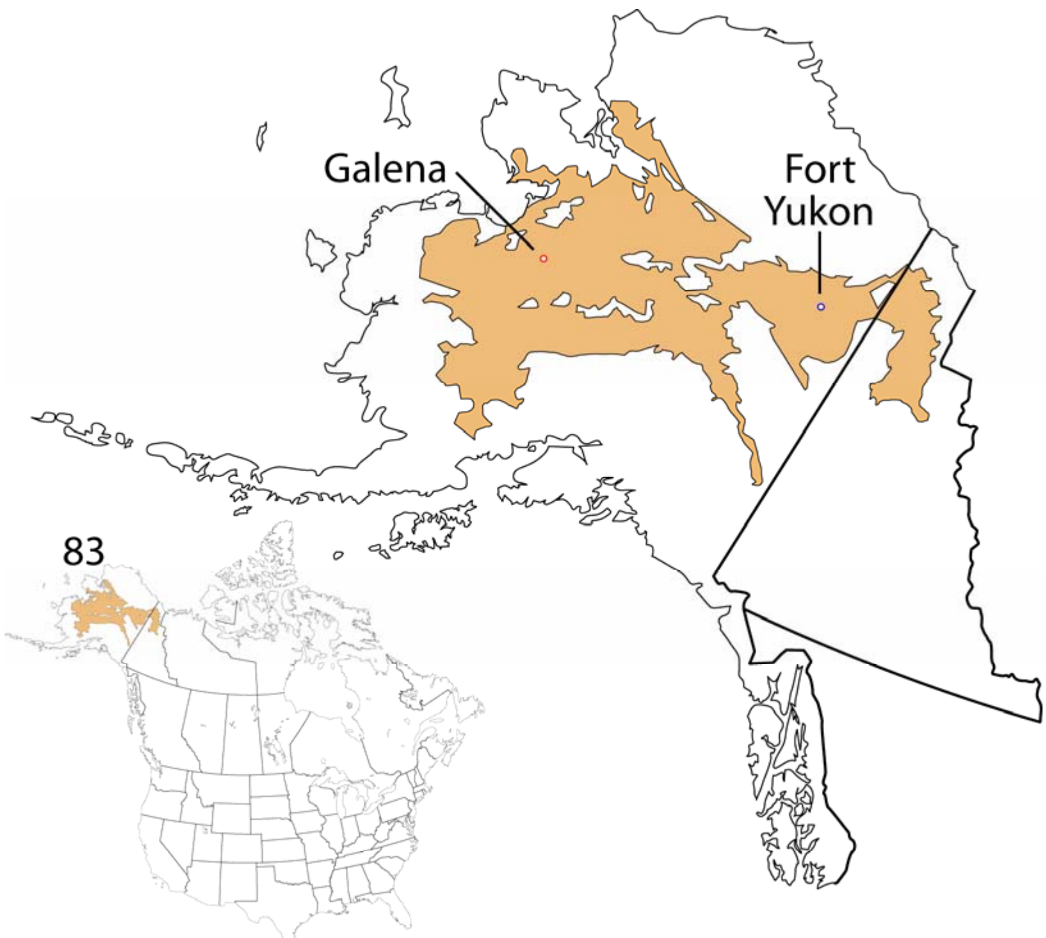


Figure I77. Interior Alaska/Yukon Lowland Taiga.

Galena, Alaska

Sorex cinereus
Sorex monticolus
Sorex arcticus
Lepus americanus
Lepus othus
Tamiasciurus hudsonicus
Castor canadensis
Clethrionomys rutilus
Microtus oeconomus
Ondatra zibethicus
Lemmus nigripes
Synaptomys borealis
Dicrostonyx groenlandicus
Erethizon dorsatum
Canis lupus
Vulpes lagopus
Vulpes vulpes
Ursus americanus
Ursus arctos
Martes americanum
Mustela erminea
Mustela nivalis
Mustela vison
Gulo gulo
Lontra canadensis
Lynx canadensis
Alces alces
Rangifer tarandus
Ovis dalli

Fort Yukon, Alaska

Sorex cinereus
Sorex monticolus
Sorex arcticus
Lepus americanus
Marmota caligata
Spermophilus parryii
Tamiasciurus hudsonicus
Castor canadensis
Clethrionomys rutilus
Microtus oeconomus
Microtus xanthognathus
Ondatra zibethicus
Lemmus nigripes
Synaptomys borealis
Dicrostonyx rubricatus
Erethizon dorsatum
Canis latrans
Canis lupus
Vulpes lagopus
Vulpes vulpes
Ursus americanus
Ursus arctos
Martes americanum
Mustela erminea
Mustela nivalis
Mustela vison
Gulo gulo
Lontra canadensis
Lynx canadensis
Alces alces
Rangifer tarandus
Ovis dalli

84. Alaska Peninsula Montane Taiga

Chignik, Alaska

56° 12’ N, 158° 14’ W

max. temp. – 6.6 °C

mean temp. – 4.4 °C

min. temp. – -0.3 °C

precipitation – 286.5 cm/yr

Kodiak, Alaska

57° 45’ N, 152° 30’ W

max. temp. – 7.8 °C

mean temp. – 4.7 °C

min. temp. – 1.6 °C

precipitation – 191.4 cm/yr

Figure I78. Alaska Peninsula Montane Taiga.

Chignik, Alaska

Sorex cinereus
Sorex monticolus
Sorex arcticus
Lepus othus
Spermophilus parryii
Microtus oeconomus
Ondatra zibethicus
Zapus hudsonius
Erethizon dorsatum
Canis lupus
Vulpes vulpes
Ursus arctos
Mustela erminea
Mustela nivalis
Mustela vison
Gulo gulo
Lontra canadensis
Lynx canadensis
Rangifer tarandus

Kodiak, Alaska

Sorex cinereus
Sorex monticolus
Sorex arcticus
Myotis lucifugus
Spermophilus parryii
Microtus oeconomus
Dicrostonyx groenlandicus
Erethizon dorsatum
Canis lupus
Vulpes vulpes
Ursus arctos
Mustela erminea
Gulo gulo
Lontra canadensis
Lynx canadensis
Rangifer tarandus

85. Cook Inlet Taiga

Kenai, Alaska

60° 40’ N, 151° 19’ W

max. temp. – 6.4 °C

mean temp. – 1.7 °C

min. temp. – -3.2 °C

precipitation – 55.4 cm/yr

Wasilla, Alaska

61° 32’ N, 149° 26’ W

max. temp. – 8.0 °C

mean temp. – 2.7 °C

min. temp. – -2.7 °C

precipitation – 42.2 cm/yr

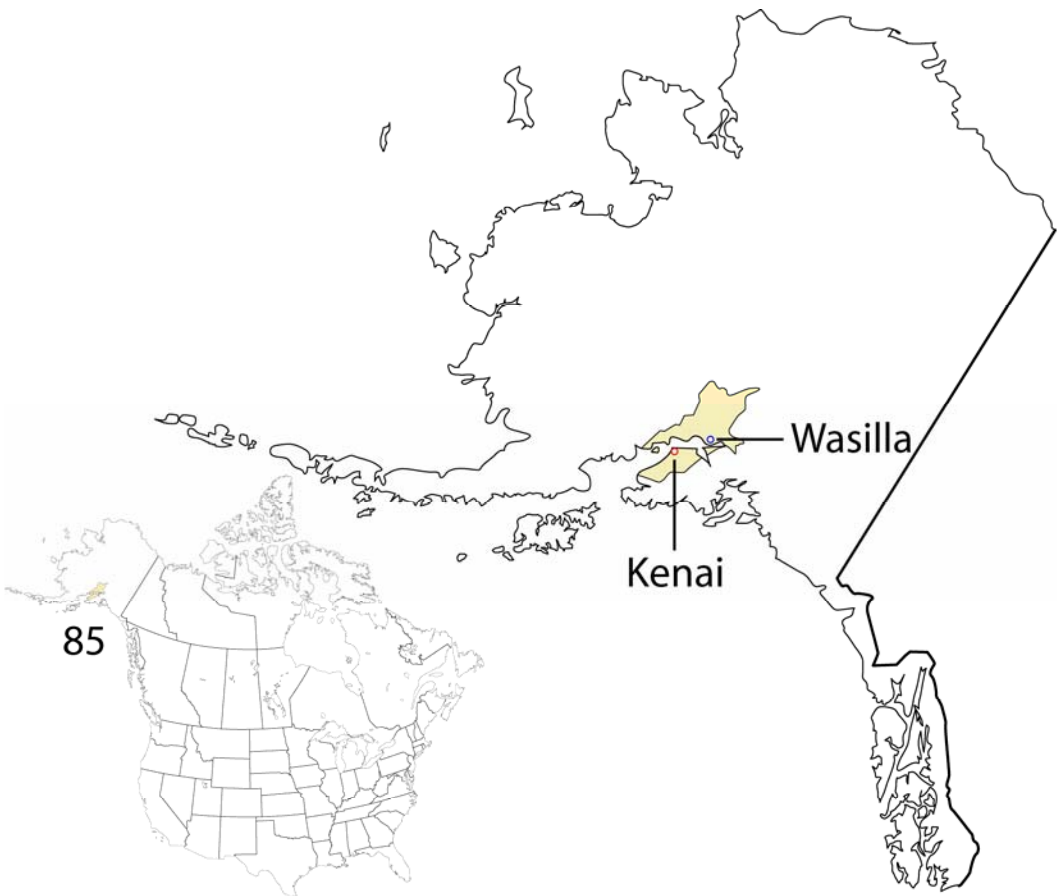


Figure I79. Cook Inlet Taiga.

Kenai, Alaska

Sorex cinereus
Sorex monticolus
Sorex palustris
Sorex hoyi
Myotis lucifugus
Lepus americanus
Marmota caligata
Tamiasciurus hudsonicus
Glaucomys sabrinus
Castor canadensis
Clethrionomys rutilus
Microtus pennsylvanicus
Microtus oeconomus
Microtus miurus
Ondatra zibethicus
Synaptomys borealis
Zapus hudsonius
Erethizon dorsatum
Canis latrans
Canis lupus
Vulpes vulpes
Ursus americanus
Ursus arctos
Martes americanum
Mustela erminea
Mustela nivalis
Mustela vison
Gulo gulo
Lontra canadensis
Lynx canadensis
Alces alces
Rangifer tarandus
Ovis dalli

Wasilla, Alaska

Sorex cinereus
Sorex monticolus
Sorex palustris
Sorex hoyi
Myotis lucifugus
Lepus americanus
Marmota caligata
Spermophilus parryii
Tamiasciurus hudsonicus
Glaucomys sabrinus
Castor canadensis
Clethrionomys rutilus
Microtus pennsylvanicus
Microtus oeconomus
Microtus miurus
Ondatra zibethicus
Synaptomys borealis
Zapus hudsonius
Erethizon dorsatum
Canis latrans
Canis lupus
Vulpes vulpes
Ursus americanus
Ursus arctos
Martes americanum
Mustela erminea
Mustela nivalis
Mustela vison
Gulo gulo
Lontra canadensis
Lynx canadensis
Alces alces
Rangifer tarandus
Ovis dalli

86. Copper Plateau Taiga

Lake Susitna, Alaska	Glennallen, Alaska
62° 27' N, 146° 41' W	62° 07' N, 145° 32' W
max. temp. – 3.0 °C	max. temp. – 3.9 °C
mean temp. – -3.7 °C	mean temp. – -3.3 °C
min. temp. – -10.4 °C	min. temp. – -10.5 °C
precipitation – 32.0 cm/yr	precipitation – 28.4 cm/yr

Figure I80. Copper Plateau Taiga.

Lake Susitna, Alaska

Sorex cinereus
Sorex monticolus
Sorex palustris
Myotis lucifugus
Lepus americanus
Marmota caligata
Castor canadensis
Clethrionomys rutilus
Microtus pennsylvanicus
Microtus oeconomus
Microtus miurus
Ondatra zibethicus
Synaptomys borealis
Zapus hudsonius
Erethizon dorsatum
Canis latrans
Canis lupus
Vulpes vulpes
Ursus americanus
Ursus arctos
Martes americanum
Mustela erminea
Mustela nivalis
Mustela vison
Gulo gulo
Lontra canadensis
Lynx canadensis
Alces alces
Rangifer tarandus
Ovis dalli

Glennallen, Alaska

Sorex cinereus
Sorex monticolus
Sorex palustris
Myotis lucifugus
Lepus americanus
Marmota caligata
Castor canadensis
Clethrionomys rutilus
Microtus pennsylvanicus
Microtus oeconomus
Microtus miurus
Ondatra zibethicus
Synaptomys borealis
Zapus hudsonius
Erethizon dorsatum
Canis latrans
Canis lupus
Vulpes vulpes
Ursus americanus
Ursus arctos
Martes americanum
Mustela erminea
Mustela nivalis
Mustela vison
Gulo gulo
Lontra canadensis
Lynx canadensis
Alces alces
Rangifer tarandus
Ovis dalli

87. Northwest Territories Taiga

Fort McPherson, Northwest Territories

67° 26’ N, 134° 53’ W

max. temp. – -3.9 °C

mean temp. – -8.7 °C

min. temp. – -13.7 °C

precipitation – 31.3 cm/yr

Déline, Northwest Territories

65° 13’ N, 123° 26’ W

max. temp. – -1.0 °C

mean temp. – -5.9 °C

min. temp. – -10.9 °C

precipitation – 26.1 cm/yr

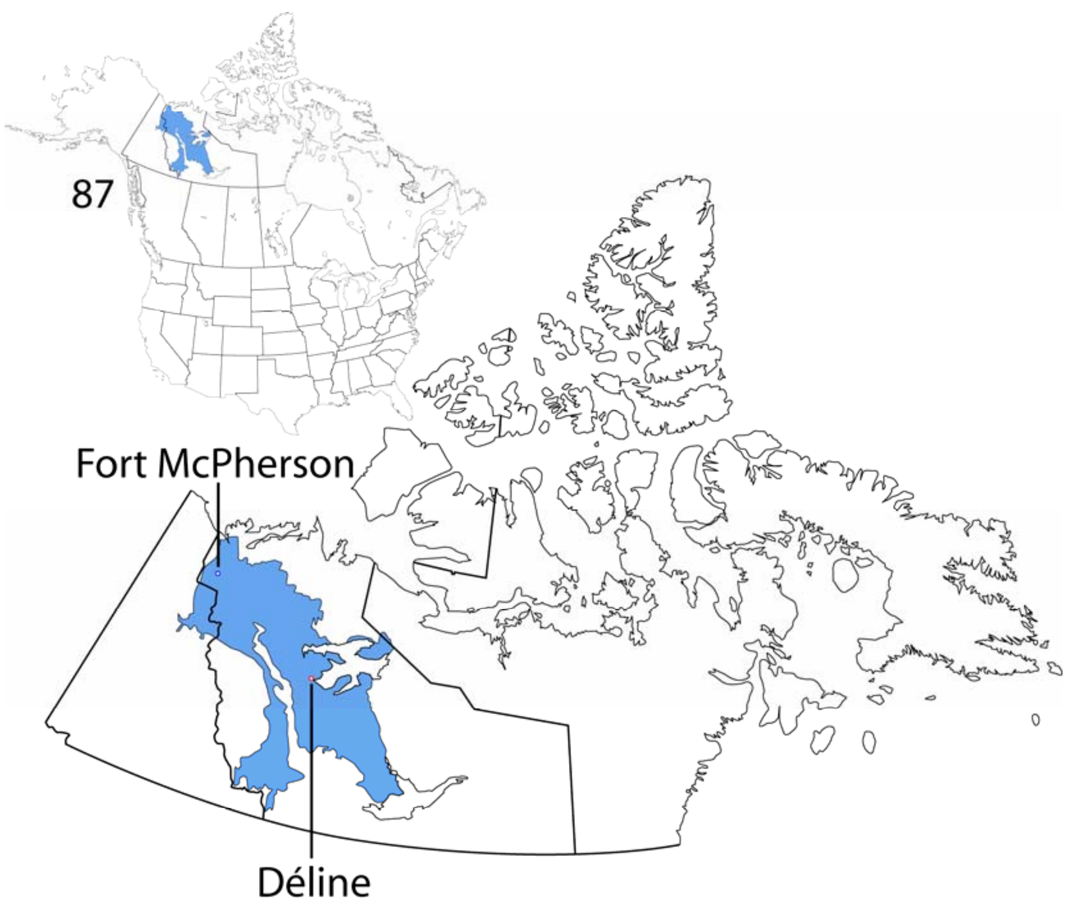


Figure I81. Northwest Territories Taiga.

Fort McPherson, Northwest Tertitories

Sorex cinereus
Sorex arcticus
Lepus americanus
Marmota caligata
Spermophilus parryii
Tamiasciurus hudsonicus
Castor canadensis
Clethrionomys rutilus
Microtus pennsylvanicus
Microtus oeconomus
Microtus xanthognathus
Microtus miurus
Ondatra zibethicus
Lemmus trimucronatus
Dicrostonyx kilangmiutak
Erethizon dorsatum

Canis lupus
Vulpes vulpes
Ursus americanus
Ursus arctos
Ursus maritimus
Martes americana
Mustela erminea
Mustela nivalis
Mustela vison
Gulo gulo
Lontra canadensis
Lynx canadensis
Alces alces
Rangifer tarandus
Oreamnos americanus

Déline, Northwest Territories

Sorex cinereus
Sorex arcticus
Sorex hoyi
Lepus americanus
Spermophilus parryii
Tamiasciurus hudsonicus
Glaucomys sabrinus
Castor canadensis
Peromyscus maniculatus
Clethrionomys rutilus
Microtus pennsylvanicus
Microtus oeconomus
Microtus xanthognathus
Ondatra zibethicus
Lemmus trimucronatus
Synaptomys borealis
Erethizon dorsatum
Canis lupus
Vulpes lagopus
Vulpes vulpes
Ursus americanus
Ursus arctos
Martes americana
Mustela erminea
Mustela nivalis
Mustela vison
Gulo gulo
Lontra canadensis
Lynx canadensis
Alces alces
Rangifer tarandus
Bos bison

88. Yukon Interior Dry Forests

Carmacks, Yukon Territory

62° 06’ N, 136° 18’ W

max. temp. – 1.9 °C

mean temp. – -4.3 °C

min. temp. – -10.5 °C

precipitation – 27.1 cm/yr

Whitehorse, Yukon Territory

60° 42’ N, 135° 04’ W

max. temp. – 4.5 °C

mean temp. – -0.7 °C

min. temp. – -5.9 °C

precipitation – 26.7 cm/yr

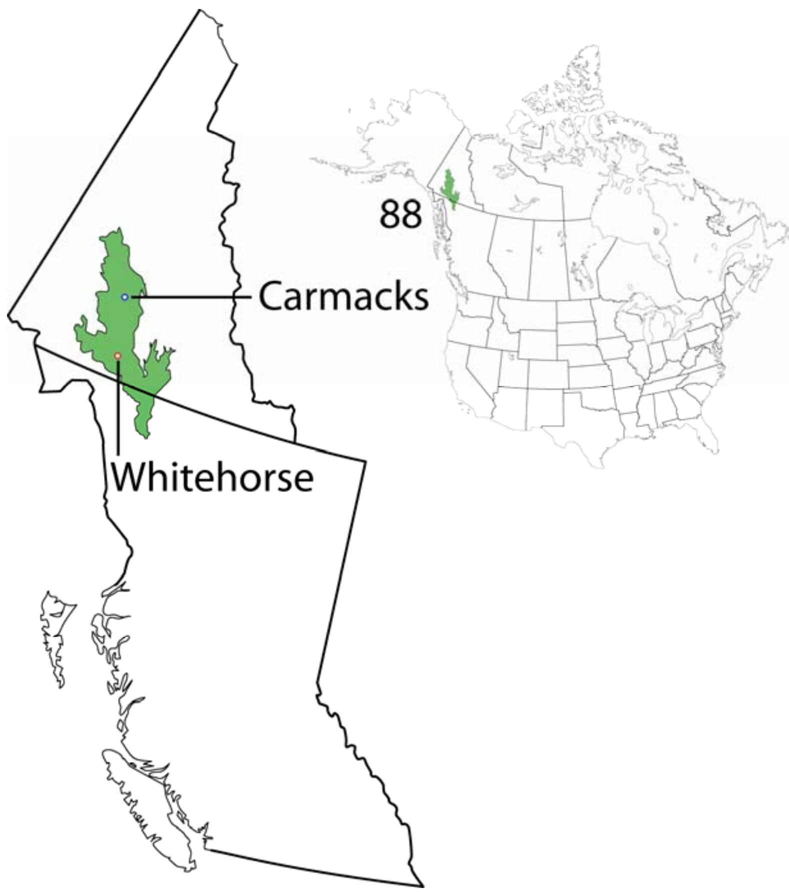


Figure I82. Yukon Interior Dry Forests.

Carmacks, Yukon Territory

Sorex cinereus
Sorex arcticus
Sorex monticolus
Sorex palustris
Sorex hoyi
Myotis lucifugus
Ochotona princeps
Lepus americanus
Neotamias minimus
Marmota monax
Marmota caligata
Spermophilus parryii
Tamiasciurus hudsonicus
Glaucomys sabrinus
Castor canadensis
Peromyscus maniculatus
Neotoma cinerea
Clethrionomys rutilus
Microtus pennsylvanicus
Microtus oeconomus
Microtus longicaudus
Ondatra zibethicus
Lemmus sibiricus
Synaptomys borealis
Zapus hudsonius
Erethizon dorsatum
Canis latrans
Canis lupus
Vulpes vulpes
Ursus americanus
Ursus arctos
Martes americana
Mustela erminea
Mustela nivalis
Mustela vison
Gulo gulo
Lontra canadensis
Puma concolor
Lynx canadensis
Odocoileus hemionus
Alces alces
Rangifer tarandus
Ovis nivicola

Whitehorse, Yukon Territory

Sorex cinereus
Sorex palustris
Sorex arcticus
Sorex monticolus
Sorex hoyi
Myotis lucifugus
Ochotona princeps
Lepus americanus
Neotamias minimus
Marmota monax
Marmota caligata
Spermophilus parryii
Tamiasciurus hudsonicus
Glaucomys sabrinus
Castor canadensis
Peromyscus maniculatus
Neotoma cinerea
Clethrionomys rutilus
Phenacomys ungava
Microtus pennsylvanicus
Microtus oeconomus
Microtus longicaudus
Ondatra zibethicus
Lemmus sibiricus
Synaptomys borealis
Zapus hudsonius
Erethizon dorsatum
Canis latrans
Canis lupus
Vulpes vulpes
Ursus americanus
Ursus arctos
Martes americana
Mustela erminea
Mustela nivalis
Mustela vison
Gulo gulo
Lontra canadensis
Lynx canadensis
Puma concolor
Odocoileus hemionus
Alces alces
Rangifer tarandus
Ovis nivicola

89. Northern Cordillera Forests

Dease Lake, British Columbia

58° 25’ N, 130° 00’ W

max. temp. – 5.0 °C

mean temp. – -0.8 °C

min. temp. – -6.5 °C

precipitation – 42.6 cm/yr

Watson Lake, Yukon Territory

60° 07’ N, 128° 49’ W

max. temp. – 3.1 °C

mean temp. – -2.9 °C

min. temp. – -8.8 °C

precipitation – 40.4 cm/yr

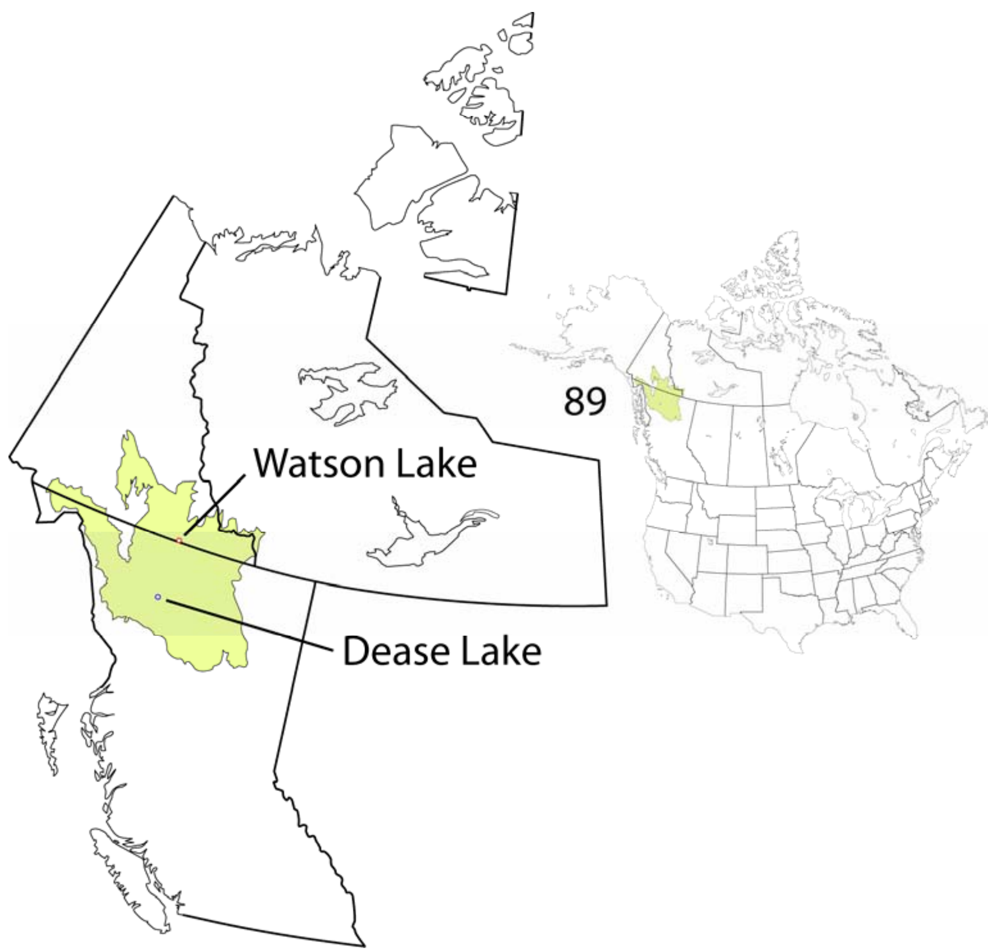


Figure I83. Northern Cordillera Forests.

Dease Lake, British Columbia

Sorex cinereus
Sorex monticolus
Sorex palustris
Sorex hoyi
Myotis lucifugus
Lepus americanus
Marmota caligata
Spermophilus parryi
Neotamias minimus
Tamiasciurus hudsonicus
Glaucomys sabrinus
Castor canadensis
Peromyscus maniculatus
Neotoma cinerea
Clethrionomys rutilus
Clethrionomys gapperi
Microtus pennsylvanicus
Ondatra zibethicus
Synaptomys borealis
Zapus hudsonius
Zapus princeps
Erethizon dorsatum
Canis latrans
Canis lupus
Vulpes vulpes
Ursus americanus
Ursus arctos
Martes americana
Martes pennanti
Mustela erminea
Mustela nivalis
Mustela vison
Gulo gulo
Lontra canadensis
Lynx canadensis
Alces alces
Rangifer tarandus
Oreamnos americanus
Ovis dalli

Watson Lake, Yukon Territory

Sorex cinereus
Sorex palustris
Sorex arcticus
Sorex monticolus
Sorex hoyi
Myotis lucifugus
Lepus americanus
Neotamias minimus
Marmota monax
Marmota caligata
Spermophilus parryii
Tamiasciurus hudsonicus
Glaucomys sabrinus
Castor canadensis
Peromyscus maniculatus
Neotoma cinerea
Clethrionomys rutilus
Phenacomys ungava
Microtus pennsylvanicus
Microtus oeconomus
Microtus longicaudus
Ondatra zibethicus
Lemmus sibiricus
Synaptomys borealis
Zapus hudsonius
Erethizon dorsatum
Canis latrans
Canis lupus
Vulpes vulpes
Ursus americanus
Ursus arctos
Martes americana
Mustela erminea
Martes pennanti
Mustela vison
Gulo gulo
Lontra canadensis
Puma concolor
Lynx canadensis
Odocoileus hemionus
Alces alces
Rangifer tarandus
Ovis nivicola

90. Muskwa/Slave Lake Forests

Fort Nelson, British Columbia

58° 50’ N, 122° 36’ W

max. temp. – 5.0 °C

mean temp. – -0.7 °C

min. temp. – -6.4 °C

precipitation – 45.2 cm/yr

Hay River, Northwest Territories

60° 50’ N, 115° 46’ W

max. temp. – 2.1 °C

mean temp. – -2.9 °C

min. temp. – -7.9 °C

precipitation – 32.0 cm/yr

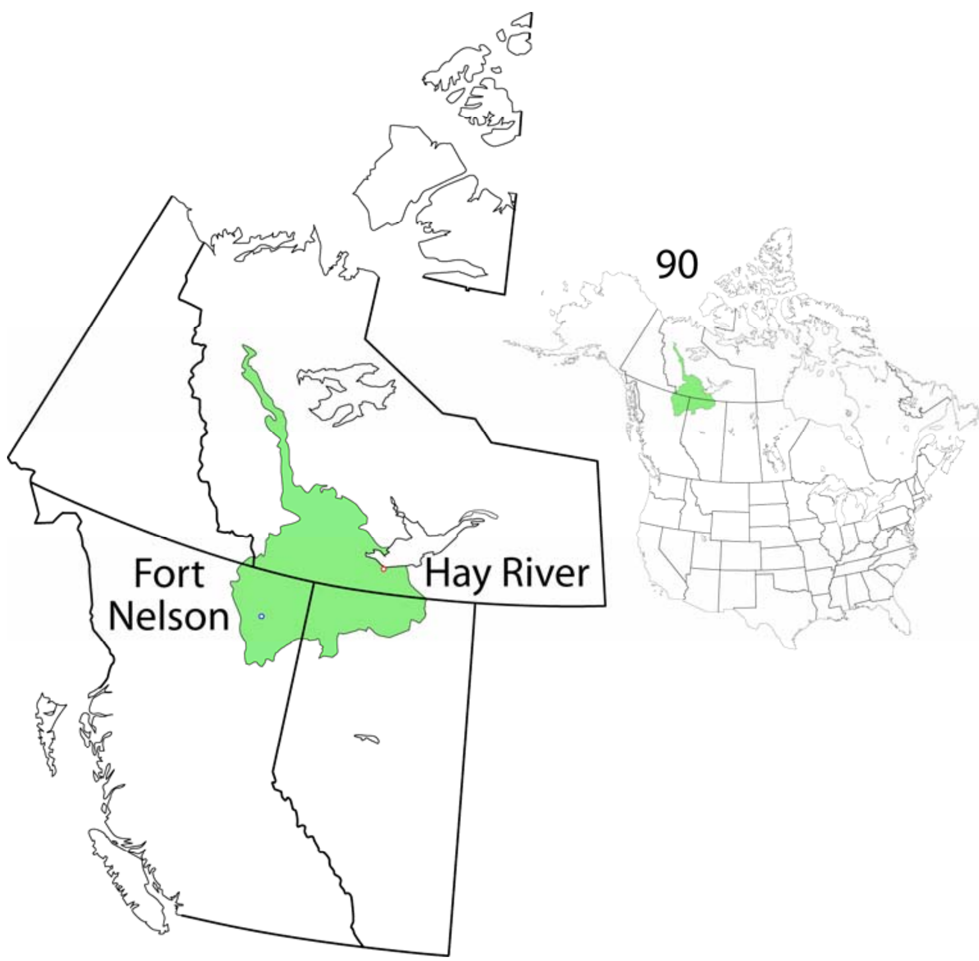


Figure I84. Muskwa/Slave Lake Forests.

Fort Nelson, British Columbia

Sorex cinereus
Sorex monticolus
Sorex palustris
Sorex hoyi
Myotis lucifugus
Lepus americanus
Neotamias minimus
Tamiasciurus hudsonicus
Glaucomys sabrinus
Castor canadensis
Peromyscus maniculatus
Neotoma cinerea
Clethrionomys gapperi
Phenacomys ungava
Microtus pennsylvanicus
Microtus longicaudus
Ondatra zibethicus
Zapus hudsonius
Zapus princeps
Erethizon dorsatum
Canis latrans
Canis lupus
Vulpes vulpes
Ursus americanus
Ursus arctos
Martes americana
Martes pennanti
Mustela erminea
Mustela nivalis
Mustela vison
Gulo gulo
Lontra canadensis
Mephitis mephitis
Lynx canadensis
Cervus canadensis
Odocoileus hemionus
Alces alces
Rangifer tarandus
Bos bison

Hay River, Northwest Territories

Sorex cinereus
Sorex monticolus
Sorex palustris
Sorex arcticus
Myotis lucifugus
Lepus americanus
Neotamias minimus
Marmota monax
Tamiasciurus hudsonicus
Glaucomys sabrinus
Castor canadensis
Peromyscus maniculatus
Clethrionomys gapperi
Phenacomys ungava
Microtus pennsylvanicus
Microtus xanthognathus
Ondatra zibethicus
Synaptomys borealis
Zapus hudsonius
Erethizon dorsatum
Canis latrans
Canis lupus
Vulpes vulpes
Ursus americanus
Ursus arctos
Martes americana
Martes pennanti
Mustela erminea
Mustela nivalis
Mustela vison
Gulo gulo
Lontra canadensis
Mephitis mephitis
Lynx canadensis
Odocoileus hemionus
Alces alces
Rangifer tarandus
Bos bison

91. Northern Canadian Shield Taiga

Yellowknife, Northwest Territories

62° 27’ N, 114° 26’ W

max. temp. – -0.2 °C

mean temp. – -4.6 °C

min. temp. – -9.0 °C

precipitation – 28.1 cm/yr

Ennadai Lake, Nunavut

61° 08’ N, 100° 54’ W

max. temp. – -5.1 °C

mean temp. – -9.4 °C

min. temp. – -13.6 °C

precipitation – 29.3 cm/yr

Figure I85. Northern Canadian Shield Taiga.

Yellowknife, Northwest Territories

Sorex cinereus
Sorex palustris
Sorex arcticus
Sorex hoyi
Lepus americanus
Lepus arcticus
Spermophilus parryii
Tamiasciurus hudsonicus
Castor canadensis
Peromyscus maniculatus
Clethrionomys rutilus
Phenacomys ungava
Microtus pennsylvanicus
Microtus xanthognathus
Ondatra zibethicus
Lemmus trimucronatus
Synaptomys borealis
Erethizon dorsatum
Canis lupus
Vulpes lagopus
Vulpes vulpes
Ursus americanus
Ursus arctos
Martes americana
Mustela erminea
Mustela nivalis
Mustela vison
Gulo gulo
Lontra canadensis
Lynx canadensis
Alces alces
Rangifer tarandus

Ennadai Lake, Nunavut

Sorex ugyunak
Sorex arcticus
Sorex hoyi
Lasiurus cinereus
Lepus americanus
Spermophilus parryii
Tamiasciurus hudsonicus
Glaucomys sabrinus
Castor canadensis
Clethrionomys gapperi
Phenacomys ungava
Microtus pennsylvanicus
Microtus xanthognathus
Ondatra zibethicus
Synaptomys borealis
Dicrostonyx richardsoni
Zapus hudsonius
Erethizon dorsatum
Canis lupus
Vulpes lagopus
Vulpes vulpes
Ursus americanus
Ursus arctos
Martes americana
Martes pennanti
Mustela erminea
Mustela nivalis
Mustela vison
Gulo gulo
Lontra canadensis
Lynx canadensis
Alces alces
Rangifer tarandus
Ovibos moschatus

92. Mid-Continental Canadian Shield Forests

Fort McMurray, Alberta	The Pas, Manitoba
56° 39’ N, 111° 13’ W	53° 58’ N, 101° 06’ W
max. temp. – 6.7 °C	max. temp. – 5.4 °C
mean temp. – 0.7 °C	mean temp. – 0.1 °C
min. temp. – -5.3 °C	min. temp. – -5.2 °C
precipitation – 45.6 cm/yr	precipitation – 44.3 cm/yr

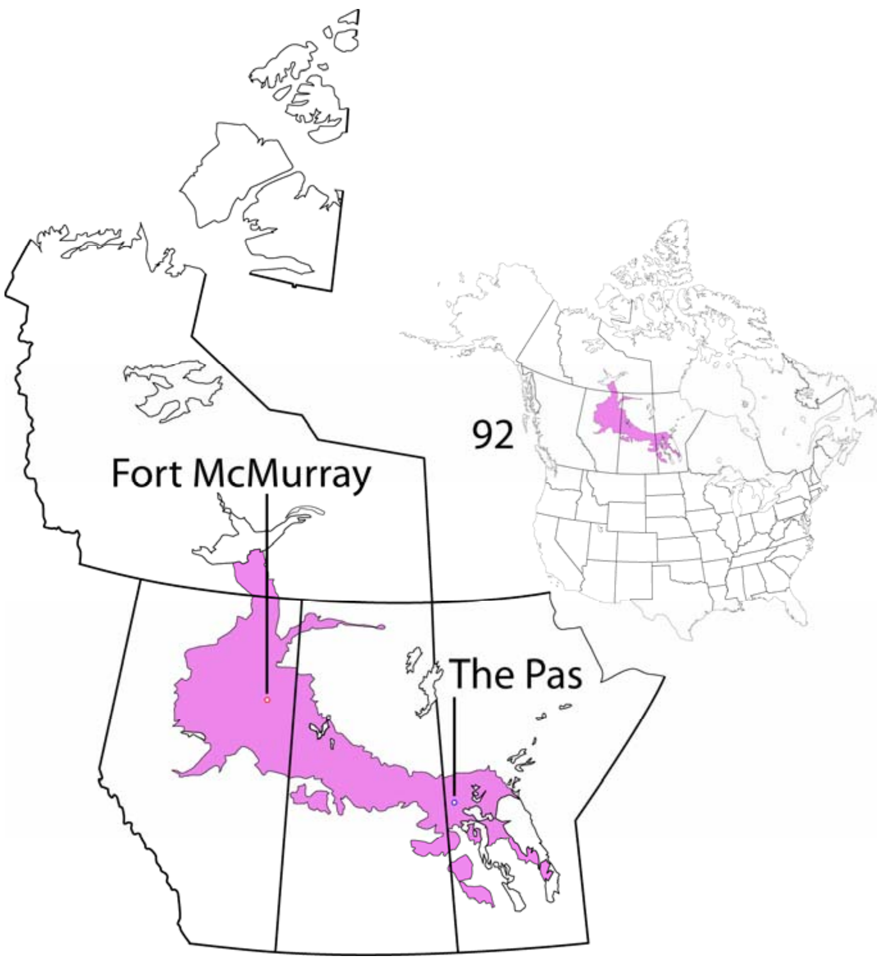


Figure I86. Mid-Continental Canadian Shield Forests.

Fort McMurray, Alberta

Sorex cinereus
Sorex palustris
Sorex arcticus
Myotis lucifugus
Myotis septentrionalis
Lasiurus cinereus
Eptesicus fuscus
Lepus americanus
Neotamias minimus
Marmota monax
Tamiasciurus hudsonicus
Glaucomys sabrinus
Castor canadensis
Peromyscus maniculatus
Clethrionomys gapperi
Phenacomys ungava
Microtus pennsylvanicus
Microtus xanthognathus
Ondatra zibethicus
Synaptomys borealis
Zapus hudsonius
Erethizon dorsatum
Canis latrans
Canis lupus
Vulpes vulpes
Ursus americanus
Ursus arctos
Martes americana
Martes pennanti
Mustela erminea
Mustela nivalis
Mustela vison
Gulo gulo
Lontra canadensis
Mephitis mephitis
Lynx canadensis
Cervus canadensis
Odocoileus hemionus
Alces alces
Rangifer tarandus
Bos bison

The Pas, Manitoba

Sorex cinereus
Sorex palustris
Sorex arcticus
Blarina brevicauda
Myotis lucifugus
Myotis septentrionalis
Lasiurus cinereus
Lepus americanus
Neotamias minimus
Marmota monax
Tamiasciurus hudsonicus
Glaucomys sabrinus
Castor canadensis
Peromyscus maniculatus
Clethrionomys gapperi
Phenacomys ungava
Microtus pennsylvanicus
Ondatra zibethicus
Synaptomys borealis
Zapus hudsonius
Erethizon dorsatum
Canis lupus
Ursus americanus
Ursus arctos
Martes americana
Martes pennanti
Mustela erminea
Mustela nivalis
Mustela vison
Gulo gulo
Lontra canadensis
Mephitis mephitis
Lynx canadensis
Cervus canadensis
Alces alces
Rangifer tarandus
Bos bison

93. Midwestern Canadian Shield Forests

Thompson, Manitoba	Red Lake, Ontario
55° 58’ N, 97° 52’ W	51° 04’ N, 93° 47’ W
max. temp. – 3.0 °C	max. temp. – 6.4 °C
mean temp. – -3.2 °C	mean temp. – 0.9 °C
min. temp. – -9.4 °C	min. temp. – -4.6 °C
precipitation – 51.7 cm/yr	precipitation – 64.0 cm/yr

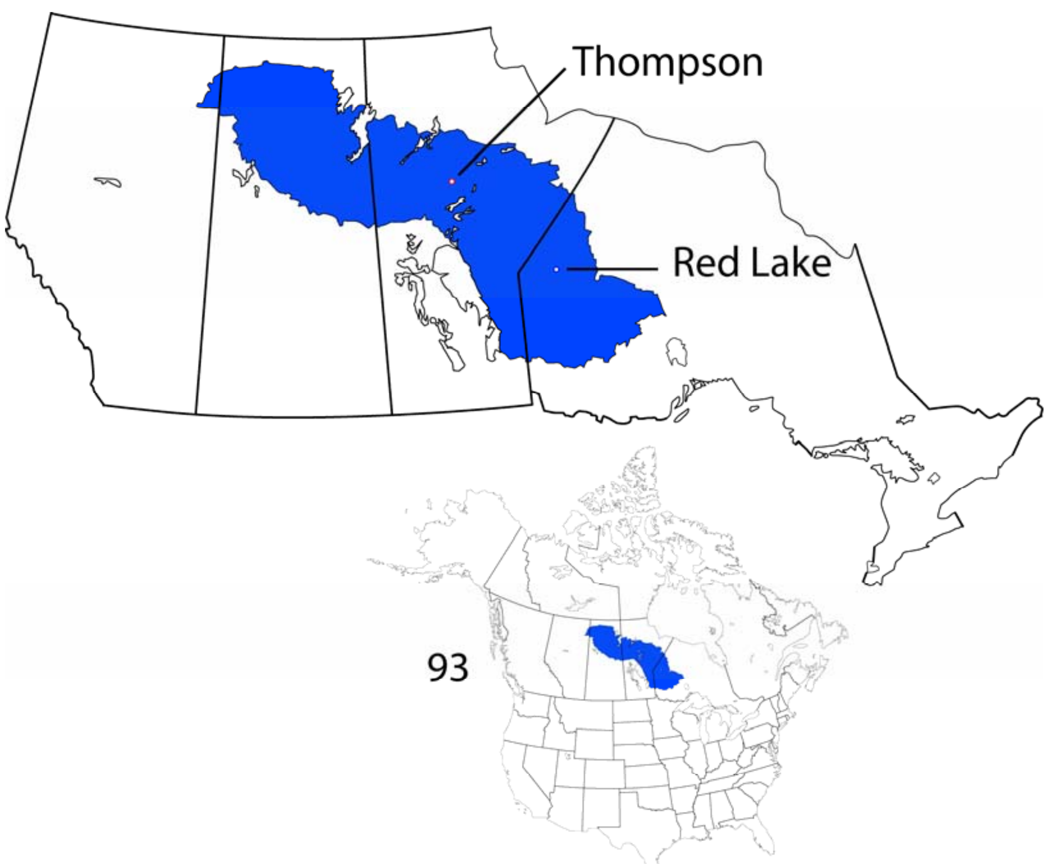


Figure I87. Midwestern Canadian Shield Forests.

Thompson, Manitoba

Sorex cinereus
Sorex palustris
Sorex arcticus
Myotis lucifugus
Lasiurus cinereus
Lepus americanus
Neotamias minimus
Marmota monax
Tamiasciurus hudsonicus
Glaucomys sabrinus
Castor canadensis
Peromyscus maniculatus
Clethrionomys gapperi
Phenacomys ungava
Microtus pennsylvanicus
Ondatra zibethicus
Synaptomys borealis
Zapus hudsonius
Erethizon dorsatum
Canis lupus
Vulpes lagopus
Vulpes vulpes
Ursus americanus
Ursus arctos
Martes americana
Martes pennanti
Mustela erminea
Mustela nivalis
Mustela vison
Gulo gulo
Lontra canadensis
Mephitis mephitis
Lynx canadensis
Alces alces
Rangifer tarandus

Red Lake, Ontario

Sorex cinereus
Sorex palustris
Sorex arcticus
Myotis lucifugus
Lasiurus cinereus
Lasionycteris noctivagans
Lepus americanus
Neotamias minimus
Marmota monax
Tamiasciurus hudsonicus
Glaucomys sabrinus
Castor canadensis
Peromyscus maniculatus
Clethrionomys gapperi
Phenacomys ungava
Microtus pennsylvanicus
Ondatra zibethicus
Synaptomys borealis
Zapus hudsonius
Erethizon dorsatum
Canis lupus
Vulpes vulpes
Ursus americanus
Martes americana
Martes pennanti
Mustela erminea
Mustela nivalis
Mustela vison
Gulo gulo
Lontra canadensis
Mephitis mephitis
Lynx canadensis
Odocoileus virginianus
Alces alces
Rangifer tarandus

94. Central Canadian Shield Forests

Geraldton, Ontario

49° 46’ N, 86° 55’ W

max. temp. – 6.6 °C

mean temp. – 0.3 °C

min. temp. – -6.0 °C

precipitation – 76.0 cm/yr

Matagami, Quebec

49° 46’ N, 77° 49’ W

max. temp. – 5.5 °C

mean temp. – -0.7 °C

min. temp. – -6.9 °C

precipitation – 90.6 cm/yr

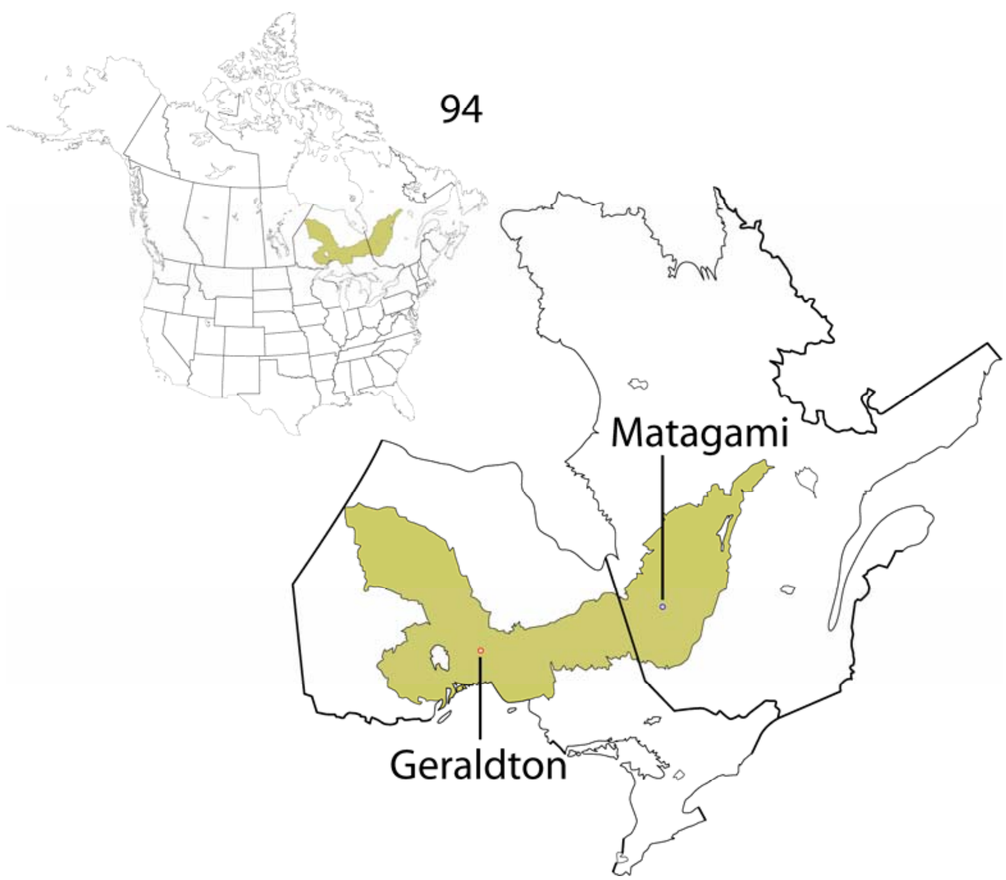


Figure I88. Central Canadian Shield Forests.

Geraldton, Ontario

Sorex cinereus
Sorex arcticus
Condylura cristata
Myotis lucifugus
Lasiurus cinereus
Lasionycteris noctivagans
Eptesicus fuscus
Lepus americanus
Tamias striatus
Neotamias minimus
Marmota monax
Tamiasciurus hudsonicus
Glaucomys sabrinus
Castor canadensis
Peromyscus maniculatus
Clethrionomys gapperi
Phenacomys ungava
Microtus pennsylvanicus
Ondatra zibethicus
Synaptomys cooperi
Zapus hudsonius
Napaeozapus insignis
Erethizon dorsatum
Canis latrans
Canis lupus
Vulpes vulpes
Ursus americanus
Martes americana
Martes pennanti
Mustela erminea
Mustela nivalis
Mustela vison
Gulo gulo
Lontra canadensis
Mephitis mephitis
Lynx canadensis
Cervus canadensis
Odocoileus virginianus
Alces alces
Rangifer tarandus

Matagami, Quebec

Sorex cinereus
Sorex arcticus
Condylura cristata
Myotis lucifugus
Lasiurus cinereus
Lasionycteris noctivagans
Eptesicus fuscus
Lepus americanus
Tamias striatus
Marmota monax
Tamiasciurus hudsonicus
Glaucomys sabrinus
Castor canadensis
Peromyscus maniculatus
Clethrionomys gapperi
Phenacomys ungava
Microtus pennsylvanicus
Microtus chrotorrhinus
Ondatra zibethicus
Synaptomys cooperi
Zapus hudsonius
Napaeozapus insignis
Erethizon dorsatum
Canis lupus
Vulpes vulpes
Ursus americanus
Martes americana
Martes pennanti
Mustela erminea
Mustela nivalis
Mustela vison
Gulo gulo
Lontra canadensis
Mephitis mephitis
Lynx canadensis
Odocoileus virginianus
Alces alces
Rangifer tarandus

95. Southern Hudson Bay Taiga

Churchill, Manitoba

58° 44’ N, 94° 03’ W

max. temp. – -2.7 °C

mean temp. – -6.9 °C

min. temp. – -11.0 °C

precipitation – 43.2 cm/yr

Moosonee, Ontario

51° 16’ N, 80° 39’ W

max. temp. – 5.0 °C

mean temp. – -1.1 °C

min. temp. – -7.2 °C

precipitation – 68.2 cm/yr

Figure I89. Southern Hudson Bay Taiga.

Churchill, Manitoba

Sorex cinereus
Sorex palustris
Lasiurus cinereus
Lepus americanus
Lepus arcticus
Neotamias minimus
Tamiasciurus hudsonicus
Glaucomys sabrinus
Castor canadensis
Clethrionomys rutilus
Clethrionomys gapperi
Phenacomys ungava
Microtus pennsylvanicus
Microtus xanthognathus
Ondatra zibethicus
Lemmus trimucronatus
Synaptomys borealis
Dicrostonyx richardsoni
Zapus hudsonius
Erethizon dorsatum
Canis lupus
Vulpes lagopus
Vulpes vulpes
Ursus americanus
Ursus maritimus
Martes americana
Martes pennanti
Mustela erminea
Mustela nivalis
Mustela vison
Gulo gulo
Lontra canadensis
Lynx canadensis
Alces alces
Rangifer tarandus
Ovibos moschatus

Moosonee, Ontario

Sorex cinereus
Sorex arcticus
Myotis lucifugus
Lasiurus cinereus
Lepus americanus
Neotamias minimus
Marmota monax
Tamiasciurus hudsonicus
Glaucomys sabrinus
Castor canadensis
Peromyscus maniculatus
Clethrionomys gapperi
Phenacomys ungava
Microtus pennsylvanicus
Ondatra zibethicus
Synaptomys borealis
Zapus hudsonius
Erethizon dorsatum
Canis lupus
Vulpes lagopus
Vulpes vulpes
Ursus americanus
Ursus maritimus
Martes americana
Martes pennanti
Mustela erminea
Mustela nivalis
Mustela vison
Gulo gulo
Lontra canadensis
Mephitis mephitis
Lynx canadensis
Alces alces
Rangifer tarandus

96. Eastern Canadian Shield Taiga

Kuujjuarapik, Quebec

55° 17’ N, 77° 45’ W

max. temp. – 0.0 °C

mean temp. – -4.4 °C

min. temp. – -8.8 °C

precipitation – 64.9 cm/yr

Schefferville, Quebec

54° 48’ N, 66° 49’ W

max. temp. – -0.5 °C

mean temp. – -5.3 °C

min. temp. – -10.0 °C

precipitation – 82.3 cm/yr

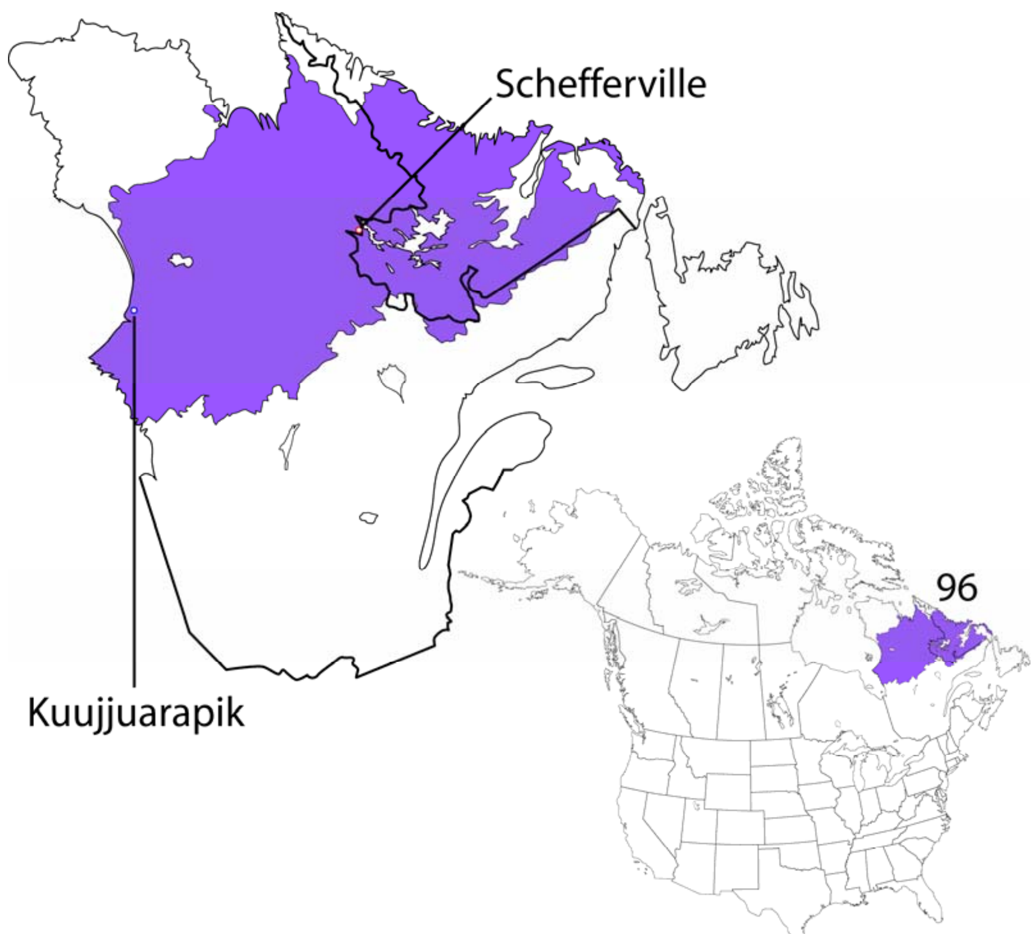


Figure I90. Eastern Canadian Shield Taiga.

Kuujjuarapik, Quebec

Sorex cinereus
Lepus americanus
Lepus arcticus
Tamiasciurus hudsonicus
Castor canadensis
Peromyscus maniculatus
Clethrionomys gapperi
Phenacomys ungava
Microtus pennsylvanicus
Synaptomys borealis
Dicrostonyx hudsonius
Zapus hudsonius
Erethizon dorsatum
Canis lupus
Vulpes lagopus
Vulpes vulpes
Ursus americanus
Ursus maritimus
Martes americana
Mustela erminea
Mustela nivalis
Mustela vison
Gulo gulo
Lontra canadensis
Lynx canadensis
Alces alces
Rangifer tarandus

Schefferville, Quebec

Sorex cinereus
Lepus americanus
Lepus arcticus
Tamiasciurus hudsonicus
Castor canadensis
Peromyscus maniculatus
Clethrionomys gapperi
Phenacomys ungava
Microtus pennsylvanicus
Ondatra zibethicus
Synaptomys borealis
Dicrostonyx hudsonius
Erethizon dorsatum
Canis lupus
Vulpes lagopus
Vulpes vulpes
Ursus americanus
Martes americana
Mustela erminea
Mustela nivalis
Mustela vison
Gulo gulo
Lontra canadensis
Lynx canadensis
Alces alces
Rangifer tarandus

97. Eastern Canadian Forests

Sept-Îles, Quebec

50° 13’ N, 66° 16’ W

max. temp. – 5.4 °C

mean temp. – 0.8 °C

min. temp. – -3.8 °C

precipitation – 115.6 cm/yr

Springdale, Newfoundland and Labrador

49° 30’ N, 56° 04’ W

max. temp. – 8.5 °C

mean temp. – 3.3 °C

min. temp. – -1.8 °C

precipitation – 100.0 cm/yr

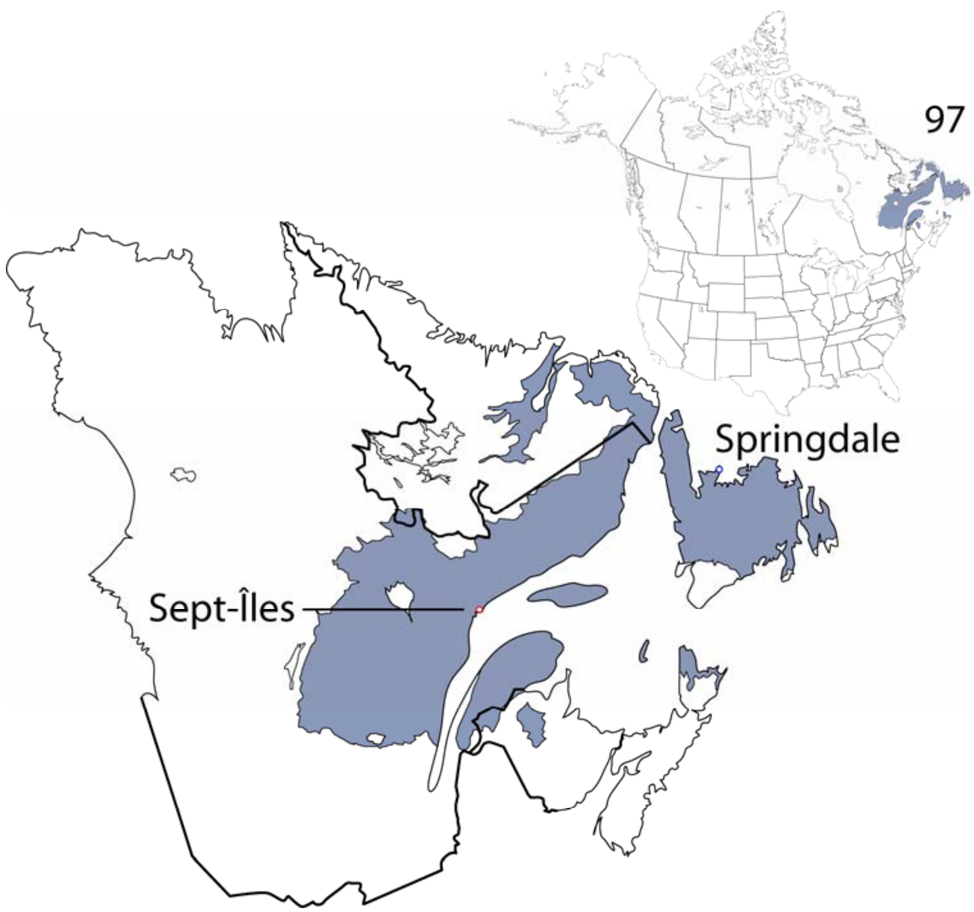


Figure I91. Eastern Canadian Forests.

Sept-Îles, Quebec

Sorex cinereus
Sorex palustris
Sorex arcticus
Condylura cristata
Myotis lucifugus
Myotis septentrionalis
Lepus americanus
Tamias striatus
Tamiasciurus hudsonicus
Glaucomys sabrinus
Castor canadensis
Peromyscus maniculatus
Clethrionomys gapperi
Phenacomys ungava
Microtus pennsylvanicus
Microtus chrotorrhinus
Ondatra zibethicus
Synaptomys cooperi
Synaptomys borealis
Zapus hudsonius
Napaeozapus insignis
Erethizon dorsatum
Canis lupus
Vulpes vulpes
Ursus americanus
Ursus maritimus
Martes americana
Martes pennanti
Mustela erminea
Mustela nivalis
Mustela vison
Gulo gulo
Lontra canadensis
Mephitis mephitis
Lynx canadensis
Odocoileus virginianus
Alces alces
Rangifer tarandus

Springdale, Newfoundland and Labrador

Myotis lucifugus
Myotis septentrionalis
Lepus americanus
Lepus arcticus
Castor canadensis
Ondatra zibethicus
Canis lupus
Vulpes vulpes
Ursus americanus
Martes americana
Mustela erminea
Gulo gulo
Lontra canadensis
Lynx canadensis
Rangifer tarandus

98. Newfoundland Highland Forests

Port aux Basgues, Newfoundland and Labrador

47° 34' N, 59° 09' W

max. temp. – 7.1 °C

mean temp. – 4.0 °C

min. temp. – 0.9 °C

precipitation – 157.0 cm/yr

Stephenville, Newfoundland and Labrador

48° 31' N, 58° 33' W

max. temp. – 8.4 °C

mean temp. – 4.6 °C

min. temp. – 0.8 °C

precipitation – 135.2 cm/yr

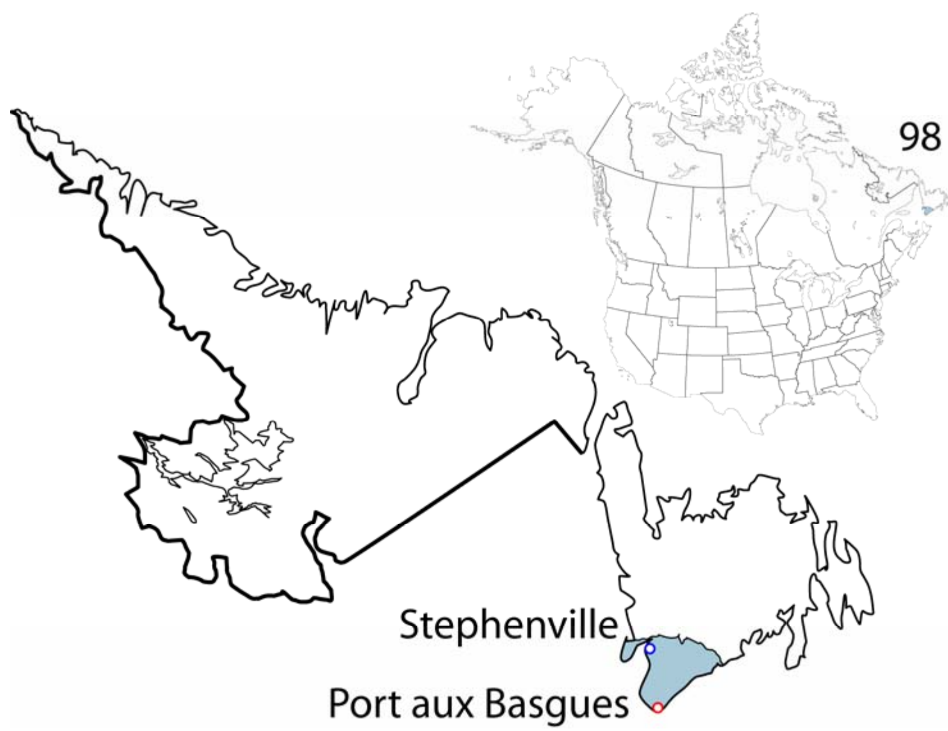


Figure I92. Newfoundland Highland Forests.

Port aux Basgues, Newfoundland and Labrador

Myotis lucifugus
Myotis septentrionalis
Lepus americanus
Lepus arcticus
Castor canadensis
Microtus pennsylvanicus
Ondatra zibethicus
Canis lupus
Vulpes vulpes
Ursus americanus
Martes americana
Mustela erminea
Gulo gulo
Lontra canadensis
Lynx canadensis
Rangifer tarandus

Stephenville, Newfoundland and Labrador

Myotis lucifugus
Myotis septentrionalis
Lepus americanus
Lepus arcticus
Castor canadensis
Microtus pennsylvanicus
Ondatra zibethicus
Canis lupus
Vulpes vulpes
Ursus americanus
Martes americana
Mustela erminea
Gulo gulo
Lontra canadensis
Lynx canadensis
Rangifer tarandus

99. South Avalon-Burin Oceanic Barrens

St. Lawrence, Newfoundland and Labrador
46° 55’ N, 55° 23’ W
max. temp. – 8.0 °C
mean temp. – 4.4 °C
min. temp. – 0.8 °C
precipitation – 156.4 cm/yr

St. Shotts, Newfoundland and Labrador
46° 37’ N, 53° 34’ W
max. temp. – 7.5 °C
mean temp. – 4.5 °C
min. temp. – 1.6 °C
precipitation – 151.3 cm/yr

Figure I93. South Avalon-Burin Oceanic Barrens.

St. Lawrence, Newfoundland and Labrador

Myotis lucifugus
Myotis septentrionalis
Lepus americanus
Lepus arcticus
Castor canadensis
Ondatra zibethicus
Canis lupus
Vulpes vulpes
Ursus americanus
Martes americana
Mustela erminea
Gulo gulo
Lontra canadensis
Lynx canadensis
Rangifer tarandus

St. Shotts, Newfoundland and Labrador

Myotis lucifugus
Myotis septentrionalis
Lepus americanus
Lepus arcticus
Castor canadensis
Ondatra zibethicus
Canis lupus
Vulpes vulpes
Ursus americanus
Martes americana
Mustela erminea
Gulo gulo
Lontra canadensis
Lynx canadensis
Rangifer tarandus

100. Aleutian Islands Tundra

Chernofski Harbor, Alaska
53° 26’ N, 167° 21’ W
max. temp. – 7.7 °C
mean temp. – 4.9 °C
min. temp. – 1.6 °C
precipitation – 140.0 cm/yr

Unalaska, Alaska
(Dutch Harbor station)
53° 54’ N, 166° 32’ W
max. temp. – 7.6 °C
mean temp. – 4.5 °C
min. temp. – 1.4 °C
precipitation – 145.6 cm/yr

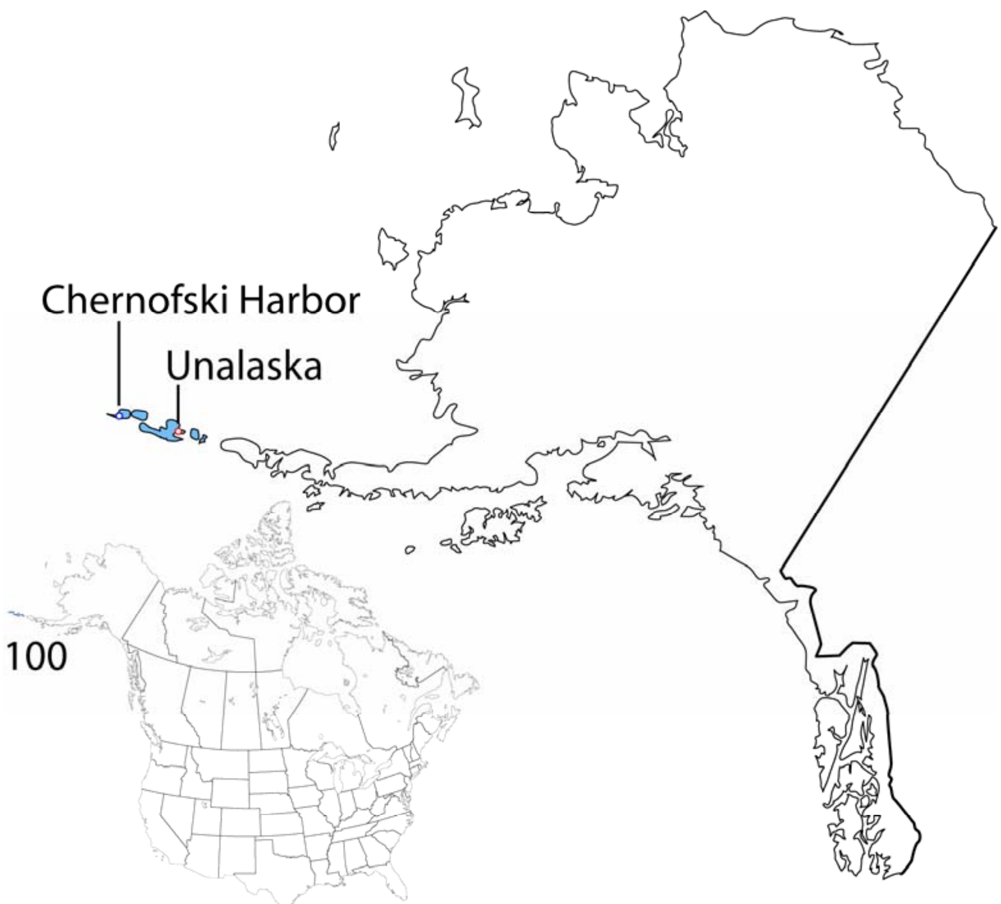


Figure I94. Aleutian Islands Tundra.

Chernofski Harbour, Alaska

Sorex cinereus
Sorex hydrodromus
Microtus oeconomus
Dicrostonyx unalascensis
Zapus hudsonius

Unalaska, Alaska

Sorex cinereus
Sorex hydrodromus
Microtus oeconomus
Dicrostonyx unalascensis
Zapus hudsonius
Rangifer tarandus

101. Beringia Lowland Tundra

Cape Romanzof, Alaska

61° 46’ N, 166° 03’ W

max. temp. – 2.8 °C

mean temp. – -1.4 °C

min. temp. – -3.9 °C

precipitation – 85.3 cm/yr

Dillingham, Alaska

59° 03’ N, 158° 31’ W

max. temp. – 4.0 °C

mean temp. – 0.8 °C

min. temp. – -2.3 °C

precipitation – 66.1 cm/yr

Figure I95. Beringia Lowland Tundra.

Cape Romanzof, Alaska

Sorex cinereus
Sorex monticolus
Sorex arcticus
Lepus othus
Clethrionomys rutilus
Microtus oeconomus
Ondatra zibethicus
Lemmus nigripes
Synaptomys borealis
Dicrostonyx nelsoni
Canis lupus
Vulpes lagopus
Vulpes vulpes
Mustela erminea
Mustela nivalis
Mustela vison
Gulo gulo
Lontra canadensis
Lynx canadensis
Rangifer tarandus

Dillingham, Alaska

Sorex cinereus
Sorex monticolus
Sorex arcticus
Myotis lucifugus
Lepus americanus
Lepus othus
Marmota caligata
Spermophilus parryii
Tamiasciurus hudsonicus
Clethrionomys rutilus
Microtus pennsylvanicus
Microtus oeconomus
Microtus miurus
Ondatra zibethicus
Lemmus nigripes
Synaptomys borealis
Dicrostonyx nelsoni
Zapus hudsonius
Canis lupus
Vulpes lagopus
Vulpes vulpes
Mustela erminea
Mustela nivalis
Mustela vison
Gulo gulo
Lontra canadensis
Lynx canadensis
Alces alces
Rangifer tarandus

102. Beringia Upland Tundra

Nome, Alaska	Cape Newenham, Alaska
64° 31’ N, 165° 27’ W	58° 38’ N, 162° 09’ W
max. temp. – 0.9 °C	max. temp. – 2.7 °C
mean temp. – -2.7 °C	mean temp. – 0.6 °C
min. temp. – -6.4 °C	min. temp. – -1.6 °C
precipitation – 42.1 cm/yr	precipitation – 120.9 cm/yr

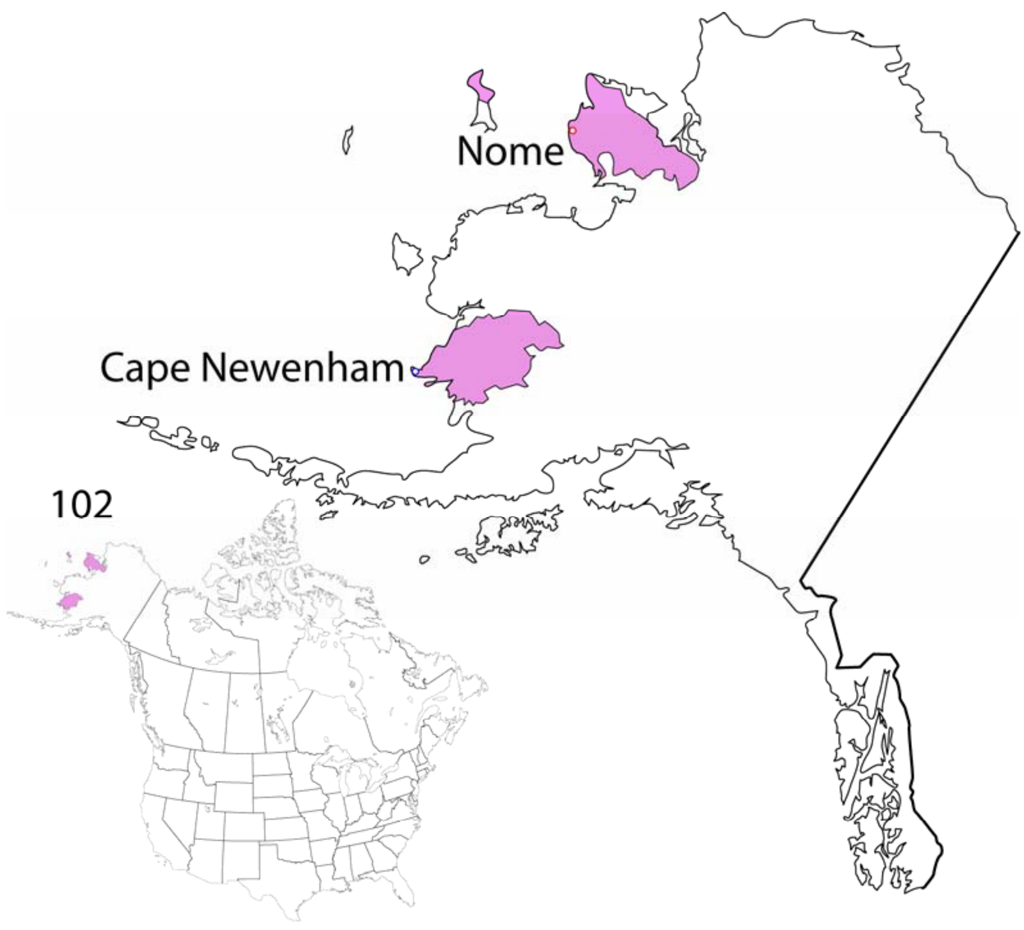


Figure I96. Beringia Upland Tundra.

Nome, Alaska

Sorex cinereus
Sorex monticolus
Sorex arcticus
Lepus americanus
Lepus othus
Spermophilus parryii
Tamiasciurus hudsonicus
Clethrionomys rutilus
Microtus oeconomus
Microtus miurus
Ondatra zibethicus
Lemmus nigripes
Dicrostonyx nelsoni
Canis lupus
Vulpes lagopus
Vulpes vulpes
Ursus arctos
Ursus maritimus
Martes americanum
Mustela erminea
Mustela nivalis
Mustela vison
Gulo gulo
Lontra canadensis
Lynx canadensis
Alces alces
Rangifer tarandus
Ovis dalli

Cape Newenham, Alaska

Sorex cinereus
Sorex monticolus
Sorex arcticus
Lepus othus
Spermophilus parryii
Tamiasciurus hudsonicus
Clethrionomys rutilus
Microtus oeconomus
Microtus miurus
Ondatra zibethicus
Lemmus nigripes
Synaptomys borealis
Dicrostonyx nelsoni
Canis lupus
Vulpes lagopus
Vulpes vulpes
Mustela erminea
Mustela nivalis
Mustela vison
Gulo gulo
Lontra canadensis
Lynx canadensis
Rangifer tarandus

103. Alaska/St. Elias Range Tundra

Port Alsworth, Alaska

60° 12’ N, 154° 18’ W

max. temp. – 6.6 °C

mean temp. – 2.1 °C

min. temp. – -2.6 °C

precipitation – 33.4 cm/yr

Tok, Alaska

63° 21’ N, 143° 03’ W

max. temp. – 2.6 °C

mean temp. – -4.2 °C

min. temp. – -11.0 °C

precipitation – 21.8 cm/yr

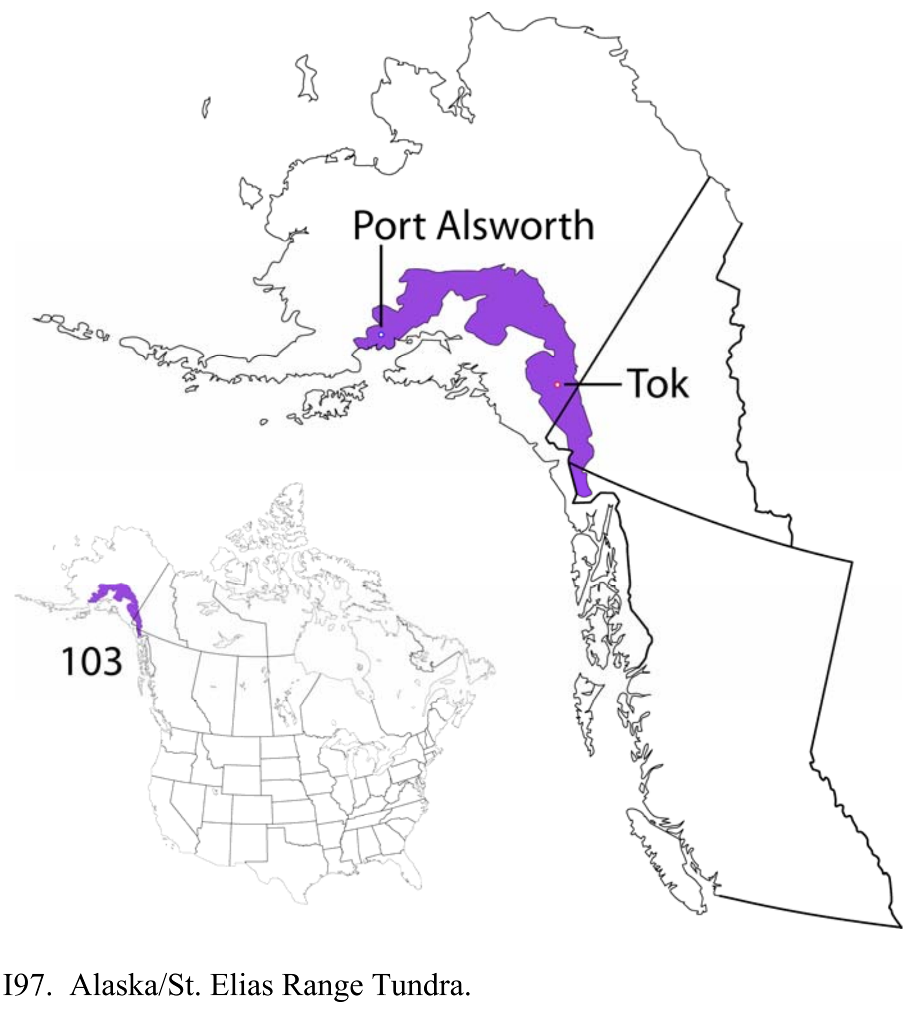


Figure I97. Alaska/St. Elias Range Tundra.

Port Alsworth, Alaska

Sorex cinereus
Sorex monticolus
Sorex arcticus
Sorex hoyi
Myotis lucifugus
Lepus americanus
Marmota caligata
Spermophilus parryii
Tamiasciurus hudsonicus
Glaucomys sabrinus
Castor canadensis
Clethrionomys rutilus
Microtus pennsylvanicus
Microtus oeconomus
Microtus miurus
Ondatra zibethicus
Lemmus nigripes
Synaptomys borealis
Zapus hudsonius
Erethizon dorsatum
Canis lupus
Vulpes vulpes
Ursus americanus
Ursus arctos
Martes americanum
Mustela erminea
Mustela nivalis
Mustela vison
Gulo gulo
Lontra canadensis
Lynx canadensis
Alces alces
Rangifer tarandus
Ovis dalli

Tok, Alaska

Sorex cinereus
Sorex monticolus
Myotis lucifugus
Ochotona collaris
Lepus americanus
Marmota caligata
Spermophilus parryii
Tamiasciurus hudsonicus
Castor canadensis
Clethrionomys rutilus
Microtus pennsylvanicus
Microtus oeconomus
Microtus longicaudus
Microtus miurus
Ondatra zibethicus
Synaptomys borealis
Zapus hudsonius
Erethizon dorsatum
Canis latrans
Canis lupus
Vulpes vulpes
Ursus americanus
Ursus arctos
Martes americanum
Mustela erminea
Mustela nivalis
Mustela vison
Gulo gulo
Lontra canadensis
Lynx canadensis
Alces alces
Rangifer tarandus
Ovis dalli

104. Pacific Coastal Mountain Tundra and Ice Fields

Tonsina, Alaska	Hyder, Alaska
61° 39’ N, 145° 10’ W	55° 55’ N, 130° 2’ W
max. temp. – 3.3 °C	max. temp. – 9.4 °C
mean temp. – -3.1 °C	mean temp. – 5.8 °C
min. temp. – -9.4 °C	min. temp. – 1.8 °C
precipitation – 31.7 cm/yr	precipitation – 220.0 cm/yr

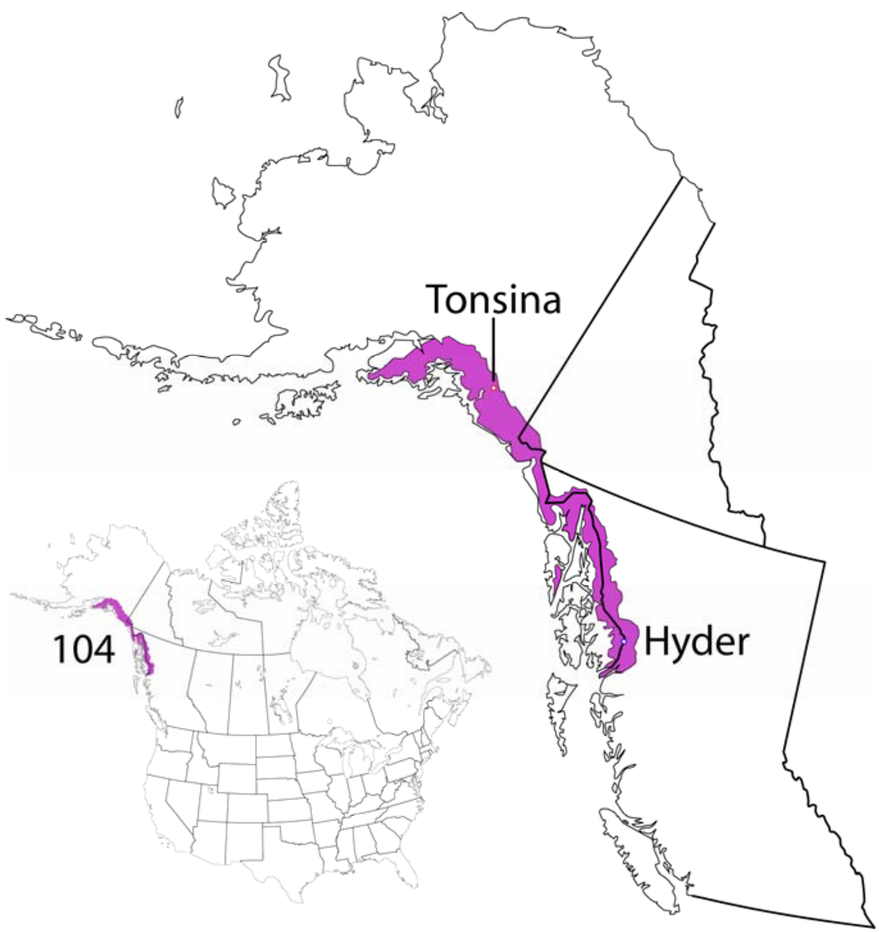


Figure I98. Pacific Coastal Mountain Tundra and Ice Fields.

Tonsina, Alaska

Sorex cinereus
Sorex monticolus
Sorex palustris
Myotis lucifugus
Lepus americanus
Marmota caligata
Castor canadensis
Clethrionomys rutilus
Microtus pennsylvanicus
Microtus oeconomus
Microtus miurus
Ondatra zibethicus
Synaptomys borealis
Zapus hudsonius
Erethizon dorsatum
Canis latrans
Canis lupus
Ursus americanus
Ursus arctos
Martes americanum
Mustela erminea
Mustela nivalis
Mustela vison
Gulo gulo
Lontra canadensis
Lynx canadensis
Alces alces
Rangifer tarandus
Ovis dalli

Hyder, Alaska

Sorex cinereus
Sorex monticolus
Sorex palustris
Myotis lucifugus
Myotis keenii
Myotis volans
Myotis californicus
Lepus americanus
Marmota caligata
Tamiasciurus hudsonicus
Glaucomys sabrinus
Castor canadensis
Peromyscus maniculatus
Microtus pennsylvanicus
Microtus longicaudus
Ondatra zibethicus
Synaptomys borealis
Zapus hudsonius
Zapus princeps
Erethizon dorsatum
Canis lupus
Ursus americanus
Ursus arctos
Martes americanum
Martes pennanti
Mustela erminea
Mustela vison
Gulo gulo
Lontra canadensis
Lynx canadensis
Odocoileus hemionus
Rangifer tarandus
Oreamnos americanus

105. Interior Yukon/Alaska Alpine Tundra

Central, Alaska

65° 34’ N, 144° 46’ W

max. temp. – 0.8 °C

mean temp. – -5.8 °C

min. temp. – -12.4 °C

precipitation – 28.0 cm/yr

Mayo, Yukon Territory

63° 37’ N, 135° 52’ W

max. temp. – 2.8 °C

mean temp. – -3.1 °C

min. temp. – -8.9 °C

precipitation – 31.3 cm/yr

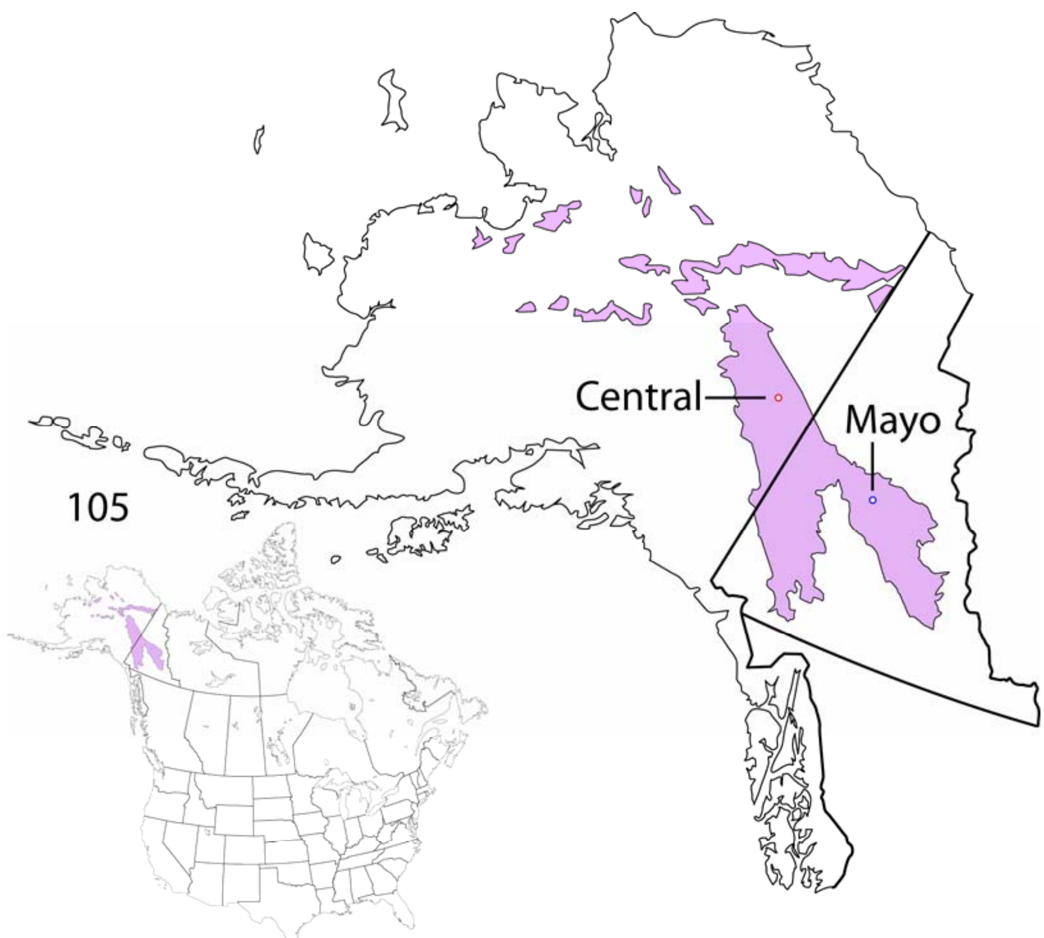


Figure I99. Interior Yukon/Alaska Alpine Tundra.

Central, Alaska

Sorex cinereus
Sorex monticolus
Sorex arcticus
Myotis lucifugus
Lepus americanus
Marmota monax
Marmota caligata
Spermophilus parryii
Tamiasciurus hudsonicus
Glaucomys sabrinus
Castor canadensis
Clethrionomys rutilus
Microtus pennsylvanicus
Microtus oeconomus
Microtus longicaudus
Microtus xanthognathus
Ondatra zibethicus
Lemmus nigripes
Synaptomys borealis
Zapus hudsonius
Erethizon dorsatum
Canis latrans
Canis lupus
Vulpes vulpes
Ursus americanus
Ursus arctos
Martes americanum
Mustela erminea
Mustela nivalis
Mustela vison
Gulo gulo
Lontra canadensis
Lynx canadensis
Alces alces
Rangifer tarandus
Bos bison
Ovis dalli
Ovis nivicola

Mayo, Yukon Territory

Sorex cinereus
Sorex monticolus
Sorex hoyi
Myotis lucifugus
Ochotona princeps
Lepus americanus
Neotamias minimus
Marmota monax
Marmota caligata
Spermophilus parryii
Tamiasciurus hudsonicus
Glaucomys sabrinus
Castor canadensis
Peromyscus maniculatus
Clethrionomys rutilus
Microtus pennsylvanicus
Microtus oeconomus
Microtus longicaudus
Microtus xanthognathus
Ondatra zibethicus
Lemmus sibiricus
Synaptomys borealis
Zapus hudsonius
Erethizon dorsatum
Canis latrans
Canis lupus
Vulpes vulpes
Ursus americanus
Ursus arctos
Martes americana
Mustela erminea
Mustela nivalis
Mustela vison
Gulo gulo
Lontra canadensis
Lynx canadensis
Odocoileus hemionus
Alces alces
Rangifer tarandus
Ovis nivicola

106. Ogilvie/MacKenzie Alpine Tundra

MacMillan Pass, Yukon Territory

63° 15’ N, 130° 02’ W

max. temp. – 0.6 °C

mean temp. – -3.6 °C

min. temp. – -7.9 °C

precipitation – 39.5 cm/yr

Tungsten, Northwest Territories

61° 57’ N, 128° 15’ W

max. temp. – 0.9 °C

mean temp. – -4.3 °C

min. temp. – -9.5 °C

precipitation – 63.9 cm/yr

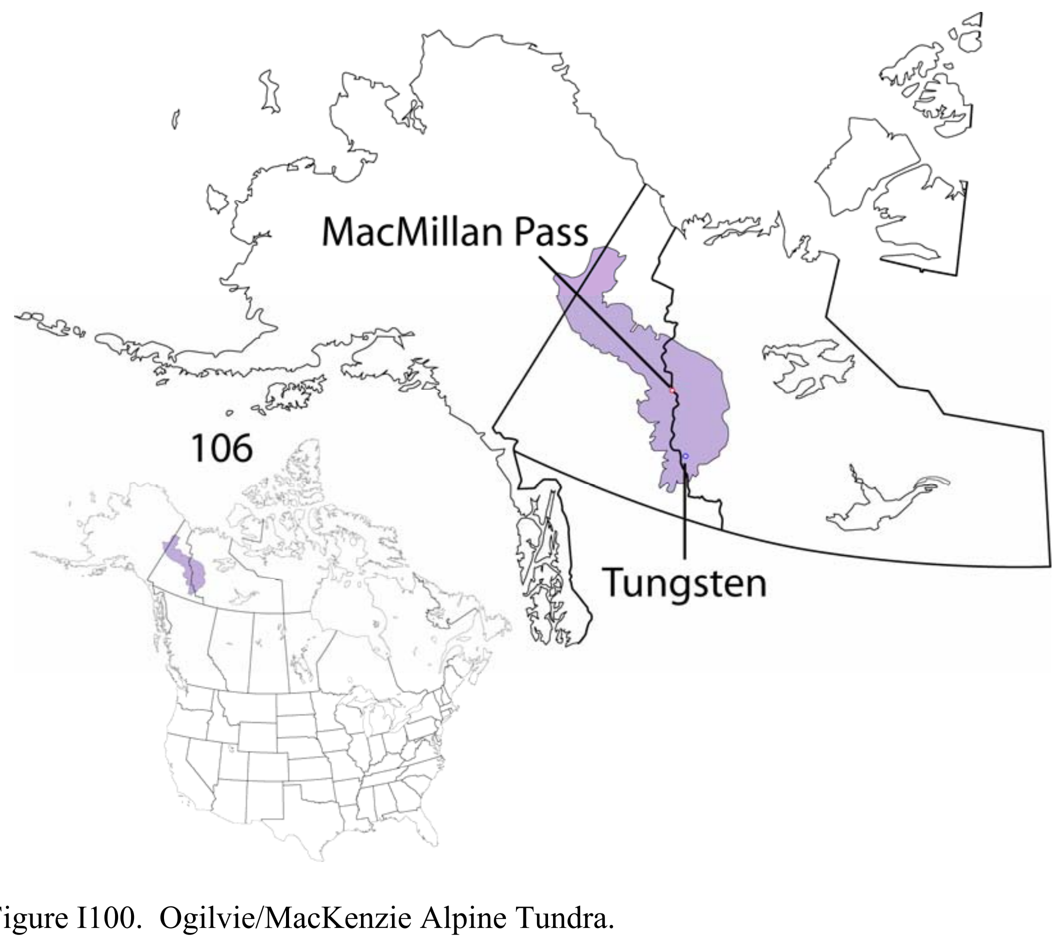


Figure I100. Ogilvie/MacKenzie Alpine Tundra.

MacMillan Pass, Yukon Territory

Sorex cinereus
Sorex monticolus
Sorex hoyi
Ochotona princeps
Lepus americanus
Neotamias minimus
Marmota caligata
Spermophilus parryii
Tamiasciurus hudsonicus
Glaucomys sabrinus
Castor canadensis
Peromyscus maniculatus
Clethrionomys rutilus
Microtus pennsylvanicus
Microtus oeconomus
Microtus longicaudus
Microtus xanthognathus
Microtus miurus
Ondatra zibethicus
Lemmus sibiricus
Synaptomys borealis
Dicrostonyx torquatus
Erethizon dorsatum
Canis latrans
Canis lupus
Vulpes vulpes
Ursus americanus
Ursus arctos
Martes americana
Mustela erminea
Mustela nivalis
Mustela vison
Gulo gulo
Lontra canadensis
Lynx canadensis
Alces alces
Rangifer tarandus
Ovis nivicola

Tungsten, Northwest Territories

Sorex cinereus
Sorex monticolus
Sorex hoyi
Ochotona princeps
Lepus americanus
Neotamias minimus
Marmota caligata
Spermophilus parryii
Tamiasciurus hudsonicus
Glaucomys sabrinus
Castor canadensis
Peromyscus maniculatus
Neotoma cinerea
Clethrionomys rutilus
Phenacomys ungava
Microtus pennsylvanicus
Microtus oeconomus
Microtus longicaudus
Microtus xanthognathus
Microtus miurus
Ondatra zibethicus
Lemmus sibiricus
Synaptomys borealis
Zapus hudsonius
Erethizon dorsatum
Canis latrans
Canis lupus
Vulpes vulpes
Ursus americanus
Ursus arctos
Martes americana
Mustela erminea
Mustela vison
Gulo gulo
Lontra canadensis
Lynx canadensis
Puma concolor
Odocoileus hemionus
Alces alces
Rangifer tarandus
Oreamnos americanus
Ovis nivicola

107. Brooks/British Range Tundra

Ambler, Alaska	Arctic Village, Alaska
67° 05’ N, 157° 51’ W	68° 07’ N, 145° 32’ W
max. temp. – -0.2 °C	max. temp. – -3.2 °C
mean temp. – -5.6 °C	mean temp. – -9.3 °C
min. temp. – -11.2 °C	min. temp. – -15.7 °C
precipitation – 65.3 cm/yr	precipitation – 25.6 cm/yr

Figure I101. Brooks/British Range Tundra.

Ambler, Alaska

Sorex cinereus
Sorex monticolus
Sorex arcticus
Lepus americanus
Marmota broweri
Tamiasciurus hudsonicus
Clethrionomys rutilus
Microtus oeconomus
Microtus miurus
Lemmus nigripes
Dicrostonyx rubricatus
Erethizon dorsatum
Canis latrans
Canis lupus
Vulpes lagopus
Vulpes vulpes
Ursus americanus
Ursus arctos
Martes americanum
Mustela erminea
Mustela nivalis
Mustela vison
Gulo gulo
Lontra canadensis
Lynx canadensis
Alces alces
Rangifer tarandus
Ovis dalli

Arctic Village, Alaska

Sorex cinereus
Sorex monticolus
Sorex ugyunak
Sorex arcticus
Lepus americanus
Marmota broweri
Spermophilus parryii
Tamiasciurus hudsonicus
Clethrionomys rutilus
Microtus oeconomus
Microtus miurus
Lemmus nigripes
Dicrostonyx rubricatus
Erethizon dorsatum
Canis latrans
Canis lupus
Vulpes lagopus
Vulpes vulpes
Ursus americanus
Ursus arctos
Martes americanum
Mustela erminea
Mustela nivalis
Mustela vison
Gulo gulo
Lontra canadensis
Lynx canadensis
Alces alces
Rangifer tarandus
Ovis dalli

108. Arctic Foothills Tundra

Point Hope, Alaska	Umiat, Alaska
68° 21’ N, 166° 48’ W	69° 22’ N, 152° 08’ W
max. temp. – -2.8 °C	max. temp. – -6.3 °C
mean temp. – -6.3 °C	mean temp. – -11.8 °C
min. temp. – -10.7 °C	min. temp. – -17.3 °C
precipitation – 35.3 cm/yr	precipitation – 13.6 cm/yr

Figure I102. Arctic Foothills Tundra.

Point Hope, Alaska

Sorex cinereus
Sorex ugyunak
Sorex arcticus
Lepus othus
Marmota broweri
Spermophilus parryii
Clethrionomys rutilus
Microtus oeconomus
Microtus miurus
Lemmus nigripes
Dicrostonyx rubricatus
Canis latrans
Canis lupus
Vulpes lagopus
Vulpes vulpes
Ursus arctos
Mustela erminea
Mustela nivalis
Mustela vison
Lontra canadensis
Lynx canadensis
Alces alces
Rangifer tarandus
Ovis dalli

Umiat, Alaska

Sorex cinereus
Sorex ugyunak
Sorex arcticus
Lepus othus
Marmota broweri
Spermophilus parryii
Clethrionomys rutilus
Microtus oeconomus
Microtus miurus
Lemmus nigripes
Dicrostonyx rubricatus
Canis latrans
Canis lupus
Vulpes lagopus
Vulpes vulpes
Ursus arctos
Mustela erminea
Mustela nivalis
Mustela vison
Lynx canadensis
Alces alces
Rangifer tarandus
Ovibos moschatus

109. Arctic Coastal Tundra

Barrow, Alaska	Tuktoyaktuk, Northwest Territories
71° 17’ N, 156° 46’ W	69° 27’ N, 133° 00’ W
max. temp. – -9.0 °C	max. temp. – -3.7 °C
mean temp. – -12.0 °C	mean temp. – -10.2 °C
min. temp. – -15.0 °C	min. temp. – -23.1 °C
precipitation – 10.6 cm/yr	precipitation – 13.9 cm/yr

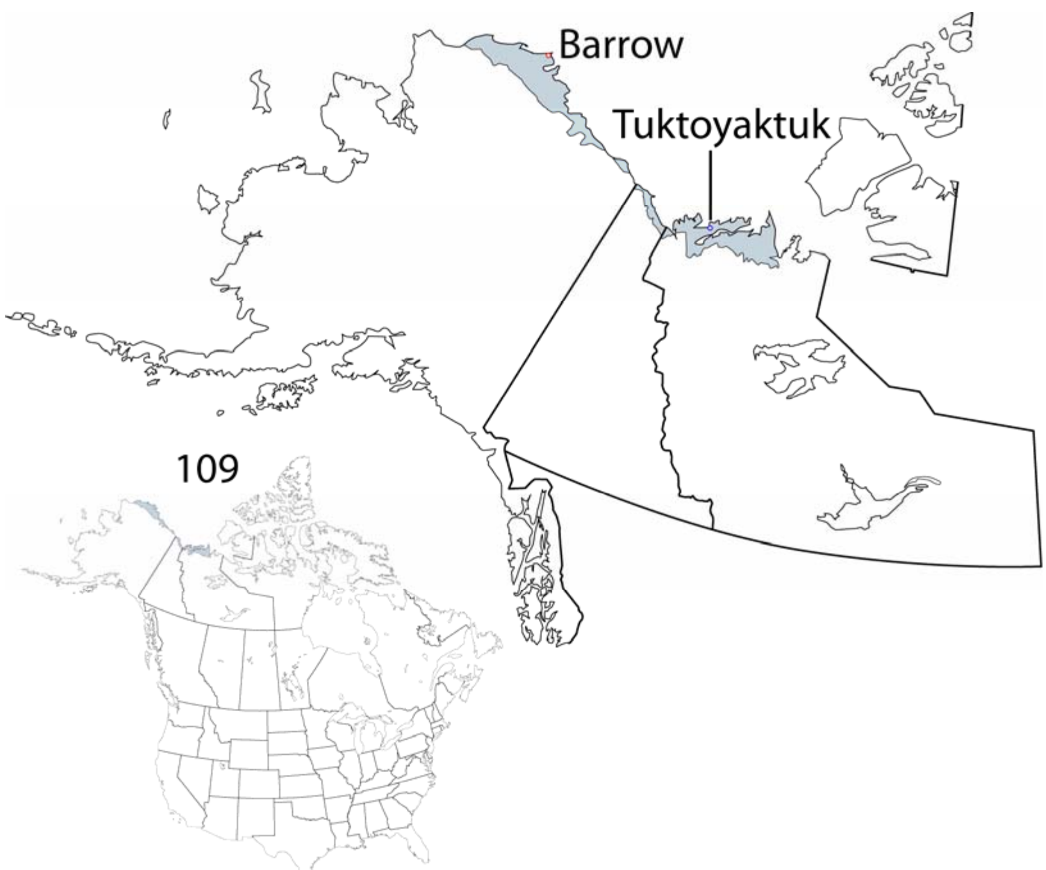


Figure I103. Arctic Coastal Tundra.

Barrow, Alaska

Sorex cinereus
Sorex ugyunak
Sorex arcticus
Lepus othus
Spermophilus parryii
Clethrionomys rutilus
Microtus oeconomus
Lemmus nigripes
Dicrostonyx rubricatus
Canis latrans
Canis lupus
Vulpes lagopus
Vulpes vulpes
Ursus maritimus
Mustela erminea
Mustela nivalis
Mustela vison
Lynx canadensis
Alces alces
Rangifer tarandus
Ovibos moschatus

Tuktoyaktuk, Northwest Territories

Sorex ugyunak
Sorex arcticus
Lepus arcticus
Spermophilus parryii
Clethrionomys rutilus
Microtus oeconomus
Ondatra zibethicus
Lemmus trimucronatus
Dicrostonyx kilangmiutak
Erethizon dorsatum
Canis latrans
Canis lupus
Vulpes lagopus
Vulpes vulpes
Ursus arctos
Ursus maritimus
Mustela erminea
Mustela nivalis
Mustela vison
Gulo gulo
Lontra canadensis
Lynx canadensis
Rangifer tarandus
Ovibos moschatus

110. Low Arctic Tundra

Rankin Inlet, Nunavut

62° 49’ N, 92° 07’ W

max. temp. – -7.3 °C

mean temp. – -11.0 °C

min. temp. – -14.7 °C

precipitation – 29.7 cm/yr

Inukjuak, Quebec

58° 28’ N, 78° 04’ W

max. temp. – -3.4 °C

mean temp. – -7.0 °C

min. temp. – -10.6 °C

precipitation – 46.0 cm/yr

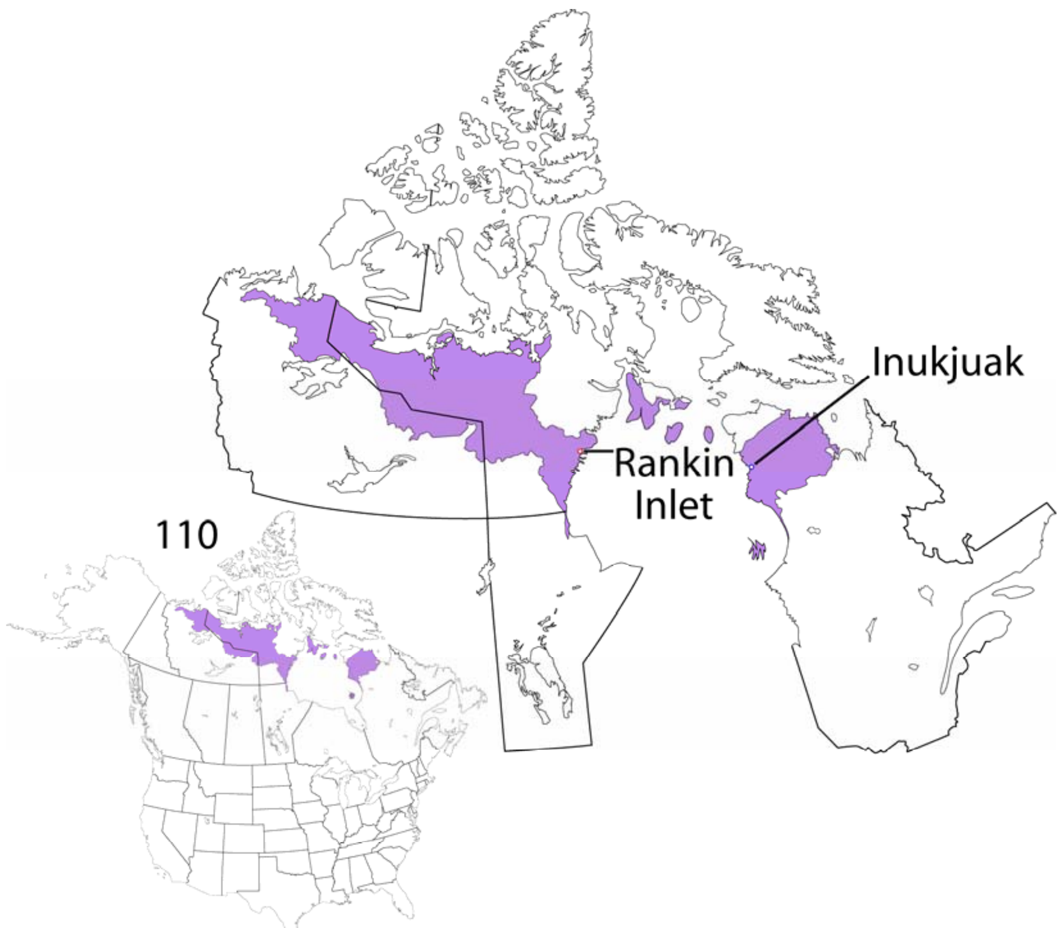


Figure I104. Low Arctic Tundra.

Rankin Inlet, Nunavut

Sorex ugyunak
Lasiurus cinereus
Lepus arcticus
Spermophilus parryii
Clethrionomys rutilus
Microtus pennsylvanicus
Lemmus trimucronatus
Dicrostonyx richardsoni
Canis lupus
Vulpes lagopus
Vulpes vulpes
Ursus arctos
Ursus maritimus
Mustela erminea
Mustela nivalis
Gulo gulo
Lynx canadensis
Rangifer tarandus
Ovibos moschatus

Inukjuak, Quebec

Lepus arcticus
Clethrionomys gapperi
Dicrostonyx hudsonius
Canis lupus
Vulpes lagopus
Vulpes vulpes
Ursus maritimus
Mustela erminea
Mustela nivalis
Gulo gulo
Lontra canadensis
Lynx canadensis
Rangifer tarandus

111. Middle Arctic Tundra

Ulukhaktok, Northwest Territories

70° 46’ N, 117° 48’ W

max. temp. – -8.2 °C

mean temp. – -11.7 °C

min. temp. – -15.1 °C

precipitation – 16.4 cm/yr

Kugluktuk, Nunavut

67° 49’ N, 115° 08’ W

max. temp. – -6.5 °C

mean temp. – -10.6 °C

min. temp. – -14.7 °C

precipitation – 24.9 cm/yr

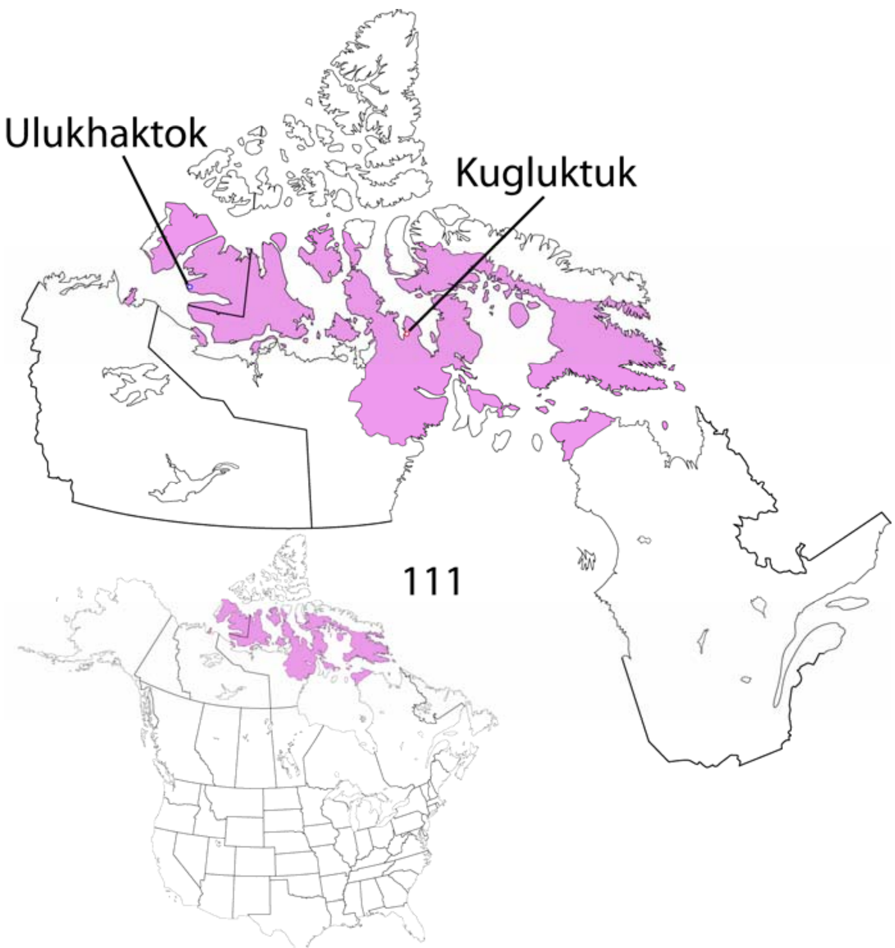


Figure I105. Middle Arctic Tundra.

Ulukhaktok, Northwest Territories

Lepus arcticus
Dicrostonyx kilangmiutak
Canis lupus
Vulpes lagopus
Ursus arctos
Ursus maritimus
Mustela erminea
Gulo gulo
Rangifer tarandus
Ovibos moschatus

Kugluktuk, Nunavut

Sorex ugyunak
Lepus arcticus
Spermophilus parryii
Lemmus trimucronatus
Dicrostonyx groenlandicus
Canis lupus
Vulpes lagopus
Ursus arctos
Ursus maritimus
Mustela erminea
Gulo gulo
Lynx canadensis
Rangifer tarandus
Ovibos moschatus

112. High Arctic Tundra

Arctic Bay, Nunavut

73° 02' N, 85° 09' W

max. temp. – -9.8 °C

mean temp. – -13.6 °C

min. temp. – -17.5 °C

precipitation – 13.1 cm/yr

Grise Fjord, Nunavut

76° 25' N, 82° 57' W

max. temp. – -12.5 °C

mean temp. – -16.3 °C

min. temp. – -19.7 °C

precipitation – 17.7 cm/yr

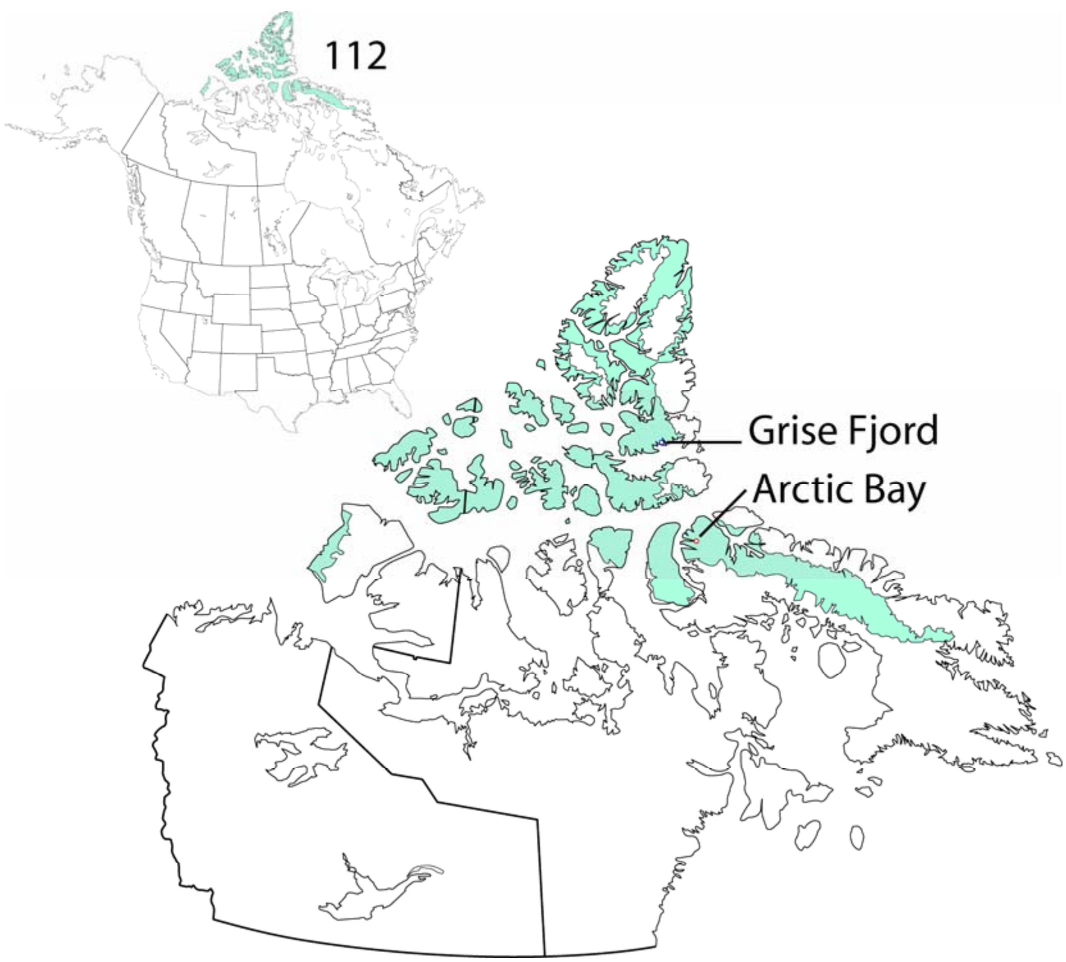


Figure I106. High Arctic Tundra.

Arctic Bay, Nunavut

Lepus arcticus
Lemmus trimucronatus
Dicrostonyx groenlandicus
Canis lupus
Vulpes lagopus
Ursus maritimus
Mustela erminea
Gulo gulo
Lynx canadensis
Rangifer tarandus

Grise Fjord, Nunavut

Lepus arcticus
Lemmus trimucronatus
Dicrostonyx groenlandicus
Canis lupus
Vulpes lagopus
Ursus maritimus
Mustela erminea
Gulo gulo
Rangifer tarandus
Ovibos moschatus

113. Davis Highlands Tundra

Qikiqtarjuaq, Nunavut

(Fox Five station)

67° 32' N, 63° 47' W

max. temp. – -8.9 °C

mean temp. – -11.8 °C

min. temp. – -14.6 °C

precipitation – 26.2 cm/yr

Cape Dyer, Nunavut

66° 34' N, 61° 37' W

max. temp. – -6.8 °C

mean temp. – -11.0 °C

min. temp. – -15.0 °C

precipitation – 60.3 cm/yr

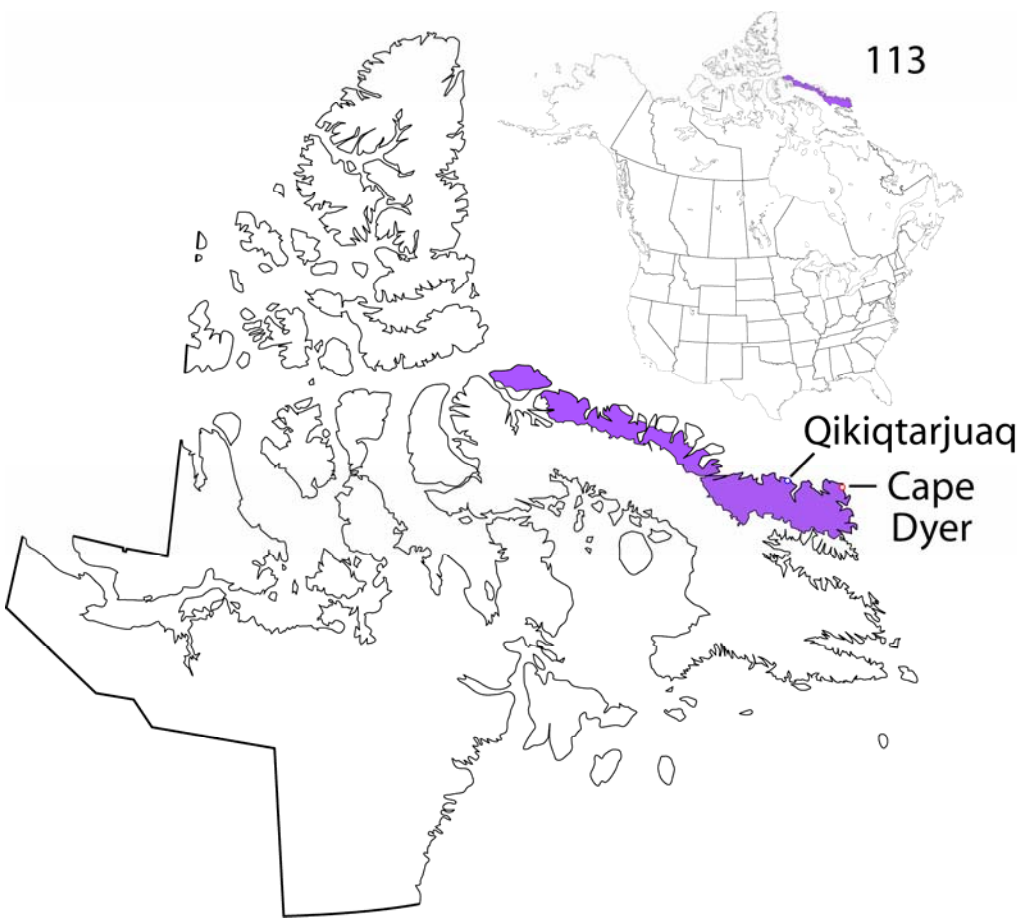


Figure I107. Davis Highlands Tundra.

Qikiqtarjuaq, Nunavut

Lepus arcticus
Lemmus trimucronatus
Dicrostonyx groenlandicus
Canis lupus
Vulpes lagopus
Ursus maritimus
Mustela erminea
Gulo gulo
Lynx canadensis
Rangifer tarandus

Cape Dyer, Nunavut

Lepus arcticus
Lemmus trimucronatus
Dicrostonyx groenlandicus
Canis lupus
Vulpes lagopus
Ursus maritimus
Mustela erminea
Gulo gulo
Lynx canadensis
Rangifer tarandus

114. Baffin Coastal Tundra

Clyde, Nunavut

70° 29’ N, 68° 31’ W

max. temp. – -9.1 °C

mean temp. – -12.8 °C

min. temp. – -16.4 °C

precipitation – 23.3 cm/yr

Cape Henry Kater, Nunavut

(climate from Cape Hooper; 68° 28’ N, 66° 49’ W)

69° 04’ N, 66° 46’ W

max. temp. – -9.4 °C

mean temp. – -12.0 °C

min. temp. – -14.6 °C

precipitation – 28.2 cm/yr

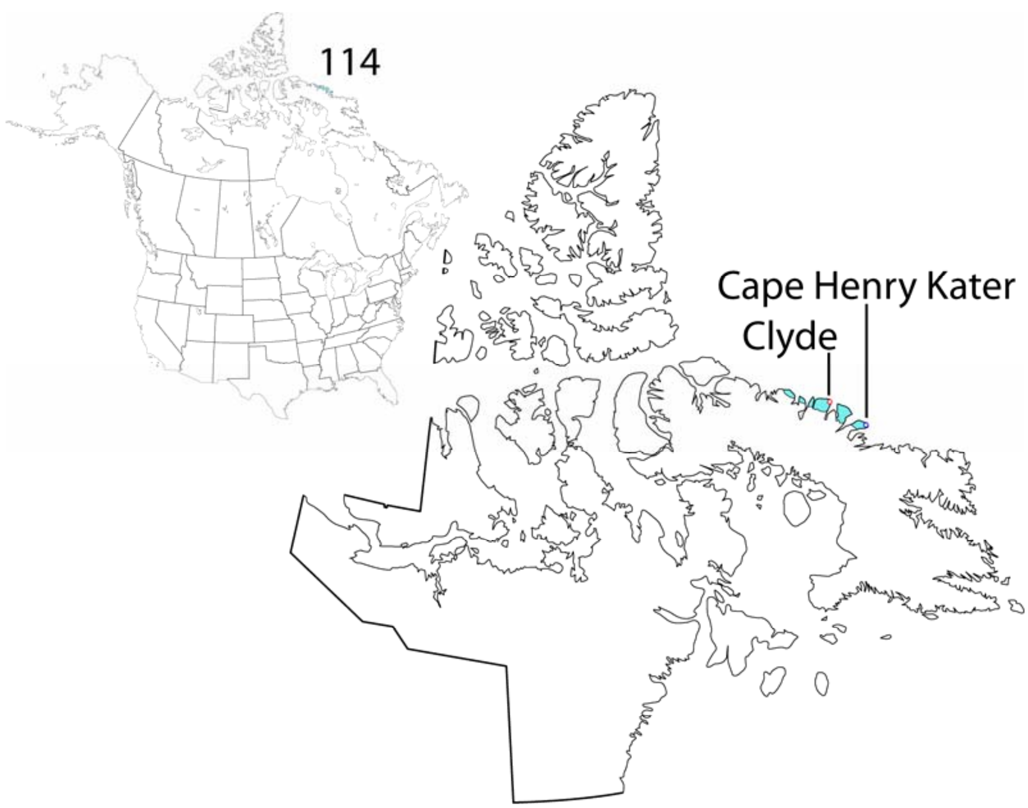


Figure I108. Baffin Coastal Tundra.

Clyde, Nunavut

Lepus arcticus
Lemmus trimucronatus
Dicrostonyx groenlandicus
Canis lupus
Vulpes lagopus
Ursus maritimus
Mustela erminea
Gulo gulo
Lynx canadensis
Rangifer tarandus

Cape Henry Kater, Nunavut

Lepus arcticus
Lemmus trimucronatus
Dicrostonyx groenlandicus
Canis lupus
Vulpes lagopus
Ursus maritimus
Mustela erminea
Gulo gulo
Lynx canadensis
Rangifer tarandus

115. Torngat Mountain Tundra

Killinek, Newfoundland and Labrador (climate from Saglek; 58° 29’ N, 62° 39’ W)

60° 25’ N, 64° 51’ W

max. temp. – -1.8 °C

mean temp. – -5.0 °C

min. temp. – -8.1 °C

precipitation – 100.1 cm/yr

Saglek, Newfoundland and Labrador

58° 29’ N, 62° 39’ W

max. temp. – -1.8 °C

mean temp. – -5.0 °C

min. temp. – -8.1 °C

precipitation – 100.1 cm/yr

Figure I109. Torngat Mountain Tundra.

Killinek, Newfoundland and Labrador

Sorex cinereus
Lepus arcticus
Castor canadensis
Peromyscus maniculatus
Clethrionomys gapperi
Phenacomys ungava
Microtus pennsylvanicus
Ondatra zibethicus
Dicrostonyx hudsonius
Erethizon dorsatum
Canis lupus
Vulpes lagopus
Vulpes vulpes
Ursus maritimus
Martes americana
Mustela erminea
Mustela nivalis
Mustela vison
Gulo gulo
Lontra canadensis
Lynx canadensis
Alces alces
Rangifer tarandus

Saglek, Newfoundland and Labrador

Sorex cinereus
Lepus arcticus
Castor canadensis
Peromyscus maniculatus
Clethrionomys gapperi
Phenacomys ungava
Microtus pennsylvanicus
Ondatra zibethicus
Synaptomys borealis
Dicrostonyx hudsonius
Erethizon dorsatum
Canis lupus
Vulpes lagopus
Vulpes vulpes
Ursus americanus
Ursus maritimus
Martes americana
Mustela erminea
Mustela nivalis
Mustela vison
Gulo gulo
Lontra canadensis
Lynx canadensis
Alces alces
Rangifer tarandus

116. Permanent Ice

Talbot Inlet, Nunavut

(climate from Eureka, NU; 79° 59' N, 85° 56' W)

77° 55' N, 77° 35' W

max. temp. – -16.4 °C

mean temp. – 19.7 °C

min. temp. – -22.9 °C

precipitation – 7.6 cm/yr

Cape Parker, Nunavut

(climate from Dundas Harbour, 74° 32' N, 82° 23' W)

79° 40' N, 75° 04' W

max. temp. – -8.1 °C

mean temp. – -11.7 °C

min. temp. – -15.3 °C

precipitation – 25.1 cm/yr

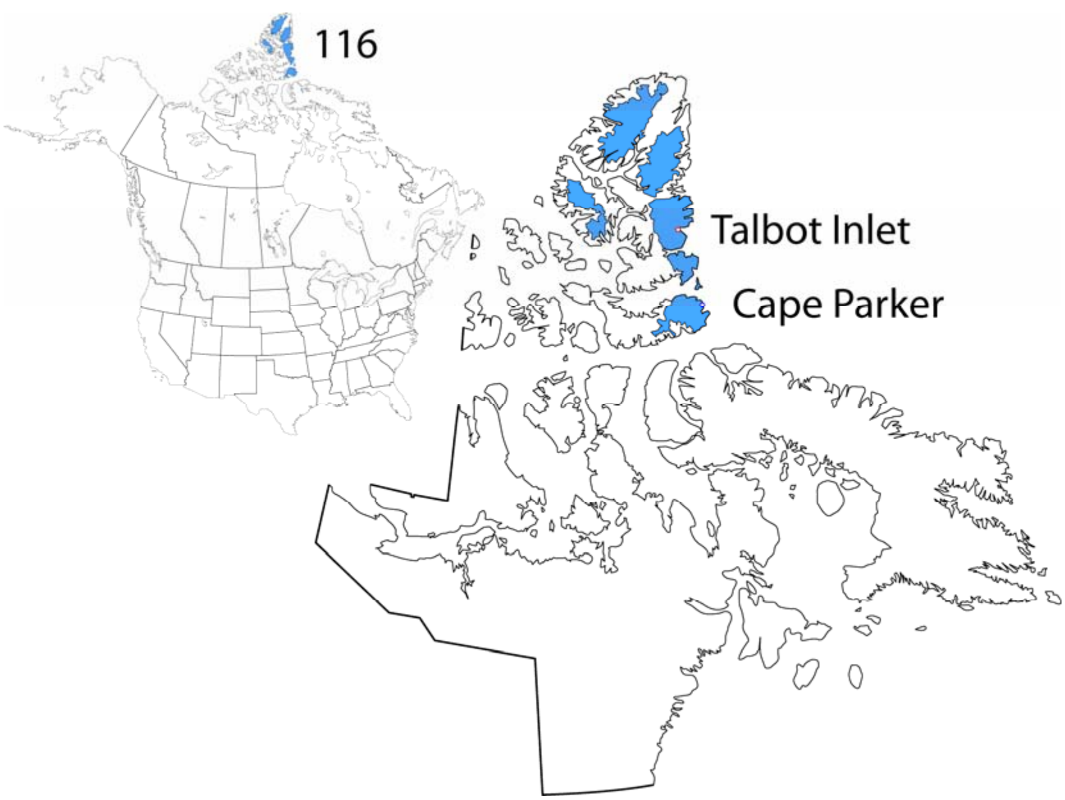


Figure I110. Permanent Ice.

Talbot Inlet, Nunavut

Lepus arcticus
Dicrostonyx groenlandicus
Canis lupus
Vulpes lagopus
Ursus maritimus
Mustela erminea
Gulo gulo
Rangifer tarandus
Ovibos moschatus

Cape Parker, Nunavut

Lepus arcticus
Dicrostonyx groenlandicus
Canis lupus
Vulpes lagopus
Ursus maritimus
Mustela erminea
Gulo gulo
Rangifer tarandus
Ovibos moschatus

APPENDIX J. DISTRIBUTION OF FOSSIL MAMMALS IN THE GLENNS FERRY FORMATION OF HAGERMAN FOSSIL BEDS NATIONAL MONUMENT

This table shows the distribution of fossil mammals occurring between the 890 and 1015 m levels on the Hagerman Horse Quarry datum (Chapter 2). Although some taxa do occur stratigraphically higher and lower within the Glenns Ferry Formation at HAFO, such specimens are rare.

The distributions are marked in 1 m increments; some elevations are represented by multiple fossil-bearing localities. The distribution of specimens of indeterminate taxonomic identification is only included when it has an impact on species disparity at that level. For example, the indeterminate camelid specimen listed at the 923 m level is only included because there are not other specimens attributable to *Hemiauchenia minimus*, *Hemiauchenia blancoensis*, or *Camelops* sp. Analyses in this chapter use a moving window average with a sliding interval of 10, 20 and 30 m in order to better represent a more complete assemblage. The indeterminate taxa are not counted within these sliding intervals if a possible taxon to which the specimen could belong is also within the intervals.

HHQ datum elevation	*Megalonyx leptostomus*	*Sorex hagermanensis*	*Sorex powersi*	*Sorex meltoni*	*Sorex* cf. *Sorex rexroadensis*	*Paracryptotis gidleyi*	Indeterminate Soricidae	*Scapanus hagermanensis*	*Hypolagus edensis*	*Hypolagus gidleyi*	*Alilepus vagus*	Indeterminate Leporidae
890												
891												
892										x		x
893										x		x
894												
895						x						
896												
897												
898												
899										x		x
900										x		x
901												
902												
903										x		x
904										x		
905	x									x		x
906										x		x
907						x						
908	x											
909										x		x
910												
911												
912			x			x		x	x	x	x	

HHQ datum elevation	*Megalonyx leptostomus*	*Sorex hagermanensis*	*Sorex powersi*	*Sorex meltoni*	*Sorex* cf. *Sorex rexroadensis*	*Paracryptotis gidleyi*	Indeterminate Soricidae	*Scapanus hagermanensis*	*Hypolagus edensis*	*Hypolagus gidleyi*	*Alilepus vagus*	Indeterminate Leporidae
913										x		
914										x		x
915						x		x		x		x
916						x				x		
917										x		
918										x		
919				x		x				x		x
920										x		
921						x						
922				x		x			x	x	x	
923	x					x				x		
924										x		x
925	x					x			x	x		
926										x		x
927		x								x		
928										x		x
929										x		
930						x				x		x
931	x									x		x
932										x		x
933	x					x		x		x	x	
934						x				x		
935						x						
936												
937												

HHQ datum elevation	*Megalonyx leptostomus*	*Sorex hagermanensis*	*Sorex powersi*	*Sorex meltoni*	*Sorex* cf. *Sorex rexroadensis*	*Paracryptotis gidleyi*	Indeterminate Soricidae	*Scapanus hagermanensis*	*Hypolagus edensis*	*Hypolagus gidleyi*	*Alilepus vagus*	Indeterminate Leporidae
938						x				x		
939												
940	x					x				x		
941						x		x				
942						x				x		x
943						x				x		x
944						x				x		x
945						x			x	x	x	
946						x				x		
947												
948										x		x
949										x		
950						x				x		
951												
952												
953					x	x				x		x
954	x					x		x		x		x
955							x			x		x
956										x		x
957										x		x
958												
959												
960										x		x
961										x		x
962										x		x

HHQ datum elevation	*Megalonyx leptostomus*	*Sorex hagermanensis*	*Sorex powersi*	*Sorex meltoni*	*Sorex* cf. *Sorex rexroadensis*	*Paracryptotis gidleyi*	Indeterminate Soricidae	*Scapanus hagermanensis*	*Hypolagus edensis*	*Hypolagus gidleyi*	*Alilepus vagus*	Indeterminate Leporidae
963												
964										x		x
965												
966						x				x		x
967						x				x		
968												
969												
970								x		x		
971										x		
972	x									x		x
973												
974												
975						x						
976												
977												
978												
979												
980												
981												
982												
983												
984												
985												
986												
987												

HHQ datum elevation	*Megalonyx leptostomus*	*Sorex hagermanensis*	*Sorex powersi*	*Sorex meltoni*	*Sorex* cf. *Sorex rexroadensis*	*Paracryptotis gidleyi*	Indeterminate Soricidae	*Scapanus hagermanensis*	*Hypolagus edensis*	*Hypolagus gidleyi*	*Alilepus vagus*	Indeterminate Leporidae
988												
989												
990												
991												
992												
993												
994												
995												
996												
997												
998												
999										x		x
1000						x						
1001				x					x	x	x	
1002												
1003										x		x
1004						x				x	x	x
1005	x		x			x				x	x	
1006						x						
1007												
1008												
1009												
1010												
1011												
1012												

HHQ datum elevation	*Megalonyx leptostomus*	*Sorex hagermanensis*	*Sorex powersi*	*Sorex meltoni*	*Sorex* cf. *Sorex rexroadensis*	*Paracryptotis gidleyi*	Indeterminate Soricidae	*Scapanus hagermanensis*	*Hypolagus edensis*	*Hypolagus gidleyi*	*Alilepus vagus*	Indeterminate Leporidae
1013												
1014												
1015												

HHQ datum elevation	*Paenemarmota barbouri*	*Spermophilus* sp. A	*Spermophilus* sp. B	*Spermophilus* sp. C	Indeterminate *Spermophilus*	Indeterminate Spermophilina	*Thomomys gidleyi*	*Pliogeomys parvus*	*Oregonomys magnus*	*Perognathus maldei*	*Prodipodomys idahoensis*	Indeterminate Heteromyidae
890												
891												
892												
893				x								
894												
895												
896												
897												
898												
899												
900												
901												
902												
903												
904												
905												
906												
907												
908												
909												
910												
911	x											
912						x				x	x	
913												

HHQ datum elevation	*Paenemarmota barbouri*	*Spermophilus* sp. A	*Spermophilus* sp. B	*Spermophilus* sp. C	Indeterminate *Spermophilus*	Indeterminate Spermophilina	*Thomomys gidleyi*	*Pliogeomys parvus*	*Oregonomys magnus*	*Perognathus maldei*	*Prodipodomys idahoensis*	Indeterminate Heteromyidae
914												
915		x					x					
916							x		x			
917												
918							x					
919							x					
920												
921												
922	x				x							
923							x					x
924												
925												
926	x			x			x	x		x		
927												
928							x					
929												
930												
931	x	x										
932												
933	x				x					x		
934	x											
935												
936												
937												
938												

HHQ datum elevation	*Paenemarmota barbouri*	*Spermophilus* sp. A	*Spermophilus* sp. B	*Spermophilus* sp. C	Indeterminate *Spermophilus*	Indeterminate Spermophilina	*Thomomys gidleyi*	*Pliogeomys parvus*	*Oregonomys magnus*	*Perognathus maldei*	*Prodipodomys idahoensis*	Indeterminate Heteromyidae
939												
940		x					x		x			
941												
942												
943	x	x				x	x					
944												
945							x					
946												
947												
948												
949								x				
950												
951												
952												
953												
954												
955				x								
956												
957												
958												
959												
960												
961												
962												
963								x				

HHQ datum elevation	*Paenemarmota barbouri*	*Spermophilus* sp. A	*Spermophilus* sp. B	*Spermophilus* sp. C	Indeterminate *Spermophilus*	Indeterminate Spermophilina	*Thomomys gidleyi*	*Pliogeomys parvus*	*Oregonomys magnus*	*Perognathus maldei*	*Prodipodomys idahoensis*	Indeterminate Heteromyidae
964												
965												
966												
967												
968												
969												
970												
971												
972												
973												
974												
975	x						x					
976												
977												
978	x											
979												
980												
981												
982												
983												
984												
985												
986												
987												
988												

HHQ datum elevation	*Paenemarmota barbouri*	*Spermophilus* sp. A	*Spermophilus* sp. B	*Spermophilus* sp. C	Indeterminate *Spermophilus*	Indeterminate Spermophilina	*Thomomys gidleyi*	*Pliogeomys parvus*	*Oregonomys magnus*	*Perognathus maldei*	*Prodipodomys idahoensis*	Indeterminate Heteromyidae
989												
990												
991												
992												
993		x		x				x	x	x	x	
994												
995												
996												
997												
998												
999												
1000												
1001												
1002												
1003												
1004			x				x	x		x	x	
1005	x			x	x		x	x				
1006												
1007												
1008												
1009												
1010												
1011												
1012												
1013												

HHQ datum elevation	*Paenemarmota barbouri*	*Spermophilus* sp. A	*Spermophilus* sp. B	*Spermophilus* sp. C	Indeterminate *Spermophilus*	Indeterminate Spermophilina	*Thomomys gidleyi*	*Pliogeomys parvus*	*Oregonomys magnus*	*Perognathus maldei*	*Prodipodomys idahoensis*	Indeterminate Heteromyidae
1014												
1015												

HHQ datum elevation	*Castor californicus*	*Procastoroides intermedius*	*Peromyscus hagermanensis*	*Baiomys aquilonius*	*Baiomys minimus*	Indeterminate *Baiomys*	*Neotoma* cf. *N. quadriplicata*	*Ophiomys taylori*	*Cosomys primus*	*Mictomys vetus*	*Ondatra minor*
890									x		x
891	x										
892											
893	x								x		
894											
895									x		
896									x		
897											
898											
899											
900		x						x	x		
901									x		
902	x	x							x		
903								x			
904									x		
905											
906											
907									x		
908											
909								x	x		
910								x	x		
911	x										
912	x	x	x	x			x	x	x		x
913	x							x	x		

HHQ datum elevation	*Castor californicus*	*Procastoroides intermedius*	*Peromyscus hagermanensis*	*Baiomys aquilonius*	*Baiomys minimus*	Indeterminate *Baiomys*	*Neotoma* cf. *N. quadriplicata*	*Ophiomys taylori*	*Cosomys primus*	*Mictomys vetus*	*Ondatra minor*
914									x		
915	x							x	x		
916	x							x	x	x	x
917	x								x		x
918									x		
919	x								x		x
920	x								x		
921											
922	x		x				x	x	x		x
923	x		x			x		x	x		x
924									x		
925	x								x		
926									x		x
927									x		
928								x	x		
929	x								x		
930			x						x		
931	x								x		x
932									x		
933	x							x	x		x
934								x	x		x
935									x		
936											
937	x	x							x		
938	x								x		x

HHQ datum elevation	*Castor californicus*	*Procastoroides intermedius*	*Peromyscus hagermanensis*	*Baiomys aquilonius*	*Baiomys minimus*	Indeterminate *Baiomys*	*Neotoma* cf. *N. quadriplicata*	*Ophiomys taylori*	*Cosomys primus*	*Mictomys vetus*	*Ondatra minor*
939											
940	x							x	x		x
941								x	x		
942	x								x		x
943	x								x		x
944									x		
945	x								x		x
946											
947									x		x
948									x		
949									x		
950	x		x		x			x	x		x
951											
952									x		
953											
954	x		x					x			
955	x						x	x	x		
956	x							x	x		
957									x		x
958									x		
959	x										x
960											
961											
962	x										
963							x	x	x		

HHQ datum elevation	*Castor californicus*	*Procastoroides intermedius*	*Peromyscus hagermanensis*	*Baiomys aquilonius*	*Baiomys minimus*	Indeterminate *Baiomys*	*Neotoma* cf. *N. quadriplicata*	*Ophiomys taylori*	*Cosomys primus*	*Mictomys vetus*	*Ondatra minor*
964											
965											
966									x		x
967	x				x				x		x
968											
969											
970									x		
971									x		
972	x								x		x
973											
974									x		
975									x		x
976									x		
977											
978									x		
979							x				x
980											
981											
982											
983											
984											
985								x	x		
986											
987											
988											

HHQ datum elevation	*Castor californicus*	*Procastoroides intermedius*	*Peromyscus hagermanensis*	*Baiomys aquilonius*	*Baiomys minimus*	Indeterminate *Baiomys*	*Neotoma* cf. *N. quadriplicata*	*Ophiomys taylori*	*Cosomys primus*	*Mictomys vetus*	*Ondatra minor*
989											
990									x		
991											
992	x								x		x
993	x		x					x	x		x
994											
995											
996											
997											
998											
999											x
1000	x								x		
1001											
1002								x			x
1003									x		x
1004	x		x	x				x	x		x
1005	x		x					x	x		x
1006									x		x
1007											
1008											
1009											
1010											
1011											
1012											
1013	x										

HHQ datum elevation	*Castor californicus*	*Procastoroides intermedius*	*Peromyscus hagermanensis*	*Baiomys aquilonius*	*Baiomys minimus*	Indeterminate *Baiomys*	*Neotoma* cf. *N. quadriplicata*	*Ophiomys taylori*	*Cosomys primus*	*Mictomys vetus*	*Ondatra minor*
1014											
1015											

HHQ datum elevation	*Canis lepophaugs*	*Borophagus hilli*	*Ursus abstrusus*	*Trigonictis cookii*	*Trigonictis macrodon*	*Mustela rexroadensis*	*Sminthosinis bowleri*	*Ferinestrix vorax*	*Taxidea* sp.	*Satherium piscinarium*	*Brevirostris breviramus*	*P. lacustris/L. rexroadensis*	*Homotherium* sp.	*Megantereon hesperus*
890														
891														
892														
893					x									
894				x	x									
895														
896														
897														
898														
899					x									
900					x					x		x		
901														
902														
903												x		
904														
905	x													
906														
907														
908														
909														
910												x		
911										x				
912	x			x	x	x				x		x		
913														
914										x				

HHQ datum elevation	*Canis lepophaugs*	*Borophagus hilli*	*Ursus abstrusus*	*Trigonictis cookii*	*Trigonictis macrodon*	*Mustela rexroadensis*	*Sminthosinis bowleri*	*Ferinestrix vorax*	*Taxidea* sp.	*Satherium piscinarium*	*Brevirostris breviramus*	*P. lacustris/L. rexroadensis*	*Homotherium* sp.	*Megantereon hesperus*
915				x	x							x		
916	x				x	x				x		x		
917										x				
918	x				x									
919			x									x		
920										x				
921	x									x		x		x
922	x			x	x					x				
923					x	x				x				
924														
925														
926										x		x		
927				x										
928										x				
929	x											x		
930	x									x		x		
931		x			x	x								
932					x	x								
933														
934														
935														
936					x					x		x		
937	x				x					x		x		
938										x		x		
939												x		

HHQ datum elevation	*Canis lepophaugs*	*Borophagus hilli*	*Ursus abstrusus*	*Trigonictis cookii*	*Trigonictis macrodon*	*Mustela rexroadensis*	*Sminthosinis bowleri*	*Ferinestrix vorax*	*Taxidea* sp.	*Satherium piscinarium*	*Brevirostris breviramus*	*P. lacustris/L. rexroadensis*	*Homotherium* sp.	*Megantereon hesperus*
940												x		
941	x									x				
942					x					x		x		
943	x			x	x					x				
944														
945	x				x					x		x		
946														
947														
948	x		x									x		
949														
950					x							x		
951														
952														
953												x		
954					x									
955	x			x	x					x		x		
956														
957														
958														
959										x				
960		x								x		x	x	
961										x				
962										x				
963					x					x		x		
964														

HHQ datum elevation	*Canis lepophaugs*	*Borophagus hilli*	*Ursus abstrusus*	*Trigonictis cookii*	*Trigonictis macrodon*	*Mustela rexroadensis*	*Sminthosinis bowleri*	*Ferinestrix vorax*	*Taxidea* sp.	*Satherium piscinarium*	*Brevirostris breviramus*	*P. lacustris/L. rexroadensis*	*Homotherium* sp.	*Megantereon hesperus*
965														
966					x					x				
967														
968					x									
969					x									
970										x				
971														
972	x									x		x		
973														
974	x									x				
975								x		x	x			
976														
977														
978														
979														
980										x				
981			x											
982														
983														
984										x				
985														
986														
987														
988														
989														

HHQ datum elevation	*Canis lepophaugs*	*Borophagus hilli*	*Ursus abstrusus*	*Trigonictis cookii*	*Trigonictis macrodon*	*Mustela rexroadensis*	*Sminthosinis bowleri*	*Ferinestrix vorax*	*Taxidea* sp.	*Satherium piscinarium*	*Brevirostris breviramus*	*P. lacustris/L. rexroadensis*	*Homotherium* sp.	*Megantereon hesperus*
990	x				x					x				
991														
992														
993				x	x									
994														
995														
996														
997					x									
998												x		
999														
1000										x				
1001	x					x	x	x	x	x		x		
1002														
1003														
1004	x						x			x				
1005		x		x			x				x			
1006	x			x	x					x				
1007														
1008														
1009														
1010														
1011		x												
1012					x									
1013														
1014														

HHQ datum elevation	*Equus shoshonensis*	*Platygonus pearcei*	*Odocoileus* sp.	*Ceratomeryx prenticei*	*Hemiauchenia minimus*	*Hemiauchenia blancoensis*	*Camelops* sp.	indet. Camelidae	*Mammut americanum*
890									
891									
892									
893									
894					x				
895									
896									
897									
898									
899									
900									x
901									
902							x		x
903									
904									
905		x						x	
906									
907	x	x							
908									
909									
910		x							
911									
912		x							x
913		x							
914					x	x			x

HHQ datum elevation	*Equus shoshonensis*	*Platygonus pearcei*	*Odocoileus* sp.	*Ceratomeryx prenticei*	*Hemiauchenia minimus*	*Hemiauchenia blancoensis*	*Camelops* sp.	indet. Camelidae	*Mammut americanum*
915	x					x			
916		x				x			x
917	x								
918					x				
919									
920	x								
921									
922									
923		x					x		
924	x								
925		x							x
926	x							x	
927									
928	x								
929									
930									
931									
932									
933		x						x	x
934	x				x				
935		x				x			
936									
937		x							
938	x	x			x				x
939									

HHQ datum elevation	*Equus shoshonensis*	*Platygonus pearcei*	*Odocoileus* sp.	*Ceratomeryx prenticei*	*Hemiauchenia minimus*	*Hemiauchenia blancoensis*	*Camelops* sp.	indet. Camelidae	*Mammut americanum*
940									
941									
942		x			x				
943	x						x		x
944									
945	x	x				x			
946	x								
947									
948									
949									
950	x	x	x						
951									
952									
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954									
955	x							x	x
956									
957		x							
958	x								
959									
960	x				x				
961	x								
962									
963									
964									

HHQ datum elevation	*Equus shoshonensis*	*Platygonus pearcei*	*Odocoileus* sp.	*Ceratomeryx prenticei*	*Hemiauchenia minimus*	*Hemiauchenia blancoensis*	*Camelops* sp.	indet. Camelidae	*Mammut americanum*
965									
966	x								
967									
968	x	x							x
969									
970	x								
971									
972									
973									
974									
975		x							
976									
977									
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979									
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981									
982		x							
983									
984									
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HHQ datum elevation	*Equus shoshonensis*	*Platygonus pearcei*	*Odocoileus* sp.	*Ceratomeryx prenticei*	*Hemiauchenia minimus*	*Hemiauchenia blancoensis*	*Camelops* sp.	indet. Camelidae	*Mammut americanum*
990									
991									
992									
993	x	x							x
994									
995									
996									
997									
998									
999									x
1000	x								
1001									
1002									x
1003									
1004	x		x				x		x
1005	x	x	x	x	x		x		x
1006	x	x							x
1007									
1008									
1009									
1010									
1011									
1012									
1013									
1014									

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