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The distribution abundance and habitat requirements of the Sierra mountain beaver in Yosemite National Park

Paul A. Todd

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The Distribution, Abundance, and Habitat
Requirements of the Sierra Mountain Beaver
in Yosemite National Park

by

Paul A. Todd
B.S., Lewis and Clark College, 1984

Presented in partial fulfillment of the requirements
for the degree of Masters of Science
University of Montana
1990

Approved by

Chairman, Board of Examiners

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The Distribution, Abundance and Habitat Requirements of the Sierra Mountain Beaver in Yosemite National Park (56 pp.)

Director: Lee H. Metzgar

Abstract

A 2-year study of the Sierra mountain beaver (Aplodontia rufa californica) in Yosemite National Park, California was undertaken to describe distribution, abundance, and habitat requirements and to compare historic and present distributions. Three of 7 subspecies are now designated as candidates for the Federal Endangered Species List and general concern over their status led to this study. I surveyed 8, 15 km long random tracts of riparian habitat in Yosemite for the presence of mountain beavers. Thirty-three active sites were found in the random survey and 8 others were located from historic records or by chance.

Mountain beavers were found between elevations of 5,200 ft. and 10,700 ft., near small perennial springs and streams. Historic distribution has changed in the park due to dispersal and natural and human caused local extinctions. Abundance has probably not changed significantly in the park over the past 100 years, but development pressures have impacted several active sites.

I utilized discriminant function analysis to identify variables that distinguish used from unused habitat, and to develop a model that will facilitate predicting and enhancing potential habitat. Out of 12 variables, shrub and herbaceous plant abundance, stream depth, and stream gradient were most associated with habitat use.

Management actions should focus on monitoring abundance and distribution in the park and evaluating the status of mountain beavers in adjacent areas where they are more threatened by human disturbances.
I would like to thank all persons who helped with technical, logistical, financial and moral support throughout my study. Without their knowledge and patience the project would have been impossible.

The study was funded by a grant from Yosemite Association and the B&B Dawson Award from the Environmental Studies Program, University of Montana.

I am particularly indebted to my committee members at the University of Montana, all of whom were extremely supportive and encouraging. My committee chairman, Dr. Lee Metzgar, Director of Wildlife Biology, gave me endless technical advice and personal encouragement. His positive attitude and ability to solve problems were invaluable. Dr.’s Kerry Foresman, Bert Pfeiffer, and Les Marcum all gave their undivided attention through critiques and technical advice.

Dr. Jan van Wagtendonk, Research Scientist, Yosemite National Park, initially informed me of the need for research on the Sierra mountain beaver. He supported my study the entire time; lending expertise, encouragement, equipment and office space. Tom Roy, Director of Environmental Studies gave me crucial logistical and personal backing in the early phases of my investigation.

Two mountain beaver researchers supplied me with essential background information and advice. Dale Steele encouraged me to pursue the investigation and accompanied me to several mountain beaver sites. He lent photographs, technical reports, and reviewed my material. Paul Beier contributed his technical assistance and publications in wildlife habitat modeling. Without his advice, the analysis would have been extremely difficult. I am indebted to Dr.’s Hans Zuuring and David Patterson for advising me on statistical methods and problems. Steve Chaddee provided writing assistance and constant support.

I must also thank my mother and father, for they more than anyone have allowed me to pursue my wishes - always backing my endeavors and instilling in me a love for the environment.

Last of all I want to thank Mary Beth. She had to listen to more explanations about what mountain beavers are than anyone would dream of, but gave constant support throughout the project. I am lucky.
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Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.
The mountain beaver (*Aplodontia rufa*), is the single representative of the family Aplodontidae and is considered the world’s most primitive living rodent (Vaughn 1986). Only distantly related to the true beaver (*Castor canadensis*), the mountain beaver is fossorial, about the size and appearance of a tailless muskrat (*Ondatra zibethica*) and typically makes extensive burrow systems in soft, damp ground.

The seven subspecies of mountain beavers are distributed only along the pacific slope area of western North America from lower British Columbia south to the Sierra Nevada mountains of California. Within this range they are confined to moist and cool environments - a function of their poor ability to concentrate urine and low tolerance for temperature extremes (Nungesser and Pfeiffer 1965).

**Status**

The Sierra mountain beaver (*A. r. californica*) is relatively uncommon throughout its range. Unlike most areas used by mountain beavers in northern California, Oregon and Washington, preferred habitat is rare in the Sierra Nevada due to this region’s seasonal aridity. As a result the Sierra mountain beaver has a scattered distribution typically living in small, disjunct populations restricted to perennial springs and creeks of considerable elevation and gradient (Beier 1989, Orr 1949, Wright 1969).
As early as 1901-15 J. Muir, C. Camp, and J. Grinnell observed populations of the Sierra mountain beaver in Yosemite National Park. Since these original accounts, additional observations in Yosemite and the Sierra have been few. These include investigations at Huntington Lake (Ingles 1959), Sequoia National Park (Wright 1969), the Truckee River basin (Beier 1989), and the Mono Basin-Mammoth Lakes region (Steele 1989). Steele found fewer populations on the western slope of the Sierra Nevada than indicated by earlier collection records. He attributes this possible decline to pressures from grazing, water diversions, and development.

Three subspecies of the mountain beaver are now candidates for the Federal Endangered Species List: *A. r. nigra* (category 1); *A. r. phaea* (category 2) and the Mono Basin populations of *A. r. californica* (category 2) (Drewry 1989). The California Department of Fish and Game now recognizes *A. r. phaea* and *A. r. nigra*, two coastal subspecies, as "Mammalian species of special concern" (Williams 1986).

Researchers from the U.S. Fish and Wildlife Service Region 1, California Department of Fish and Game, and Yosemite National Park placed a high priority on mountain beaver research in the Yosemite area (G. Kobetich, C. Larsen, and J. van Wagendonk, pers. commun.). They particularly desired information on the present and historic distribution of *A. r. californica*, its food and habitat requirements, and recommendations pertaining to its management.
Objectives

Study objectives were to: 1) estimate mountain beaver abundance and distribution in Yosemite National Park; 2) compare current abundance and distribution of mountain beavers in Yosemite with their known, historic abundance and distribution; 3) develop a model similar to Beier's (1989) to predict potential habitat; and 4) make management and monitoring recommendations to the concerned agencies. The investigation took place during the summer field seasons of 1988 and 1989.

Animal Characteristics

Evolution

Aplodontids arose in western North America during the late Eocene and early Oligocene (35-45 million years ago) and, unlike many mammals, have undergone relatively little distributitional or morphological changes during this time (Shotwell 1958). Due to their ancient record and primitive physiology, the mountain beaver is often referred to as a "living fossil" (Pfeiffer 1954). Taylor (1918) states that the family Aplodontia is entirely North American in origin, development, and present distribution, although other authors describe some fossil remains from Asia and Europe (Godin 1964). Before the Sierran-Cascade formation that began approximately 5-10 million years ago, Aplodontids ranged into the Great Basin region but are now restricted to the moist and cool Pacific Coast of North America (Shotwell 1958) (Fig. 1).

The highly specialized Mylagaulids, extinct relatives of the mountain beaver, are thought to have evolved from Aplodontids in the early Miocene or late Oligocene
(20-27 million years ago) and ranged over most of North America. Mylagaulids became extinct during the same extreme climatic changes that reduced Aplodontid distribution (Shotwell 1958, Vaughn 1986).

Fig. 1. Distribution of the seven subspecies of mountain beavers, *Aplodontia rufa* (modified from Godin 1964).
The present range of mountain beavers is near the center of origin and distribution of the family Aplodontidae which is unique for a mammalian species (McGrew 1941). According to Shotwell (1958) the reaction of Aplodontidae to climatic changes is different from that of most other mammals. Instead of changing, becoming extinct, or migrating peripherally at the advent of climatic extremes, they changed very little after the Miocene and instead moved with their environment which was sharply compressed. Shotwell (1958) knows of "no other mammal whose distributional history can be so well defined and correlated with evidences of floral change. The much greater distribution and diversity of most other mammals does not allow such a study."

Distribution

The restriction of mountain beavers to the west coast of North America has puzzled many zoologists. Within this limited but diverse geographical area they appear to be confined to moist and cool environments much like redwood trees (Sequoia) (Grinnell and Storer 1924).

Six of the 7 mountain beaver subspecies are found in California (Fig. 1). Three of these 6 (A.r.humboldtiana, A.r. nigra, and A.r. phaea) are endemic to the state. A. r. californica is nearly so but occurs in the Nevada portion of the Tahoe basin (Hall 1981, Steele 1989). With the exception of A. r. californica which inhabits the Sierra Nevada, mountain beavers occur only in the coastal regions of the state where their distinct habitat requirements are more common.
Johnson (1971) suggested at least 3 significant reasons why the mountain beaver occurs only in these areas: 1) the necessity for a large daily water intake; 2) a thermal regulation problem; and 3) the dependency on food plants restricted to this environment. Kinney (1971) and Beier (1989) suggest that ambient temperature and moist habitat are two of the most important factors governing the animal's range. Steele (1989) made the first sighting of a mountain beaver within sagebrush-scrub habitat at a freshwater seep on the shore of Mono Lake. This was contradictory to other sightings because of the area's sparse vegetation and arid climate. Numerous authors have inferred that optimal mountain beaver habitat consists of a large variety of herbaceous and woody riparian food plants (Beier 1989, Camp 1918, Price 1894, Orr 1949, Todd 1989).

History

Mountain beavers were first described by Lewis and Clark while at Fort Clatsop (Astoria, Oregon) during the winter of 1805-1806. They did not observe a live specimen but made their account from the dressed mountain beaver skins of the Clatsop people. In his journal entry of Feb. 26, 1806, Lewis tells of the mountain beaver:

Sewelel is the Chinook and Clatsop name for a small animal found in the timbered country of this coast... the natives make great use of the skins of this animal in forming their robes. (Burroughs 1961)

Sewelel is a common name that is still used today but was actually the natives' name for the robes made of the animal's pelt (Borrecco and Anderson 1980). Other common names are show'tl, mountain boomer, whistler, chehalis, and North
American short-tailed beaver (Lum 1878, Borrecco and Anderson 1980). The common name mountain beaver was given to *A. rufa* by early miners because of its habit of gnawing sticks like the true beaver (Price 1894). Northwest native americans commonly ate mountain beavers and considered them a choice food source (Matteson 1877).

**Taxonomy**

Because of its primitive characteristics and lack of any close living relatives, *A. rufa* has been the subject of considerable taxonomic debate and revision since it first appeared in the accounts of Lewis and Clark in 1805. Rafinisque (1817), who is credited with first naming *A. rufa*, based his classification entirely on Lewis and Clark’s sighting. His generic designation *Anisonyx*, found to be taxonomically untenable, was changed in 1829 to *Aplodontia* by Richardson (Burroughs 1961). Taylor (1918) recognized wide individual and geographic variation within the species and listed nine races. There are now seven recognized subspecies (Hall 1981).

The word *Aplodontia* comes from the Greek word haploss (simple) and odontas (teeth). The dental formula is 1/1, 0/0, 2/1, 3/3 = 22. The cheek teeth are modified hypsodont and each has a prominent style on the labial side (outside) of the upper tooth and lingual side (inside) of the lower tooth. The skull is noted for its flat upper surfaces, broad structure, and lack of post orbital processes (Godin 1964). *Aplodontia* is the only living member of the primitive infraorder Protogomorpha, whose members are characterized by masseter muscles of entirely
zygomatic origin. The family Aplodontidae is in the suborder Sciurognathi, infraorder Protrogomorpha, and superfamily Aplodontoidea (Anderson and Jones 1984).

External Characteristics

The mountain beaver is stout and well adapted for digging, with short legs, strongly clawed toes, long vibrissae, small ears and eyes, and no obvious neck. Mature animals weigh 900 to over 1,300 grams (2-3 pounds) and measure over 300 mm (12 inches) (Borrecco and Anderson 1980, Wright 1969). The animal is capable of moving rapidly, perhaps 1.5 m per second, and its gait is like the "lumbering gallop of a bear" (Grinnell and Storer 1924). The tail is short and stump-like and about 6 mm shorter than the back foot. The male and female pelage is generally blackish-gray complemented by a red-brown tinge with the exception of A.r. nigra of Pt. Arena, California, which is entirely black. Some authors describe a noticeable white spot located just below the ear (Godin 1964, Wright 1969).

Physiology and Activity

Most evidence indicates that mountain beavers do not hibernate. However, where long winters with deep snow depths prevail, periods of torpor may be required (Steele 1989). Wright (1969) found no sign of surface activity during winter months in Sequoia National Park and suggests that large snow packs could result in
hibernation. Similar observations were made in Yosemite at high elevation sites (pers. obs.).

Johnson (1971) found that the animal lacks adequate mechanisms to avoid heat stress, an important factor in its distribution. He determined that the mountain beaver has a normal body temperature of 38°C, and does not have a thermoneutral zone. In laboratory experiments, a mountain beaver was exposed to temperatures between 32°C and 35°C, and in 2 hours reached a lethal body temperature of 42°C. The lower lethal temperature was 19°-23°C.

Burrow systems are an important means by which mountain beavers can avoid extreme temperatures (Kinney 1971, Johnson 1971). Johnson found temperatures above ground to have a maximum annual fluctuation of 40.5°C while the temperature within burrows varied by only 18.3°C. Annual mean burrow temperature ranged from 2°-14°C.

The necessity for a large daily water intake appears to be universally accepted by mountain beaver researchers. Nungesser and Pfeiffer (1965) found that the animal takes in approximately 33% of its body weight in water daily, with most of this excreted as urine. However, there is some disagreement in the literature as to the necessity of free (drinking) water. Fisler (1965) kept a mountain beaver in captivity for over three months without any free water. The animal remained in good health on a varied diet of herbaceous plants including lettuce, apples, and cabbage. Schmidt-Nielsen and Pfeiffer (1970) state that mountain beavers require drinking water in great abundance at all times.
Wright (1969) found the animals to be almost 2 times as active at night as during the day. According to Ingles (1959), mountain beavers are only partially nocturnal, spending about 25% of the daylight hours foraging for riparian plant material. He found the feeding activity of Sierra mountain beavers to be divided into six or seven daily periods, each lasting up to 2 hours and 45 minutes. Daily foraging activities totalled 8 or 9 hours.

Lovejoy (1972), in his live-trapping work with _A. r. pacifica_ in western Oregon, found that adult males had an average home range size of 0.32 ha and adult females 0.17 ha. He concluded that overlapping of home ranges was common, with males making longer forays during the summer months when activity was at a peak. Neal and Borrecco (1981) found home ranges to vary between 0.10-0.17 ha in Washington. Martin (1971), with radio transmitter work in western Washington, found home ranges to average 0.24 ha with approximately 90% of recorded locations for adults occurring within 24.5 m (80 ft) of their nests. He found no significant difference between male and female home ranges and suggests that the size and shape of the range may be influenced by the quality and arrangement of the habitat.

Extensive linear movements above and below the ground are typical of dispersing subadults, which may move over 550 m (1,800 ft) in a one week period. Subadults tend to follow existing burrows and may attempt to establish nests at several sites before finding a suitable location (Martin 1971).
Reproduction

Mountain beavers have a low reproductive rate, usually not producing young until their second year. Evidence indicates they are a spontaneous ovulator with a monestrous annual cycle, producing one litter per year, with an average size of 2.5 young per litter. All ovulating females in a population do so at about the same time each year. This period is limited to several weeks. The gestation period is 28-30 days and parturition occurs in March or April (Pfeiffer 1954). Young mountain beavers are weaned at 6-8 weeks of age and emerge from their burrows in the following 2 weeks. Presumably the mothers feed the young for a short time on plants carried into the burrow. Their longevity has been estimated at 5-6 years (Lovejoy 1972).

Populations and Burrow Systems

The presence of one or more mountain beavers in a given area appears to positively influence the establishment of others. Camp (1918) wrote that overcrowded conditions may occur in one area while nearby areas of similar environment remain unused. A typical population of Sierra mountain beavers probably contains 2-12 individuals and can be completely isolated from other occupied areas (Beier 1989, Camp 1918, Steele 1989). In their southern distributional limits, populations may contain only 2-4 individuals (Wright 1969). Wright suggests that limited suitable habitat is the controlling factor in population size. The small size and extreme isolation of many Sierra mountain beaver sites is
puzzling in regards to genetic isolation and population dynamics. More information on these topics would be valuable, particularly as it pertains to dispersal patterns.

It is important to note that little is known about mountain beaver population structure and dynamics. This is due to the fact that most censusing has relied on indirect methods such as burrow estimates (Steele 1989). Because this information is so incomplete I have avoided using the term "population", and instead refer to groups of burrows as "sites" or "occupied areas."

Within occupied areas, individuals tend to be asocial (Goslow 1964, Pfeiffer 1953, Scheffer 1929, Wright 1969). Each animal lives in and vigorously defends its own burrow system, which is typically a network of tunnels where it stores food, eats, and sleeps (Camp 1918, Voth 1968, Wright 1969). Scheffer points out that even though individual burrows and home ranges overlap, no altruistic behavior has been documented.

Containing up to a bushel of vegetative material, nest chambers are approximately 50 cm high by 33 cm wide and are well protected from flooding. The mountain beaver also constructs specific fecal, refuse, and food storage chambers near the nest. The animal is known to take its fecal pellets in its mouth and toss them 15-38 cm into the fecal chamber (Goslow 1964). They will inter-mix vegetation in the fecal pile, presumably as a means of promoting decomposition. According to Goslow and Ingles (1961) these clean and sanitary habits may have played a major role in the evolutionary survival of mountain beavers.

Above ground, numerous openings to the burrow may be present, as the animals ordinarily do not repair roof cave-ins (Herlocker 1950). Although they generally
radiate from the centralized nest chamber, individual burrows extend to take in whatever brush, logs or other cover is available (Dalquest 1948). The tunnels generally lead to sources of food so the animal can easily pull material underground for consumption. Typical tunnel systems in Yosemite run 30 cm below the surface, contain 10-60 holes, and cover an area 100 m by 20 m (see Table 2; Appendix A). At sites with a significant snow pack, the burrows are most easily seen in early spring just after the snow has melted and before the willows and dogwood are leaved out (Grinnell and Storer 1924, pers. obs.). Generally a little hillock, often with a pile of cut vegetation, marks the entrance to the burrows. Dalquest (1948) reported that under snow cover, they will burrow in the snow and pack excavated dirt into the snow tunnels which appear as earth cores in the spring. He found the cores to be 60-120 cm long and slightly larger than the diameter of the animal (16 cm).

Habitat

Areas occupied by mountain beavers are often well sheltered from view by thick riparian vegetative cover. In the humid climates of Oregon and Washington they can occupy sloped areas with an abundance of vegetation away from running water (Godin 1964, Scheffer 1929). However, in the relatively xeric Yosemite region, "extensive thickets of preferred food plants are scarce and ...the mountain beaver must as a rule be content with limited tunnel systems through the narrow willow fringes along streams" (Camp 1918). Twelve areas in Sequoia National Park with
sign of mountain beavers were characterized as meadow-riparian habitat (Wright 1969).

Historically, mountain beavers in Yosemite were recorded at elevations from 1,500 m (5,000 ft) in Wawona to 3,000 m (10,000 ft) on the slope of Kuna Creek at the head of Lyell Canyon (see Table 1; Fig. 2). In the Truckee River basin, elevation and stream gradient had the strongest associations with habitat use (Beier 1989). Beier suggests that mountain beavers probably don’t respond to these factors directly, but rather to a cool thermal regime, adequate soil drainage, and abundant food supply.

The vegetation of mountain beaver habitat in the Sierra Nevada is typically dominated by one or more of the following shrub species: dogwood (*Cornus*), labrador tea (*Ledum glandulosum*), willow (*Salix*), alder (*Alnus*) and aspen (*Populus tremuloides*). Common understory species include cow parsnip (*Heracleum lanatum*), corn lily (*Veratrum californicum*), and fireweed (*Epilobium*) (Steele 1989, Todd 1989). Dominant species at 3 active sites in Sequoia National Park included triangle leaf groundsel (*Senecio triangularis*), hazelnut (*Corylus cornuta*), creek dogwood (*Cornus californica*), lupine (*Lupinus*), thimbleberry (*Rubus parviflorus*), white hedge nettle (*Stachys albens*), and various grasses (Wright 1969). In the Mono Basin, Steele (1989) found mountain beavers foraging on curly dock (*Rumex crispus*) and scaled grass (*Poa palustris*) associated with a freshwater seep near the shore of Mono Lake in sagebrush-scrub habitat. This population burrowed in tufa (calcium-carbonate deposits) for its shelter. Steele also reported two populations at
Deadman Pass in the Mammoth Lakes region in a lodgepole pine (Pinus contorta)-red fir (Abies magnifica) forest with a sparse understory and pumice type soil.

Foraging and Food

Foraging consists of gathering food and nesting material, which is carried a short distance and put into hay stacks near the burrow entrance or carried under ground for use. Hay stacks of freshly cut vegetation are usually left for a few days to wilt before being taken into the burrow, and sometimes attain a height of several feet. They are good indicators of the animal's presence and consist of numerous plant species (O'Brien 1981, Orr 1949). In Mono County at Valentine preserve, Steele (1989) found cow parsnip, aspen, and larkspur (Delphinium) to have >= 30% occurrence in hay stacks and to comprise > 90% of the total hay stack mass (n = 37). In Sierra County, O'Brien (1981) found larkspur, mountain alder (Alnus tenuifolia), and corydalis (Corydalis caseana) to have >= 50% occurrence and to comprise > 95% of total hay stack mass (n = 56). O'Brien found no relationship between % occurrence in hay stacks and % occurrence of plants in the vicinity of the hay stacks.

Some authors suggest that the vegetation in these piles is used primarily as building material and not for food (Camp 1918, Goslow 1964, Scheffer 1929). Voth (1968), however, states that mountain beavers may mix the stacked, wilted vegetation with fresh vegetation for food.

The mountain beaver is known for its voracious and varied appetite consisting of the leaves, stems, and bark of most available plant species. They climb trees in the Sierra Nevada such as douglas fir and white fir (Abies concolor) to a height of 6 m
to clip new growth and twigs smaller than 1.5 cm in diameter. Conspicuous on nearby trees and shrubs, these stems are easily recognized by their clean, tooth marked 45 degree cuts (Todd 1989). Voth (1968) and Steele (1986) point out that the mountain beaver eats plants that are either poisonous to or unused by other vertebrates. Voth determined that sword fern (Polystichum munitum) and bracken fern (Pteridium aquilinum) composed 82% of A. r. pacifica’s diet in the coastal mountains of Oregon. He points out that bracken fern is toxic to other herbivores. In addition to ferns, mountain beavers also consume lupine, larkspur, foxglove (Digitalis), thistle (Cirsium), and nettle (Urtica), species seldom used by most herbivores (Steele 1986). Where winter snows lie deep, mountain beavers will feed on the bark of saplings and large trees, both beneath the snow and above the crust. This explains the condition of the base of some tree trunks that appear bare and tooth-scarred when the snows melt (Scheffer 1929). The mountain beaver reingests some of its fecal pellets, possibly as a means to absorb undigested nutrients (Ingles 1961).

Associated Mammals

At least 17 other mammals have been found using mountain beaver burrows including various rodents, weasels (Mustela), badgers (Taxidea taxus), and bobcats (Lynx rufus) (Pfeiffer 1953, Godin 1964). Mountain beavers may be the primary food source for bobcats and coyotes (Canis latrans) in some areas (Phillips 1982, Smurthwaite 1986).
Study Area

Yosemite National Park is located in the central Sierra Nevada mountains of California and encompasses a total of 308,371 ha (approximately 1,200 miles²). The geography consists of a long, gentle west slope and a short, steep east escarpment that culminates in the highest peaks. Terrain includes deep canyons, large expanses of granitic rock, and glaciated peaks. Elevations range from 648-3,998 m (2,127-13,114 ft), with the lowest points along the western boundary. The park consists of 2 major river systems which drain a total of 3,000 km² (Botti 1987).

Exfoliating granitic domes and sparsely vegetated ridge tops of decomposed granite are common in the middle elevations from 2,100-2,700 m (7,000-9,000 ft). Soils are thin throughout most of Yosemite, and in general have formed in place by the disintegration and decomposition of underlying parent rock. Forest soils have been classified as members of the Inceptisol order, while those in the meadows are of the Entisol or Histosol order (Wood 1975).

The climate of Yosemite is Mediterranean and characterized by dry, warm summers and cool, moist winters. More than 95% of the Sierra’s total annual precipitation falls between October and May (Whitney 1979). Most of the precipitation falls as snow above 1,800 m (6,000 ft). Precipitation varies from 915 mm (36 inches) at 1,200 m (4,000 ft) to 1,270 mm (50 inches) at 2,600 m (8,600 ft). The snow accumulation typically persists into July each year with its greatest
accumulation between 2,400-3,000 m (8,000-10,000 ft) in elevation. The depth in April is usually in the range of 2.4-3.0 m (8-10 ft), but sometimes reaches 6 m (20 ft). Mean daily temperatures vary from 2-22°C (36-72°F) in Yosemite Valley at 1,220 m (4,000 ft) to -3.9-11.7°C (25-53°F) in Tuolumne Meadows at 2,600 m (8,600 ft) (Botti 1987).

Vegetation types in the park are extremely diverse as a result of the varied topography, soil, and climate. Approximately 78% of Yosemite is forested, 3.8% is covered by chaparral, and 3.8% is covered by meadows (Botti 1987).

The park's forests can be divided into four communities arrayed according to elevations. The mixed coniferous forest dominates the lower montane zone from 915-2,134 m (3,000-7,000 ft) and is comprised primarily of ponderosa pine (Pinus ponderosa), white fir, and Jeffrey pine (Pinus jeffryi) subtypes. The red fir forest dominates the upper montane zone, occupying deep, well drained soils from 1,980-2,740 m (6,500-9,000 ft). The lodgepole pine forest is typical of glacial basins in the lower subalpine zone, forming open stands at elevations ranging from 2,100-3,200 m (7,000-10,500 ft). The subalpine forest occupies terrain above 2,400 m (8,000 ft) and is dominated by western white pine (Pinus monticola), mountain hemlock (Tsuga mertensiana), and whitebark pine (Pinus albicaulis) (Whitney 1979).

Several different meadow types are found in the park and vary according to the proximity of dependable sources of moisture. The presence of mountain beavers is associated with moist meadows (pers. obs.) which occur on well drained, dark sandy loams, often on gentle slopes near springs or streams. These support numerous species of riparian plants described in the habitat section of Chapter I. Wet
meadows are characterized by poorly drained soils where water is in continuous supply. Soils here are soggy, high in acids and low in oxygen which results in dominant vegetation types of sedges (*Carex*), rushes (*Juncus*), and grasses.

Dry meadows occur widely above 2,440 m (8,000 ft) and are usually saturated for a short period after snow melt but drain quickly and become completely dry by late summer. These are typified by Brewer's reedgrass (*Calamagrostis breweri*), spiked trisetum (*Trisetum spicatum*), and bluegrass (*Poa*) (Whitney 1979).

**Historic Abundance And Distribution**

I defined "historic sites" as any reported location of mountain beaver sign in the Yosemite region previous to 1988. I found this information by searching literature and communicating with residents and park service personnel. In addition, a one page flyer was posted to obtain information from park visitors.

Historic sites that I could relocate and that contained current mountain beaver activity were analyzed and plotted on 1:62,500 topographic maps. Data gathered included dominant vegetation within 30 m of burrows, plant species used, elevation, stream gradient, aspect, approximate occupied area, and approximate number of burrow holes per site. Positively relocated historic sites with no sign of mountain beavers were recorded but no data were taken.
Fig. 2. Eight, 15 km random survey tracts (shaded lines) used for estimating mountain beaver abundance and distribution in Yosemite National Park, California, 21 June 1988-27 August 1989. The major drainages occurring in each tract and numbers of active mountain beaver sites found in each tract (n) were as follows: 1 = Falls Creek (n = 0); 2 = Rancheria Creek (n = 1); 3 = Return Creek (n = 1); 4 = Kuna Creek (n = 2); 5 = Murphy Creek (n = 1); 6 = Tamarack Creek (n = 1 in 1988, 0 in 1989); 7 = Grouse Creek (n = 18); 8 = Bridalveil Creek (n = 8). See appendices A and B for site data and location descriptions.
Current Abundance And Distribution

Eight randomly selected, 15 km long tracts in riparian habitat throughout Yosemite were surveyed for the presence of mountain beavers (Fig. 2). Two tracts were chosen randomly from each of 4 geographical regions in the park. To obtain these tracts, I generated 2 random points in each of the 4 regions above the 1,524 m (5,000 ft) contour. The riparian habitat crossed by a road or trail nearest each random point was the center of each tract. I then surveyed 7.5 km up and 7.5 km down the water shed along perennial rivers, creeks, and springs.

An active mountain beaver site was confirmed when burrows were found with clippings and/or haystacks. I used breaks in burrow presence of at least 50 m to distinguish between sites in densely populated areas. I then analyzed occupied areas and plotted them on 1:62,500 topographic maps as described for historic sites above.

To estimate the number of active sites in Yosemite, I extrapolated the frequency of sites found in the 120 km of the random survey tracts to all perennial riparian habitat above 1,524 m (5,000 ft) (2,018 km estimated from Yosemite's Geographical Information System).

A limited amount of live trapping was done in selected areas to confirm surveys and observe external animal characteristics. Hav-A-Hart and Tomahawk traps were placed next to active burrows and checked 4-6 times daily. I placed 2-4 pieces of bait (0.5-1 cm bits of apples, carrots, and lettuce) leading to the trap doors at 20-40 cm intervals and 10-15 pieces inside the trap with fresh riparian plant clippings.
Habitat Analysis

I analyzed the habitat of Sierra mountain beavers in Yosemite to help determine environmental variables which influence use and to develop a model to predict potential habitat. My investigation followed the general format of Beier's (1989) mountain beaver habitat use study in the Truckee River drainage (see Chapter I, Habitat). He evaluated differences between 7 physical and 12 vegetation variables for used and unused habitat. During the 1989 field season I measured 7 physical and 5 vegetation variables at 33 used and 34 unused 100 m reaches of perennial riparian habitat. One variable was categorical (susceptibility to flooding); all others were continuous. I measured stream gradient and aspect from the midpoint of every reach and determined elevation from 1:62,500 topographic maps. Stream depth and width were the averages of 3 measurements taken at 25 m intervals along the reach. Percentages of cover were estimated visually when vegetation was fully leaved, and aspen abundance was the number of trees per reach. Categories for susceptibility to flooding were based on sign of seasonal flooding (high water marks and drift material).

My goal was to collect data from random sample reaches of used and unused habitat in Yosemite. I selected all sample reaches from habitat within the 8, 15 km survey tracts depicted in Fig. 2. Each sample reach was 100 m long by 60 m wide to maintain homogeneity of habitat within samples. Beier (pers. commun.) used 700 m long reaches and found habitat within each one to be overly heterogeneous.

I randomly selected sample reaches from within areas occupied by mountain beavers in the 8, 15 km survey tracts to represent used habitat. Each of these areas
(n = 33) was divided into 2 sample reaches (1 extending above the midpoint of greatest activity and 1 below). This yielded 66 total used reaches, 33 of which were chosen randomly for analysis.

Unused sample reaches within each 15 km survey tract were allocated according to the amount of unoccupied habitat per tract. This was accomplished as:

\[ N_i = \frac{y_i}{232} \times 33 \]

where:

\[ N_i = \text{number of unused sample reaches allocated per tract } i \]
\[ 232 = \text{sum}(y_i) \]
\[ y_i = 33 - U_i \]
\[ 33 = \text{total number of unused sample reaches needed for analysis (rounded to 34)} \]
\[ U_i = \text{number of used sample reaches per tract } i. \]

For example, the Bridalveil Creek tract contained 9 of the 33 occupied areas found in the random survey tracts. The allocation of unused random samples for this tract was determined according to:

\[ N_i = \frac{y_i}{232} \times 33 = 3.4 \text{ (rounded to 3.0)} \]

where:

\[ y_i = (33 - 9) = 24. \]

No reaches were considered for analysis at elevations below 1,524 m (5,000 ft) or with > 30 degree stream gradients. I defined these parameters to meet statistical
assumptions and because mountain beavers are not known to use habitat outside of these limits in Yosemite (Todd, unpubl. data).

**Habitat Model**

Discriminant function analysis (DFA) (Norusis 1985) was used in this study to identify variables that distinguish used habitat and to generate a model to help Yosemite managers evaluate potential habitat. DFA is a statistical technique commonly utilized to investigate such problems (Capen 1984, Cavallaro et al. 1981). Linear combinations of the independent (predictor) variables are formed and serve as the basis for classifying observations into groups (Noon 1984).

DFA assumptions include: 1) predictor variables have a multivariate normal distribution; 2) variables are not correlated; and 3) group covariance matrices are equal. However, the function has been shown to perform fairly well in a variety of other situations (Norusis 1985).

To evaluate variables, I explored distributions within and relationships between each one with boxplots, dotplots, and the two sample Kolmogorov-Smirnov test. Variables with significant differences ($P < 0.01$) between used and unused reaches were considered important or related to factors affecting mountain beaver presence. Correlations between variables were examined with Spearman and pooled within-groups correlation matrices. I eliminated the least biologically meaningful and most difficult to measure variables when they were correlated ($r^2 > 0.5$) to other variables. Logarithmic and arcsin square-root transformations were used to normalize distributions when possible. Box’s M statistic was used to determine variable combinations whose group covariance matrices were unequal ($P < 0.01$).
(Norusis 1985).

I ran forced entry DFA with all combinations of the variables that met assumptions until the best classification of groups (used vs. unused) was found. A stepwise procedure was avoided because standard significance tests are invalid and results are often questionable, particularly when variables are correlated (Capen 1984, Johnson 1981). The function was tested with the cross-validation (jack knife) procedure which omits the first classification from the data set, develops a classification function using the remaining observations, then classifies the omitted observation. It then returns the first observation to the data set, omits the second observation, and repeats the same process. Cross-validation continues in this manner with all observations in the data set (Capen 1984, Lachenbruch 1975, Minitab 1988).
CHAPTER III
RESULTS

Historic Abundance and Distribution

There is no indication that historic mountain beaver abundance in Yosemite was significantly greater than present levels. However, distribution has changed due to habitat loss, local extinctions and dispersal movements. Approximately one half of the relocated historic sites contained currently active mountain beaver populations. I obtained 30 historic site descriptions from 1915-87, 11 of which were positively relocated. Five of these 11 sites (45%) had current mountain beaver activity (Table 1). Other historic sites were not relocated due to insufficient information. Naturally occurring extinctions and dispersal movements appear to have caused most distributional changes. Human impacts probably caused local extinctions at Glacier Point and Badger Pass Ski Area (Table 1).

Current Abundance and Distribution

I found more areas occupied by mountain beavers in Yosemite than expected based on previous records. Most of the random survey tracts contained active mountain beaver sites and a number of others were discovered in the course of the investigation. I found 41 sites in the park between 15 June 1988 and 24 August 1989 (Appendix A), 33 of which were in the 8, 15 km random survey tracts. Seven out of the 8 tracts had mountain beaver activity with 1-18 sites per tract. Another 11 occupied sites were reported by park visitors and employees but I did
Table 1. Eleven historic mountain beaver sites found in Yosemite National Park. 21 June-27 August, 1988. Note that 5 out of the 11 sites had sign of current mountain beaver activity. See Appendices A and B for more information on active sites.

<table>
<thead>
<tr>
<th>Site</th>
<th>Location</th>
<th>Original Observation</th>
<th>Current Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Chinquapin. Small tributary of Indian Ck. coming in from the S. 0.4 km down stream of hwy 41. 1.814 m (5.950 ft).</td>
<td>Grinnell and Storer 1924.</td>
<td>Yes</td>
</tr>
<tr>
<td>2</td>
<td>E. Fork Indian Canyon above Yosemite Valley from crossing of trail to N. Dome to head of Ck. 2.134 m (7.000 ft).</td>
<td>Grinnell and Storer 1924.</td>
<td>No</td>
</tr>
<tr>
<td>5</td>
<td>Gentry's 1.768 m (5.800 ft).</td>
<td>Grinnell and Storer 1924.</td>
<td>No</td>
</tr>
<tr>
<td>6</td>
<td>Snow Ck. 2.134-2.744 m (7.000-9.000 ft).</td>
<td>Grinnell and Storer 1924.</td>
<td>No</td>
</tr>
<tr>
<td>8</td>
<td>West Fork of Indian Canyon 2.134 m (7.000 ft).</td>
<td>Grinnell and Storer 1924.</td>
<td>No</td>
</tr>
<tr>
<td>121a</td>
<td>Kuna Ck. tributary near timberline 3.260 m (10.700 ft).</td>
<td>Grinnell and Storer 1924.</td>
<td>Yes</td>
</tr>
<tr>
<td>122</td>
<td>Kuna Ck. tributary near timberline 3.260 m (10.700 ft).</td>
<td>Grinnell and Storer 1924.</td>
<td>Yes</td>
</tr>
<tr>
<td>10</td>
<td>Porcupine Ck. above campground approx. 2.5 km. from where main fork crosses hwy 120. 2.510 m (8.240 ft).</td>
<td>Camp 1918.</td>
<td>Yes</td>
</tr>
<tr>
<td>12</td>
<td>0.8 km W. of Ostrander Rocks on tributary of Bridalveil Ck. 2.220 m (7.280 ft).</td>
<td>Camp 1918.</td>
<td>Yes</td>
</tr>
<tr>
<td>21</td>
<td>Glacier Pt. top of ledge trail. 2.195 m (7.200 ft).</td>
<td>Presnall and Carlisle 1931.**</td>
<td>No</td>
</tr>
<tr>
<td>26</td>
<td>Headwaters of Moss Ck. approx. 0.4 km down from hwy. 120. 1.549 m (5.080 ft).</td>
<td>Winter 1987. **</td>
<td>No</td>
</tr>
<tr>
<td>27</td>
<td>Badger Pass Ski Area above parking lot; head of Grouse Ck. 2.220 m (7.280 ft).</td>
<td>Johnston 1987.**</td>
<td>Yes</td>
</tr>
</tbody>
</table>

* Grinnell and Storer reported this site at 10,000 ft. Two sites were found in 1988 at 10,700, presumably the same site as historically recorded and the highest elevation known for mountain beavers.

** Information from Yosemite Research Library wildlife records.
not confirm these (Appendix B). One abandoned site was identified in August 1989 that was active the previous year (Appendix A).

Based on my random surveys, I estimate that mountain beavers now occupy 200-550 sites in Yosemite. In general, sites were most concentrated and largest in the red fir forests where small, protected perennial creeks and springs are more common. The mean elevation for all sites found randomly (n = 33) was 2,304 m ± 445 (SD) (7,557 ft). Fifty % of these occurred from 2,047-2,332 m (6,715-7,650 ft), but ranged from 1,585-3,262 m (5,200-10,700 ft), the highest elevation recorded for mountain beavers.

The geographical extent and numbers of burrow systems in occupied areas varied greatly between sites, and both appear to reflect the abundance of suitable habitat. Length and width of occupied areas averaged 134 m ± 117(SD) and 25 m ± 20(SD) respectively. Burrow entrances averaged 43 ± 45(SD) per site but ranged from 5-175 (Table 2).

Table 2. Geographical extent and number of burrow holes for active mountain beaver sites (N = 41) in Yosemite National Park, California, 21 June 1988-27 August 1989. See Appendix A for complete data set.

<table>
<thead>
<tr>
<th>Geographical Extent</th>
<th>Length (m)</th>
<th>Width (m)</th>
<th>#Burrow Holes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Median</td>
<td>87</td>
<td>20</td>
<td>25</td>
</tr>
<tr>
<td>Mean</td>
<td>134</td>
<td>25</td>
<td>43</td>
</tr>
<tr>
<td>Quartile 1</td>
<td>45</td>
<td>14</td>
<td>14</td>
</tr>
<tr>
<td>Quartile 3</td>
<td>200</td>
<td>30</td>
<td>60</td>
</tr>
<tr>
<td>Maximum</td>
<td>450</td>
<td>100</td>
<td>175</td>
</tr>
<tr>
<td>Minimum</td>
<td>15</td>
<td>5</td>
<td>4</td>
</tr>
</tbody>
</table>

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Mountain beavers in Yosemite used a wide variety of woody and herbaceous species that occurred within approximately 30 m of burrow systems. I found 48 plant species clipped or stacked by mountain beavers (Table 3). Six tree, 14 shrub, and > 28 herbaceous plant species comprised those used. Some plants such as red fir, dogwood, willow, and corn lily were used most frequently (>= 20% occurrence) but all available plant material appeared to be utilized (Table 3). I did not estimate % occurrence or mass of plant species per haystack (see O'Brien (1981) and Steele (1989) in Chapter I, Foraging and Food).

Live trapping was successful at 2 out 3 sites in Yosemite. I caught 5 animals in 33 trap nights (15% trap success) at Chinquapin and Shepherd Lake. The individual at Shepherd Lake was trapped mid-day and died accidentally in the live trap (now in Yosemite Museum collection). Mortality probably occurred from heat stress; the other individuals were trapped at night with no apparent harmful effects. I placed the trap under dense willow cover and checked it every 2-3 hours, but this may have been too long to leave it unattended. I recommend that traps be checked every hour during the day and several times throughout the night.

Characteristics of the live trapped animals and 1 road kill (San Francisco State University museum collection) suggest that pelage color of the Sierra mountain beaver in Yosemite may differ from other groups. The mature individuals I trapped had a definite red-brown dorsal tinge to an otherwise slate grey pelage. Wright (1969) describes similar coloration with the exception of a white spot immediately below the ears on individuals from Sequoia National Park. Beier (pers. commun.) observed specimens in the Truckee River basin that were uniformly slate grey.
Table 3. Plant species stacked and/or clipped by mountain beavers at 41 active sites in Yosemite National Park, California. 21 June 1988-27 August 1989. Occurrence identifies % of the 41 sites where each species was used.

<table>
<thead>
<tr>
<th>Plant species (N = 48)</th>
<th>Common name</th>
<th>Occurrence (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trees (n = 6)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Abies concolor</td>
<td>white fir</td>
<td>12</td>
</tr>
<tr>
<td>Abies magnifica</td>
<td>red fir</td>
<td>22</td>
</tr>
<tr>
<td>Calocedrus decurrens</td>
<td>incense cedar</td>
<td>2</td>
</tr>
<tr>
<td>Pinus contorta</td>
<td>lodgepole pine</td>
<td>10</td>
</tr>
<tr>
<td>Populus tremuloides</td>
<td>aspen</td>
<td>15</td>
</tr>
<tr>
<td>Tsuga mertensiana</td>
<td>mountain hemlock</td>
<td>2</td>
</tr>
<tr>
<td>Shrubs (n = 14)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Castaneopsis sempervirens</td>
<td>chinquapin</td>
<td>2</td>
</tr>
<tr>
<td>Cornus cornuta</td>
<td>hazel</td>
<td>3</td>
</tr>
<tr>
<td>Cornus spp.</td>
<td>dogwood</td>
<td>24</td>
</tr>
<tr>
<td>Ledum glandulosum</td>
<td>labrador tea</td>
<td>5</td>
</tr>
<tr>
<td>Lonicera involucrata</td>
<td>honeysuckle</td>
<td>5</td>
</tr>
<tr>
<td>Potentilla fruticosa</td>
<td>bush cinquefoil</td>
<td>5</td>
</tr>
<tr>
<td>Ribes nevadense</td>
<td>Sierra currant</td>
<td>5</td>
</tr>
<tr>
<td>Ribes montigenum</td>
<td>alp. prickly currant</td>
<td>2</td>
</tr>
<tr>
<td>Ribes viscosissimum</td>
<td>sticky currant</td>
<td>5</td>
</tr>
<tr>
<td>Rhododendron occidentalis</td>
<td>rhododendron</td>
<td>5</td>
</tr>
<tr>
<td>Salix lemmonii</td>
<td>Lemmon's willow</td>
<td>15</td>
</tr>
<tr>
<td>Salix oreasteri</td>
<td>Sierra willow</td>
<td>12</td>
</tr>
<tr>
<td>Salix scouleri ana</td>
<td>Scouler's willow</td>
<td>7</td>
</tr>
<tr>
<td>Sambucus spp.</td>
<td>elderberry</td>
<td>2</td>
</tr>
<tr>
<td>Herbaceous (n &gt; 28)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Achillea lanulosa</td>
<td>yarrow</td>
<td>2</td>
</tr>
<tr>
<td>Aconitum columbianum</td>
<td>monkshood</td>
<td>5</td>
</tr>
<tr>
<td>Adenocaulon bicolor</td>
<td>trail plant</td>
<td>2</td>
</tr>
<tr>
<td>Athyrium alepstrae</td>
<td>lady fern</td>
<td>7</td>
</tr>
<tr>
<td>Carex spp.</td>
<td>sedge</td>
<td>2</td>
</tr>
<tr>
<td>Delphinium spp.</td>
<td>larkspur</td>
<td>5</td>
</tr>
<tr>
<td>Epilobium spp.</td>
<td>fireweed</td>
<td>15</td>
</tr>
<tr>
<td>Gaevrythum spp.</td>
<td>bedstraw</td>
<td>2</td>
</tr>
<tr>
<td>Geranium californicum</td>
<td>California geranium</td>
<td>5</td>
</tr>
<tr>
<td>Heracleum lanatum</td>
<td>cow parsnip</td>
<td>17</td>
</tr>
<tr>
<td>Lilium parvum</td>
<td>alpine lily</td>
<td>2</td>
</tr>
<tr>
<td>Lupinus latifolius</td>
<td>broad-leaved lupine</td>
<td>15</td>
</tr>
<tr>
<td>Mentha spicata</td>
<td>spearmint</td>
<td>2</td>
</tr>
<tr>
<td>Mertensia ciliata</td>
<td>lungwort</td>
<td>10</td>
</tr>
<tr>
<td>Pedicularis groenlandica</td>
<td>elephant heads</td>
<td>2</td>
</tr>
<tr>
<td>Perideridia parishii</td>
<td>Parish's yamaph</td>
<td>2</td>
</tr>
<tr>
<td>Poaceae spp.</td>
<td>grass</td>
<td>5</td>
</tr>
<tr>
<td>Polygonum bistortoides</td>
<td>American bistort</td>
<td>2</td>
</tr>
<tr>
<td>Pteridium aquinum</td>
<td>bracken fern</td>
<td>5</td>
</tr>
<tr>
<td>Senecio clarkianus</td>
<td>triangle lf groundsel</td>
<td>7</td>
</tr>
<tr>
<td>Senecio triangulbaris</td>
<td>groundsel</td>
<td>7</td>
</tr>
<tr>
<td>Smilacina stellata</td>
<td>false Solomon's seal</td>
<td>5</td>
</tr>
<tr>
<td>Solidago canadensis</td>
<td>meadow goldenrod</td>
<td>2</td>
</tr>
<tr>
<td>Thalictrum fendleri</td>
<td>meadow rue</td>
<td>7</td>
</tr>
<tr>
<td>Veratrum californicum</td>
<td>corn lily</td>
<td>20</td>
</tr>
<tr>
<td>Unknown (3+)</td>
<td></td>
<td>10</td>
</tr>
</tbody>
</table>
Further comparisons should be made by making use of available museum collections described by Steele (1989).

**Habitat Analysis**

In general, used habitat had more shrub cover, steeper stream gradients, narrower and shallower streams, more herbaceous growth, and more soil than unused habitat. Nine out of the 12 predictor variables showed significant differences between used and unused habitat ($P < 0.01$) (Table 4).

Shrub % cover and herbaceous % cover were 2 of the most important variables for discriminating between used and unused perennial riparian habitat (Fig. 3). Most (75%) of the used reaches were covered > 60% by shrub species and > 90% by herbaceous species. Over 13 different species comprised the shrub cover and > 28 species comprised the herbaceous cover (Table 3). Stream depth was also important. On used reaches it averaged 2.7 cm ± 1.9(SD) with 50% of the observations ranging from 1.2-3.7 cm as compared to 6.7-21.7 cm for unused reaches.

Although stream gradient did not improve the classification results (see Habitat Model below), it was considerably different between used and unused habitat (Kolmogorov-Smirnov, $P < 0.001$). Stream gradient on used reaches averaged 11.8° ± 5.0(SD) and ranged from 6-27°, as compared to 5.9° ± 4.6(SD) on unused reaches. Running water was present at all sites, but in some was only visible trickling through the bottom of burrow holes. Mean elevation for used habitat was 2,303 m ± 445(SD) (7,557 ft).
Table 4. Mean and median values for 12 habitat variables on reaches used (n=33) and unused (n=34) by mountain beavers in Yosemite National Park, California, 1989. Significant differences between distributions are denoted by an asterisk (Kolmolgorov-Smirnov, \(P < 0.01\)). The last column shows the coefficients used in the discriminant function, which was developed using cross validation.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Present Mean</th>
<th>Present Median</th>
<th>Absent Mean</th>
<th>Absent Median</th>
<th>Discriminant Function</th>
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<tr>
<td>Stream Gradient (deg)</td>
<td>11.8 (10.0)</td>
<td>5.9 (5.5)</td>
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<tr>
<td>Elevation (m)</td>
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<td>2.587 (2.697)</td>
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<td>Aspect*</td>
<td>227 (260)</td>
<td>220 (235)</td>
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<td></td>
<td></td>
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<tr>
<td>Flood Susceptibility*</td>
<td>1.0 (1.0)</td>
<td>2.4 (2.0)</td>
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<td></td>
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<tr>
<td>Stream depth* (cm)</td>
<td>2.7 (2.7)</td>
<td>17.0 (12.0)</td>
<td>-1.6208</td>
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<td>Stream width (cm)</td>
<td>18.2 (9.7)</td>
<td>222 (135)</td>
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<td>Soil cover (%)</td>
<td>90.5 (97)</td>
<td>72.4 (80)</td>
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<tr>
<td>Shrub cover (%)</td>
<td>71.9 (70)</td>
<td>32.9 (25)</td>
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<td>Herbaceous cover (%)</td>
<td>79.1 (80)</td>
<td>55.6 (60)</td>
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<td>Willow cover (%)</td>
<td>28.4 (10)</td>
<td>19.9 (12.5)</td>
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<tr>
<td>Dogwood cover (%)</td>
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<td>0.9 (0)</td>
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<tr>
<td>Aspen abundance</td>
<td>3.9 (0)</td>
<td>0.6 (0)</td>
<td>-1.4284</td>
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<td></td>
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</tbody>
</table>

* Reporting these values can be nonsensical if aspect distributions are bimodal. In this case distributions were not bimodal and the contrast is valid.

* Flood Susceptibility index: 1 = no sign of seasonal flooding, 2 = sign of occasional seasonal flooding, 3 = sign of major occasional seasonal flooding, 4 = sign of major and regular seasonal flooding.

* log10 transferred.
Habitat Model

Shrub % cover, \( \log_{10} \) stream depth, and herbaceous % cover met most assumptions for DFA (distributions were slightly nonnormal) and gave the best classification results (Table 4, Fig. 3). When tested with cross validation, the function correctly classified 94% of the used and 85% of the unused sample reaches.

Many of the variables were correlated \((r^2 > 0.5)\); therefore I reduced them to the most biologically meaningful and uncorrelated group before entry into DFA. Some of these had nonnormal distributions or unequal group covariances (Box’s M, \( P < 0.01 \)). For example, dogwood % cover and stream depth showed great differences between used and unused habitat but group covariances were too heterogeneous for DFA. Logarithmic transformations corrected these problems for stream depth, but neither logarithmic nor arcsin square-root transformations corrected the problems for dogwood % cover.
Fig. 3. Boxplots depicting medians (+), quartiles (I), and outliers (*) for shrub cover (A), $\log_{10}$ stream depth (B), and herbaceous cover (C) on reaches used (n=33) vs. unused (n=34) by mountain beavers in Yosemite National Park, California, 1989. Used reaches were significantly different than unused reaches for each variable (Kolmogorov-Smirnov, $P \leq 0.001$).
CHAPTER IV
DISCUSSION

Historic Abundance and Distribution

J. Muir (1901) was the first person to describe mountain beavers in Yosemite after observing them near sloping meadows and rushing water at high elevation. Grinnell and Storer (1924) found mountain beavers in Yosemite to be resident locally in small numbers from 1,770-3,050 m (5,800-10,000 ft). They recorded sign at Aspen Valley, Gentrys, Chinquapin, in both forks of Indian Canyon (above Yosemite Valley), near Porcupine Flat, and in the head of Lyell Canyon. From their site descriptions (some are in Camp (1918)), I was able to relocate 6 sites only 2 of which were still used. Camp reported 4 sites at Porcupine Creek, Chinquapin, and near Ostrander rocks. Of these I relocated 3, all of which were still used by mountain beavers (Table 1).

In Sequoia National Park, Wright (1969) found mountain beavers at 3 sites and sign of past activity in 9 different areas. Other historic records in Sequoia National Park from 1928-1968 indicate periodic disappearance (Wright 1969). Wright agrees with Sumner (1953) that populations may die out or move away as food supplies dwindle, but may sometimes reappear later in the same area. Beier (1989) concluded that there was no change in habitat use by Sierra mountain beavers over the last 50 years in the Truckee River basin. In particular, neither human activity nor the introduction of true beavers had forced mountain beavers out of their historically used habitat.
This information agrees with my data and I suggest that populations have historically been unstable and scattered in Yosemite. The distributional changes that have occurred in the park, whether due to extinction, recolonization, or dispersal, are not abnormal for a species such as the mountain beaver which is near the edge of its range (Wright 1969). With the exception of developments at Glacier Point and Badger Pass Ski Area (Table 1), it appears that mountain beaver abundance and distribution have been affected minimally by human activity in Yosemite.

However, populations surrounding the park which are not as well protected from water diversions, grazing and development may have experienced unnatural local extinctions due to human activity. Steele (1989) found only 5 extant populations out of 33 historic Sierran sites. Loss of habitat due to sheep grazing in the late 1800’s may have played a significant role in reducing abundance and distribution throughout the Sierra (J. Keay, pers. commun.). Unfortunately, locations of mountain beavers in the Sierra prior to 1900 are not available.

**Current Abundance and Distribution**

My estimate of 200-550 mountain beaver sites in Yosemite assumes that the random survey tracts were a good representation of potential mountain beaver occurrence in the park. Defining a cluster of burrow systems as a site was difficult in some situations such as along Grouse Creek where tunneling was nearly continuous from the Glacier Point road downstream 2-3 km.

It is also difficult to extrapolate from numbers of sites to numbers of animals. This is due in part to the fact that censusing within populations (see Chapter I, Populations and Burrow Systems) has relied on indirect methods such as burrow
estimates (Steele 1989). Beier (pers. commun.) estimated population size in the Sierra to be < 8 adults, Steele (1989) 6-12, and Camp (1918) only 2. Given estimates of 2-12 adults per site, we might expect to find 440-6,600 adults living in the park at this time.

I only surveyed riparian habitat above 1,524 m (5,000 ft) because mountain beavers are not known to occupy areas below this elevation in Yosemite. However, their possible occupancy of some locations here, particularly on lush northern exposures, cannot be ruled out.

Habitat Analysis and Model

My results suggest that the Sierra mountain beaver requires abundant riparian food plants but that species composition is relatively unimportant. Steele (1989) and Grinnell and Storer (1924) came to similar conclusions and Beier (1989) points out that abundant shrubs may also provide thermal and escape cover. This was particularly evident in Yosemite at high elevations where extreme temperature and deep snow are common.

Many sites are found along springs and small creeks where water may not be visible above ground but can always be seen running through the bottom of burrows (Wright 1969, pers. obs.). When I found sites close to larger creeks, the burrow systems were usually associated with nearby seepage areas. Stream depth in used sites averaged 2.7 cm with 50% of the observations ranging from 1.2-3.7 cm. These small perennial water sources allow constant water supply while minimizing the probability of complete flooding.
Stream gradient is consistently an important factor governing mountain beaver presence in the Sierra (Beier 1989, Camp 1918, Wright 1969, pers obs.). Although gradient did not improve my model, the mean for used reaches greatly exceeded the mean for unused reaches. Beier also found gradient strikingly different between used and unused habitat in the Truckee River basin and suggests that steeper gradients may promote water drainage, and prevent burrow flooding.

Beier (1989) found high elevations strongly associated with Sierra mountain beaver presence. In Yosemite, elevation was slightly lower for used habitat than unused habitat. This is probably a reflection of the park's generally high elevations. However, the mean elevation for used habitat (X = 2,304 m) in Yosemite was greater than Beier's (X = 2,137 m) and supports his suggestion that higher elevations are preferred because they are associated with relatively low mean temperatures.

Aspect did not differ significantly between used and unused habitat, an observation also congruent with Beier's. Although statistically insignificant, I did notice a trend above 2,745 m (9,000 ft) where mountain beavers tended to occupy southwest facing slopes. Persistent cold temperatures and snow pack at these elevations may typically prevent them from occupying other exposures.

Overall my results agree strongly with Beier (1989) who suggests that "habitat use by mountain beavers involves strict requirements for an appropriate thermal regime and adequate soil drainage, and somewhat more flexible requirements for food". In Yosemite they use relatively high gradient, high elevation small perennial creeks and springs with an abundance of riparian plants. By doing so, mountain beavers are fulfilling microclimate needs while minimizing exposure to intolerable stochastic events such as flooding and high temperatures.
CHAPTER V
MANAGEMENT RECOMMENDATIONS

Human Impacts

Because mountain beaver populations in the central and southern Sierra tend to be isolated and are near the edge of their species' range, they may require special attention when management decisions are made. Development pressures from projects within Yosemite have impacted mountain beavers, but probably have not greatly reduced overall abundance and distribution. Outside the park, population and habitat loss due to human activity has been more of a threat (Steele 1989).

Maintenance and development activities near perennial seeps, streams and creeks between 1,220-3,660 m (4,000-12,000 ft) should not be undertaken until the site is investigated for the presence of mountain beavers and potential habitat (see Model Application below). Particular attention should be paid to moist seep areas where flowing water may not be immediately obvious, because water can be confined to burrows. These areas are prime mountain beaver habitat. Projects such as the renovation or construction of parking lots, roads, buildings, or campgrounds should maintain a buffer of at least 25 m (80 ft) from existing burrow entrances and centers of potential habitat. Within Yosemite, the Badger Pass Ski Area complex exterminated what appears to have been used habitat (pers. obs.). Currently there are active burrow systems directly above the parking lot and below the buildings on Grouse Creek. These were protected in a recent parking lot expansion. Mountain beavers are no longer found at Glacier point, most likely due to the construction of parking lots over perennial water sources.
Steele (1989) found that water diversion projects including the L.A. aqueduct in Mono County and utility water storage projects throughout the Sierra have reduced suitable stream side habitat for mountain beavers. He also determined that grazing and brush clearing will impact populations as evidenced at Pt. Arena where cattle have stepped into burrows and crushed runways.

Unoccupied but potential habitat may be a necessary "reservoir" of habitat for mountain beavers to ensure population structure and dynamics. Many unused perennial creeks and springs with abundant shrub cover in the Yosemite region include potential habitat (Camp 1918, Grinnell and Storer 1924, pers. obs.). These areas can be evaluated with my model (see Model Application below) and should be left unperturbed to maintain natural corridors for dispersal and colonization (Steele 1989, pers. obs.).

Timber cutting activities in the central Sierra probably have little impact on mountain beavers unless operations directly damage used or potential habitat (e.g., tree felling or vehicle use in meadow-riparian areas) (pers. obs.). Mountain beavers are known to cause considerable damage to conifers in Oregon and Washington by eating and gnawing on young second growth trees (Borrecco and Anderson 1980, Martin 1971, Neal and Borrecco 1981). In the Sierra, however, conifer damage is insignificant and primarily seen during winter months (O'Brien 1982, Steele 1989, pers. obs.).

Model Application

As a predictor of mountain beaver presence and potential habitat in Yosemite, the tested model correctly classified 94% of the used reaches and 85% of the unused
reaches. From a management standpoint where preservation is the aim, the prior error rate (6%) is most critical because it is the probability of rejecting areas which are suitable habitats for the species involved (Capen 1984, Marcot 1984, Rice et al. 1981). Because the model has a relatively low probability of misclassifying used habitat, it can be employed as an aid in predicting and enhancing potential mountain beaver habitat in Yosemite.

To utilize the model, plots should be 100-200 m by 60 m wide and centered over the habitat to be considered (30 m on each side of the spring or creek). Sites below 1,524 m (5,000 ft) and with gradients < 5 or > 30 degrees should not be evaluated because they were not used in developing the model and appear to be the distributional extremes of mountain beavers in Yosemite. Percent cover is measured by visual estimates when vegetation is fully leaved. Stream depth (cm) is the average of 3 evenly spaced measurements along the water source. Values should then be entered into the following function:

$$PUSE = (0.0313)(\text{SHRUB PERCENT COVER}) - (1.6208)(\log_{10} \text{STREAM DEPTH}) + (0.1360)(\text{HERBACEOUS PERCENT COVER}) - 1.4284.$$

If $PUSE > 0$ the site is predicted to be potential habitat. In this case we can expect to incorrectly predict unsuitable habitat as suitable habitat 14% of the time. If $PUSE < 0$ the site is probably not suitable for mountain beavers, and we can expect to reject areas that are in fact suitable 7% of the time. These are prediction errors (P. Beier, pers. commun.) and should not be confused with the 6% model classification error discussed above. Note that the higher prediction error leads to
conservative management: 14% of the time the model would hold up projects for mountain beaver habitat that really isn’t there. When the model predicts that an area is unsuitable, it is very likely (93%) correct.

Monitoring

Monitoring mountain beavers in Yosemite is important for 3 reasons: 1) to evaluate fluctuations in abundance and distribution; 2) to use this information as baseline data for comparison with similar information from less pristine areas in the Sierra; and 3) to investigate associations between distributional changes and climate changes that may occur within the next century.

To evaluate fluctuations in population abundance, distribution, and size within the park, sites should be relocated and compared to previous records (Appendices A and B; topographic maps provided to Yosemite’s Research Division). Five-10 sites near roads can be investigated within a 1 day period, and backcountry sites can be visited in several days. Monitoring should be done every 7-10 years and include at least the same sites that were done in previous monitoring investigations.

Future studies should compare abundance and distribution in Yosemite to other less protected areas. This is one way to effectively estimate the Sierra mountain beaver’s true status and the level of protection necessary to ensure its continued existence throughout its historic range (C. Larsen, pers. commun.).

With global warming and drying climates (Mckibben 1989), mountain beaver distribution in the Sierra may contract to areas where more desirable thermal regimes could be found (e.g. higher elevations and northern exposures). If precipitation decreases significantly, perennial water sources currently used may dry
up resulting in local extinctions. Mountain beaver distributional changes could be one of the first biological impacts of changing climates. Further investigations attempting to correlate these changes should be made.
CHAPTER VI
SUMMARY

The mountain beaver is a fossorial rodent and includes 7 subspecies ranging from lower British Columbia south, to the southern Sierra Nevada mountains of California. Sierra mountain beavers inhabit the Sierra Nevada mountains where populations are typically scattered and restricted to small, middle-high elevation perennial water sources. Three subspecies, including the Mono Basin populations of Sierra mountain beavers, are currently designated as candidates for the Federal Endangered Species List. General concern and lack of knowledge about the mountain beaver in Yosemite National Park and the central Sierra Nevada led to this investigation. My study estimated Yosemite’s current mountain beaver abundance and distribution, compared these current levels with the known, historic levels, and developed a model to enhance and predict potential habitat. Management recommendations were also made, emphasizing habitat protection and long term monitoring.

Eight, randomly selected 15 km tracts of riparian habitat were surveyed for the presence of mountain beavers. I confirmed active sites when I found burrows with haystacks and/or clippings. Location, plant species used, extent of occupied area, and habitat characteristics were recorded for all sites. I compared 12 environmental variables between 33 used and 34 unused random sample reaches of habitat. I then utilized discriminant function analysis (DFA) to identify variables that distinguish used habitat and to facilitate predicting potential habitat.
Approximately 1/2 of the relocated historic sites contained active mountain beaver populations. Although distribution has changed due to habitat loss, local extinctions, and dispersal movements, there is no indication that historic abundance was significantly different than present levels.

Current abundance and distribution within the park was greater than expected based on previous records. Thirty-three occupied areas were found in the random survey with 8 others located from historic records or by chance. I estimate 200-550 active mountain beaver sites now exist in the park. Areas occupied at each site ranged from 15-450 m long by 5-100 m wide and occurred at elevations between 1,585-3,262 m (5,200-10,700 ft), the highest known record for mountain beavers.

In general, used habitat had more riparian plant cover, steeper stream gradients, smaller streams, and more soil than unused habitat. Shrub % cover, log10 stream depth, and herbaceous % cover met most assumptions for discriminant function analysis and were highly associated with habitat use. Utilizing these 3 variables, the function correctly classified 94% of the used and 85% of the unused sample reaches. These results substantiate Beier’s (1989) findings which suggest that mountain beavers are probably responding primarily to a cool thermal regime, adequate soil drainage, and abundant food supply.

Management recommendations for Sierra mountain beavers in the Yosemite region focus on minimizing human impacts, predicting and enhancing potential habitat, and implementing a long term monitoring program. To minimize development impacts, a buffer of all activity should be maintained of at least 25 m from existing burrows or potential habitat. The model developed in this study has a low probability of misclassifying used habitat, and will be useful as an aid for identifying and
enhancing potential habitat. Long term monitoring should evaluate fluctuations in abundance and distribution, compare Yosemite's population status with other less pristine areas, and investigate associations between mountain beaver distributional changes and climate changes.
LITERATURE CITED


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APPENDIX A. Habitat data on 41 mountain beaver sites in Yosemite National Park, California, from 21 June 1988-27 August 1989. Numbers 1-27, 121, and 122 are relocated historic sites. Numbers 101-132 and 27 are sites found in the random survey tracts and used in the habitat model. Numbers 501-505 were found by chance (503 was used as a substitute for 132 in developing the habitat model because this site was unoccupied in 1989). Location descriptions are in Appendix B and also are drawn on 1:62,500 topographic maps available through the Yosemite National Park Research Division.
Appendix A (continued)

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<th>CRK</th>
<th>SITE UTME</th>
<th>UTMN</th>
<th>GR</th>
<th>ASP</th>
<th>ELEV F</th>
<th>DPTH</th>
<th>WDTH</th>
<th>SL</th>
<th>SB</th>
<th>HB AS</th>
<th>WL</th>
<th>DW</th>
<th>LENGTH</th>
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</table>

CRK: Creek name on which site is located. Brid = Bridalveil, gros = Grouse, ilil = Illilouette, indi = Indian, kuna = Kuna, murf = Murphy, porc = Porcupine, retu = Return, rncb = Rancheria, stub = Stubblefield, tama = Tamarack, tild = Tilden, wolf = no name creek draining Whitewolf area.

UTME: UTM East coordinate.

UTMN: UTM North coordinate.

GR: Stream Gradient.

ASP: Aspect.

ELEV: Elevation (ft).

F: Flood susceptibility index (see Table 4 for index values).

DPTH: Stream depth.

WDTH: Stream width.

SL: Soil % cover.

SH: Shrub % cover.

HB: Herbaceous % cover.

AS: Aspen % cover.

WL: Willow % cover.

DW: Dogwood % cover.

LENGTH: Length (m) of occupied site.

BRDTH: Width (m) of occupied site.

HOLES: Number of burrow holes per occupied site.
APPENDIX B. Locations for 41 confirmed active mountain beaver sites and 11 unconfirmed sites in Yosemite National Park, California, June 1989-August 1990. Site numbers 1-27, 121 and 122 are relocated historic sites (Table 1), 101-132 were found in the random surveys, 501-505 were found by chance, and 801-811 are occupied areas reported to but not confirmed by this investigation. Confirmed sites are drawn on 1:62,500 topographic maps available through the Yosemite National Park Research Division. See Appendix A for site data.

1. Approximately .4 km down Indian Creek from where Highway 41 crosses it, the burrows can be found along an indistinct tributary/seepage area that flows in from the south to Indian Creek. The tributary is not on topo map. Yosemite quad.

10. Porcupine Creek above campground approximately 2.4 km from where main fork crosses highway 120. Follow right branch of main fork (it branches approximately 1.9 km from highway 120). Stream gradient increases just before site which is on small islands in main fork and along small seepage area to the east. Hetch Hetchy quad.

12. Approximately .5 km down from the top of drainage that runs southwest into Bridalveil Creek. Drainage starts about 350 m northwest of Ostrander rocks. Drainage is easily seen from top of Ostrander rocks. Yosemite quad.

27. Approximately 50 m from northeast most part of Badger Pass parking lot (near meadow) where the creek goes into a culvert and under pavement. Burrows along creek on west side of meadow extend about .4 km to head of creek which is indistinct. Yosemite quad.

101. Nine degrees and approximately 300 m from outlet of Shepherd Lake. 226 degrees to highest peak just southwest of Shepherd Lake. Burrows start in seepage area heavily covered by shrubs about 100 m from creek that drains the lake (east side of creek). Matterhorn quad.

102. Tributary of Rancheria Creek's headwaters that run into upper Kerrick meadow. The stream drains a small lake and runs northeast. Site is about 400 m downstream from the small lake. Crown point is at 112 degrees and Cirque mountain is at 65 degrees. Willows are thick and generally a difficult site to locate. Matterhorn quad.

103. Along Grouse Creek approximately 1/2 way between Glacier Point road and Badger Pass ski lodge. Yosemite quad.

104. Along tributaries of Grouse Creek that begin just below Glacier Point road and meet Grouse Creek about .8 km downstream. Site is made up of 4 or 5 burrow systems that appear to be disjunct. Tributaries are not marked on 15 minute quad. Yosemite quad.

105. Approximately .8 km down from where Grouse Creek goes under glacier point road; 500-400 m below site 104. First place since headwaters of creek that
aspen is growing. Small tributary comes in from the southwest (not marked on quad). Open rocky area is approximately 100 m downstream. Yosemite quad.

106 & 107. A small tributary about 400 m long (not marked on quad) runs from 230 degrees (southwest) into Grouse Creek. 106 is at the junction on a steep bank for the most part and 107 is above 106 on the tributary. Tributary enters Grouse Creek just below rocky area described in 105. Yosemite quad.

108. Approximately .8 km below Glacier Point road on Grouse Creek where a small intermittent tributary joins in. Sites 104-108 are all before a marked tributary comes in from the northwest. Yosemite quad.

109. At the top of a tributary (not marked on quad) running into Grouse Creek below site 108. Burrows well hidden by dogwood and willow and generally difficult site to relocate. Yosemite quad.

110. Grouse Creek along main fork but associated with a swampy spring area directly adjacent to creek. Site is 400-500 m downstream from 109. Yosemite quad.

111. Approximately 500 m from 110 along small tributary (not marked on quad) coming in from east. Site is about 20 m from Grouse Creek. Yosemite quad.

112. 500-700 m downstream from 111 along steep seepage area draining into Grouse Creek. Yosemite quad.

113. Approximately 700 m downstream from 112 along small tributary (not marked on quad) coming into Grouse Creek from the east. Yosemite quad.

114 & 115. 114 is 400-500 m below 113 in another small seepage area. 115 is about 300 m down on the east side of the creek. Yosemite quad.

116 & 117. Approximately 2 km up first mapped (on quad) tributary of Grouse Creek below Badger Pass. Yosemite quad.

118. About 3 km up tributary described for 117. Yosemite quad.

119. Approximately 2 km up from crossing of Grouse Creek on highway 140 where a very indistinct tributary comes in steeply from the south. Occupied area is at extreme top of this tributary where water is only seen running through burrows. Yosemite quad.

120. Above and below trail that goes from May Lake to the Murphy Creek trail. Only a few indistinct burrows above trail with most below it. This is a prominent seepage area often used by hikers for drinking water. The top of Polly dome is approximately 100 degrees. It’s in an avalanche area and not obvious as a tributary of Murphy Creek because it seeps into soil before joining it. Tuolumne Meadows quad.
121. Just below timberline on tributary of Kuna Creek. Donahue Peak is at 175 degrees and Amelia Earhart is at 266 degrees. Small waterfall is about 50 m above it. Willow is extremely dense here. Mono Craters quad.

122. Up and slightly south along a different braid of Kuna Creek in another densely covered area of willow. There are many small braids of Kuna Creek which make for an abundance of seepage areas. Mono Craters quad.

123. Along Trail toward Ostrander Lake on first creek that trail crosses after lost bear meadow. This creek is a tributary to Bridalveil Creek and runs into Bridalveil from the northeast. Burrows start approximately 200 m up from where trail crosses the tributary. Yosemite quad.

124. At the confluence of first perennial tributary that flows into Bridalveil Creek below Ostrander Lake. Very thick shrubs and aspen for the first time along Bridalveil creek from Lost Bear Meadow to Ostrander Lake. Yosemite quad.

125 & 126. A confusing area. 125 is along a small tributary to Bridalveil Creek with good seepage and a lot of mountain beaver activity. 126 is along the intermittent tributary on the Yosemite quad that has a small pond part way down it. Both are in: T3S, R22E, SW 1/4, Section 33.

127 & 128. Yosemite quad in same area as 125 and 126 with numerous seepage areas and springs. Very confusing area and not worth trying to relocate specific sites.

129. Intermittent tributary of tributary to Bridalveil Creek (on quad and runs parallel to trail that goes to Deer Camp). Site is at confluence of these 2 tributaries but burrows are mostly along intermittent one. T3S, R22E, NE 1/4 of SW 1/4, section 31 on Yosemite quad.

130. Along intermittent tributary (on map) that crosses the trail to Deer Camp/Grouse Lake junction just to south of where trail crosses the south fork tributary of Bridalveil creek. In T4S, R22E, NE 1/4 of SW 1/4, section 6 of Yosemite quad.

131. Site is on the south fork tributary of Bridalveil Creek about 2 km downstream from where its 2 headwater branches come together. Large red fir forested slope to the east. Yosemite quad.

132. Go up Tamarack Creek from campground about 4 km. Just past a meadow there’s an earthen waterfall and site was upstream 100-200 m. This site was used 27 August 1988 but not 1 year later. No other sign was found in the area. Hetch Hetchy quad.

501. Take trail from Whitewolf toward Harden Lake (left at first junction on trail going east from the lodge). Once past the junction, cross 4 small creeks and go up the fifth creek about 5 km to its head. Hetch Hetchy quad.
502. Along tributary of Bridalveil Creek 1 mile at 290 degrees from Ostrander rocks. Burrows extend from headwaters of stream through a lush grove of aspen. Yosemite quad.

503. Site is at the head of Stubblefield canyon in seepage area in bowl to southeast of Tower Peak. From the site, it is 90 degrees to Ehmbeck Peak and 118 degrees to a high point directly across Stubblefield Creek. Willow was dense but no conifers. Tower Peak quad.

504. On headwaters of Tilden Creek above northwest shore of Mary Lake (long side). 167 degrees to Craig Peak and 101 degrees to Tower Peak. Lush willow but no trees nearby except scattered ones up slope. Large talus about 100 m to west that extends almost to shore of Mary Lake. Tower Peak quad.

505. Site is on north fork of Clark Fork of Illilouette Creek 200-300 m from where it joins the Clark Fork. A prominent dome is 307 degrees from the site. Merced Peak quad.


803. Head of Bridalveil Creek. T3S, R21E, NW 1/4 of SW 1/4.


808. 0.4 km downstream from lake that is 2 miles northwest of Mt. Clark. Lake is just above 2680 m (8800 feet) and drains into the Clark Fork of Illilouette Creek (Benedict, pers. commun., 1977).

809. East side of Glacier Canyon (outside eastern boundary of park) by creek that flows from Dana Plateau (Olwyler, pers. commun., 1976)

810. Tuolumne Meadows. T1S, R23E, SE 1/4 of NW 1/4, section 1.

811. Cold Canyon. Near where trail crosses creek approximately 2 km south of Elbow Hill. Tuolumne Meadows quad.