Fire Effects on the Point Reyes Mountain Beaver (*Aplodontia rufa phaea*)

Gary M. Fellers
Western Ecological Research Center, USGS Point Reyes National Seashore
Point Reyes, CA 94956

David Pratt
National Park Service
Point Reyes National Seashore
Point Reyes, CA 94956

Jennifer L. Griffin
PO Box 1503
Mendocino, CA 95460

Abstract

In October of 1995, the Vision Fire burned 5,000 ha (12,354 acres) on the Point Reyes peninsula. In most of the non-forested areas, the fire burned the vegetation and associated leaf litter down to mineral soil. This effectively cleared the ground and revealed thousands of mountain beaver (*Aplodontia rufa*) burrow openings that had been well hidden and difficult to find prior to the fire. In the first six months after the fire, we surveyed 730 ha (1,800 acres) of burned coastal scrub and riparian habitat to 1) count the number of burrow openings that existed at the time of the fire, and 2) evaluate whether there were signs of post-fire mountain beaver activity. Based on our counts of burrow openings and assumptions about the number created by each individual, we estimated that only 0.4 - 1.2% of the 5,000 mountain beavers within the burn area survived the fire.

Mountain beaver populations could recover either by immigration from outside the fire area, or by growth of the small populations that survived within the burn area. To evaluate recovery within the burned area, we monitored mountain beaver activity for five years at eight sites where mountain beavers survived. By the end of the first year, one of these sites no longer had any mountain beaver activity. In another two sites, the numbers of active burrows remained low; we believe that both of those sites were occupied by only one or a few non-reproducing individuals. In four other sites, the number of active burrows returned to approximately pre-fire levels by the third year, and the remaining site recovered by the fourth year.

To evaluate immigration from surrounding areas, we repeatedly surveyed three sites where mountain beavers disappeared, two near the edge of the burn and one 1.0 km inside the burn. One at the edge had a few active burrows in the third, fourth, and fifth years post-fire, but the other two sites showed no sign of activity after five years. We estimate that it will take 15-20 years post-fire for the mountain beaver population to recover to the pre-fire estimate of approximately 5,000 individuals.

Mountain beaver in burrow. (USGS)

Introduction

Mountain beavers (*Aplodontia rufa*) are an unusual and primitive species of rodent. They are about the size of a muskrat (27-30 cm long), but they have a short (1 cm) tail. Mountain beavers feed on a wide variety of vegetation including coyote brush (*Baccharis pilularis*), sword fern (*Polystichum munitum*), cow parsnip (*Heracleum lanatum*), blackberries (*Rubus ursinus*), poison oak (*Toxicodendron diversilobum*), California nettle (*Urtica dioica*), foxglove (*Digitalis purpurea*), and thistle (*Cirsium* sp.) (Steele, 1989; pers. obs.). They live in underground burrows that are typically dug in dense thickets or in forest openings. The presence of 15-18 cm diameter burrow openings (Grinnell and Storer, 1924) is often the most conspicuous evidence of mountain beaver activity. Typically, there are multiple openings in an area of only about 14-16 m^2. Camp (1918) described the burrow system:

"Wherever the aplodontia lives it digs extensive underground tunnels that in a populous colony form a network of passages a few inches beneath the surface of the ground. Each burrow system has many openings to the surface, but excavated dirt and rubbish is pushed out usually at only a few of these holes."

A mountain beaver needs 1/3 of its body weight in water every day (Nungesser and Pfeifer, 1965) because its kidneys are simple and inefficient at conserving water (Sperber, 1944). An adult needs to consume 295-450 ml of water each day, by drinking or from food. Because of this, mountain beavers are restricted to areas near water or with extensive summer fog along the Pacific coast.

Mountain beavers range from the southwest corner of British Columbia south through western Washington and Oregon. In California, their range extends through the Sierra Nevada Mountains and barely into Nevada. Along

the California coast, mountain beavers are found south to near Cape Mendocino. Further south, small, isolated coastal populations occur at both Point Arena (Mendocino County) and Point Reyes (Marin County).

The Point Reyes mountain beaver (*A. rufa phaea*) is only known to occur in western Marin County, almost entirely within Point Reyes National Seashore where it is found on cool, moist, north-facing slopes in moderately dense coastal scrub. This scrub vegetation typically includes coyote brush as well as sword fern, bracken fern (Pteridium aquilinum), poison oak, California nettle, and cow parsnip, which tend to grow in the moister areas.

Most of the area occupied by the Point Reyes mountain beaver was regularly burned by Coast Miwok Indians who once occupied the Point Reyes peninsula. In the last 100 years, however, fires have been far less frequent and routinely suppressed. This fire control has resulted in a buildup of highly combustible fuels (Sugnet and Martin, 1985).

The Vision Fire of October 3-12, 1995 burned 5,000 ha (12,354 acres) 94% of the burn area was within Point Reyes National Seashore (Fig. 1.). The fire consumed mostly coastal scrub, but also some Bishop Pine (*Pinus muricata*) and Douglas fir (*Pseudotsuga menziesii*) forest, grassland, and riparian habitats. The fire burned 40% of the known range of the Point Reyes mountain beaver, including the majority of what was believed to be prime habitat.

Study Area

Point Reyes National Seashore is a 28,757 ha (71,059 acre) natural area located 50 km NW of San Francisco. The park includes 10,767 ha (25,370 acres) of officially designated wilderness. Major plant communities include Douglas fir forest, Bishop pine forest, coastal scrub, and grasslands.

Methods

Pre-Fire Surveys (1984 - 1994)

Prior to the Vision Fire, mountain beaver habitat within Point Reyes National Seashore was systematically surveyed to evaluate the distribution and habitat preference of mountain beavers within the Seashore. Thickets were surveyed by walking the perimeter and exploring natural openings and indentations in the vegetation. A stout wooden pole was used to move aside vegetation and make burrow openings more obvious.

When burrows were not detected, thickets were traversed at approximately 25 m intervals. Many thickets were so dense that it was not possible to penetrate them (without cutting a swath through the vegetation); these thickets were examined only around the perimeter. After the Vision fire, we could see that burrow openings were scattered throughout the thickets and were not always observable from the perimeter. It is clear that both burrow openings and entire populations had been missed during the pre-fire surveys.

Openings in forests were surveyed by traversing the entire opening at approximately 20 m intervals, making sure to inspect areas that appeared to be particularly suitable for mountain beavers.

In addition to their distinctive size, mountain beaver burrow openings are always found in groups or clusters (Lyon, 1907; Camp, 1918). We assumed that mountain beavers were present when we found > 5 suitably sized burrow openings in an area of < 25 m^2. We counted the number of openings observed, but it was not practical to quantify population size.

We use the term site for each group of mountain beaver burrows that are separated from other burrows by at least 50 m, a distance not regularly traversed by this species (Martin, 1971).

Population refers to the mountain beaver(s) occupying a site. A population can range from a single individual to hundreds of animals.

Initial Post-Fire Surveys (1995 - 1996)

Post-fire surveys were conducted primarily in coastal scrub. In this habitat, the fire reduced the vegetation to a few charred skeletons of the larger bushes, and the charred bases of sword ferns. Mountain beaver burrow openings were fully exposed, allowing us to map distribution and estimate population size. Additionally, a layer of ash covered the ground, including the burrow openings and dirt piles associated with burrows that pre-dated the fire. Burrow openings utilized post-fire were conspicuously ash-free and easily detected.

Between December 6, 1995 and April 25, 1996, we spent 20 person-days surveying 730 ha (1,800 acres) in the northwest part of the burn area (Fig. 1). This survey area included all of the Home Ranch Creek and Whitegate Valley watersheds upstream from the Muddy Hollow Road, and most of the Glenbrook Creek watershed above the same road. We also surveyed

the site of one well-known mountain beaver population on the Laguna Ranch, near the center of the burn.

We estimated the area occupied by mountain beaver at each site by pacing, and counted or estimated the number of burrow openings. Areas surveyed and the location of burrow openings were plotted in the field on 7.5' USGS topographic maps. By late April 1996 (6 months after the fire) the regrowth of vegetation made it impractical to continue mapping.

Photo Documentation

We confirmed that fresh digging at burrows was due to mountain beavers by deploying infrared-triggered still and video cameras at sites with fresh dirt at burrow openings. Cameras were a modified Olympus Mini DLX, triggered by a Trailmaster 1500 unit (Goodson & Associates, Lenexa, KS 66215). The Trailmaster system utilized a transmitter and receiver. The transmitter was situated so the infrared beam was about 3" above the ground. A picture was taken when beam was broken for at least 0.15 sec. We configured the Trailmaster so that the camera would not be triggered again for at least one minute. The camera was set to take pictures 24 hours per day. We checked the cameras every two weeks to replace film and batteries, as needed. Sony video cameras in waterproof housings (CompuTech, Bend, OR 97708) were deployed in a similar fashion except that the camera was triggered by a passive infrared sensor that detected motion in a general area (similar to a burglar alarm). Once triggered, the camera recorded 60 sec of video.

Burrow Temperature

To evaluate whether the loss of vegetation affected burrow temperature, we monitored temperature at two burrow systems, one at Muddy Hollow within the burn area and the other outside at Home Ranch. The burrows were both on north-facing 40-45% slopes, where coyote brush, coffee berry (*Rhamnus californica*), and poison oak were the predominant pre-fire vegetation. The burrows were carefully matched for similarity in slope, exposure, and pre-fire vegetation. One burrow was at Muddy Hollow (burned) and the other at Home Ranch (unburned). We deployed a temperature logger (Hobo, Onset Computer, Pocasset, MA 02559) at the entrance and another 1.5 m deep at each burrow. Temperature was recorded at noon every day for a year beginning April 19, 1996.

Monitoring (1996 - 2000)

We surveyed in late spring and early summer since that is when we have observed the highest level of mountain beaver activity (e.g., fresh burrowing, cut vegetation) at Point Reyes. In November 1996 (13 months after the fire) and in the late spring and early summer of 1997, 1998, 1999, and 2000, we resurveyed 11 sites that had been surveyed immediately after the fire. At eight sites we had observed active mountain beaver burrows in the initial post-fire surveys (A-H, Table 3, Fig. 1). We used these eight sites to evaluate post-fire persistence and population growth. The three other sites (X-Z) were places where there had been pre-fire populations, but where we found no mountain beaver activity immediately after the fire. Two of these three sites were located at the edge of the burn and

Vision Fire viewed from Limantour Road.

the other was 1.0 km inside the fire area. These three sites were used to evaluate if, and how rapidly, mountain beavers immigrated from outside the burn area.

Complete resurveys of the 11 focal areas were not possible since newly grown vegetation obscured many of the burrows. Hence, we surveyed 1) in the immediate vicinity of all active burrows found during the initial post-fire field work, and 2) along transects spaced at 10 m intervals across the entire site. In the 1996 and 1997 surveys, we noted only the presence or absence of active burrow openings and the general locations where burrow openings were found. In 1998, 1999, and 2000, we counted active burrow openings and extrapolated to get the estimated total number of openings.

Results

Pre-Fire Surveys (1984-1994)

Surveys were conducted on 69 days between July 6, 1984 and March 10, 1994. We visually searched for burrow openings and collapsed tunnels. Mountain beaver burrows were observed at 74 survey sites prior to the Vision Fire (Fig. 2, Table 1); 70 of these represented sites not previously recorded (Dale Steele, personal communication; California Natural Diversity Data Base). Forty-six of these were outside the Vision fire area, while 28 were within the burn.

Initial Post-Fire Surveys (1995 - 1996)

We estimated that in the 730 ha (1,800 acre) area surveyed (15% of the burn area), 46,300 burrow openings were present at 107 sites at the time of the fire (Table 1). These sites were primarily on north-facing slopes, and encompassed 60 ha (149 acres), 8% of the total area surveyed. Within the 107 sites, there was a mean of 8 burrow openings per 100 m^2 (Table 2). If we make assumptions about the number of burrow openings associated with each burrow system and the number of individuals that occupy each burrow system, it is possible to estimate the total number of animals represented by the openings we observed. In 1918, Camp trapped mountain beavers at Point Reyes and calculated that each burrow system had nine openings. Aside from a short time when young are born, each burrow system is normally occupied by a single individual (Pfeiffer, 1954), though Grinnell and Storer (1924) found two adults in a burrow system in the Yosemite area. Using these numbers (9 openings and one animal per burrow), the 46,300 burrow openings we observed would have represented about 5,144 individuals.

The largest site extended 2,200 m along the north-facing slope of a drainage of Home Ranch Creek. In places, burrows were scattered across the entire 100 m distance from the creek to the top of the slope. Elsewhere, the burrows were limited to a band as narrow as 20 m, along only the upper slope. Despite its large size, we considered this a single site since there were no gaps >50 m between adjacent burrows (Martin, 1971).

In the first six months after the fire, we found 110 burrow openings that had been excavated post-fire. These burrows were at 10 different sites, located in widely separated areas. One site had seven distinct clusters of burrows, another site had three clusters, and one site had two clusters. If each cluster was made by a different individual, then the 10 sites would have supported 19 individuals. These 19 animals would represent a 0.4% survival rate, based on our calculations of a pre-fire population of 5,144 individuals. No other pre-fire sites showed any sign of activity after the fire.

The average number of burrows per individual is 6.9, somewhat below the nine reported by Camp (1918), but these were new burrow systems in a highly modified habitat that my not be typical.

Photo Documentation

We photographed mountain beavers at seven sites within the burn area. In addition, we photographed five species that appeared to be sharing the burrows with mountain beavers, at least on occasion. These were brush rabbit (*Sylvilagus bachmani*), deer mouse (*Peromyscus maniculatus*), California vole (*Microtus californicus*), long-tailed weasel (*Mustela frenata*), and spotted skunk (*Spilogale gracilis*).

Burrow Temperature

Temperatures at the entrance of the burned and unburned burrows were essentially the same (13.9 versus 13.8 C, $t = 0.43$, df = 364, $p=0.66$). Temperatures measured 1.5 m into the burrow were significantly different (12.2 versus 11.4 C, $t = 5.93$, $p<0.001$). The results were similar whether data were analyzed for the entire year (as above), or for only the first 30 days when there was little vegetative regrowth.

Monitoring (1996 - 2000)

Areas With Post-Fire Burrows

Among the 10 sites that had active mountain beaver burrows in the initial post-fire survey, we resurveyed eight of these for the following five years. There were three patterns of

recovery: strong recovery (five sites), limited recovery (two sites), and extirpation (one site) (Fig. 1, Table 3). In the five sites with strong recovery (sites A - E), the number of active burrows was back to pre-fire levels within five years or less.

In the two sites with limited recovery (F and G), not only was the number of active burrow openings in 2000 far below the pre-fire levels, but there also appeared to be declines between 1998 and 1999, although there was some recovery in 1999 - 2000.

In less than a year post-fire, there were no active burrow openings at site H (Fig. 1, Table 3). We observed that the four active burrow openings found in the spring of 1996 showed no signs of activity within only a few weeks, perhaps because this site was atypical in being on an exposed south-facing slope that became too hot, or retained insufficient moisture.

Sites Without Mountain Beaver Activity in the Initial Post-Fire Surveys

Of the three sites that had no active mountain beaver burrows immediately post-fire and were surveyed annually for the next five years, one at the edge of the burn had 40 active burrow openings (probably 4 - 5 animals) in 1998 and 1999 (site X, Table 4), presumably as a result of mountain beaver immigration from outside the burn area. By 2000, there were 88 burrows; this increase could have been from immigration, or from reproduction by the individuals in the previous two years. This site was 150 m long and 20 m wide, situated on the north-facing bank of the headwaters of Home Ranch Creek. All active burrows were in dense vegetation (primarily poison oak) along the stream. The upper slope, which had hundreds of burrows before the fire, had no active burrows in 2000.

The other two monitored sites with no active burrows post-fire (sites Y and Z, Table 3) still lacked activity through 2000, even thought one site was right at the edge of the burn (site Z), and the other was only 1.0 km inside.

Discussion

The Vision Fire of October 1995 had a devastating effect on the mountain beavers living within the 5,000 ha burn area. Our pre-fire surveys (1984-94) showed that mountain beavers were common and widespread in suitable habitat at Point Reyes. Since most of the burrows were in densely vegetated areas, however, it was not possible to determine population size using our survey techniques. After the fire, much of the vegetation was reduced to ashes allowing us to make population estimates for the first time. We counted 46,300 burrow openings in 107 sites encompassing 60.2 ha. There are two studies that provide information that might be used to calculate how many individual animals occupied this area prior to the fire.

Camp (1918) reported that mountain beaver at Point Reyes had an average of nine burrow openings per mountain beaver. Using that number, the pre-fire population in the area we surveyed would have been 5,1444 individuals, and a post fire survival rate of 0.4%. There are no other data for the Point Reyes subspecies (*A. rufa phaea*), but Lovejoy and Black (1979) provide data on mountain beaver (*A. rufa pacifica*) densities in coastal Oregon. Over a two-year period, Lovejoy and Black captured 150 individual mountain beaver in a 320 x 181 m area. This would result in an average of 25.9 mountain beavers per ha. Using this density to estimate the pre-fire population in the 60.2 ha we surveyed results in an estimated population size of 1,559 mountain beaver, and a 1.2% survival rate. We are unable to determine which estimate of pre-fire population size is more accurate, but whichever number is used, it is clear that post-fire survival was extremely low (0.4 – 1.2 %).

The fire caused major changes in the habitat, reducing coastal scrub to charred sword fern bases and blackened skeletons of coyote brush. As relatively sedentary, burrowing herbivores with an unusually high daily requirement for water, those few mountain beavers that survived the fire found themselves in a rather inhospitable environment. Our temperature data showed the expected increase in temperature 1.5 m inside the burrow opening, but the increase was small (0.8 C) and probably not biologically important. More importantly, there was a loss of available food, an overall drying of the local habitat, and a general lack of moisture.

Surveys for fresh dirt outside burrow openings and photographs from remote-triggered cameras suggested that only 19 mountain beavers survived within the surveyed fire area. This number represents only 0.4 – 1.2% of the population that we estimate had previously inhabited the surveyed area. While this number would be low if we had overlooked active burrows in our initial post-fire surveys, it could also be high. At sites D, E, and F, there were three, seven, and two distinct clusters of active

Long-tailed weasel.

burrows, which we assumed had been made by 12 different individuals. If some of the individuals were responsible for digging at more than one cluster of burrows, our estimates of survival would be too high.

Actual causes of death for most of the mountain beavers are difficult to assess. In spite of a great deal of field work by ourselves and other biologists, only one dead mountain beaver was found after the fire. We believe that most mountain beavers died in their burrows, probably from excess heat, smoke, or lack of water.

Mountain beavers reach sexual maturity in their second year and give birth to 2-3 (rarely four) young in the spring (Pfeiffer, 1958). Longevity has been estimated at 5 – 6 years (Lovejoy, 1972). Given an average of 2.5 young per litter, a pair of mountain beavers would give rise to 20 descendants after three years (with complete survival). The population would then double every year. If we assume that one pair of mountain beavers survived in each of the five strong recovery sites (A, B, C, D, and E; Table 4), this rate of increase would explain the observed population growth.

Interestingly, in three of the sites with strong recovery, the number of active burrows five years post-fire was about twice the number prior to the fire (A, C, and D; Table 4). In these three somewhat limited areas (6,000 and 8,000 m^2), it appears that habitat changes occurred during the first four years post-fire that must have improved conditions for mountain beavers. While we have not been able to evaluate exactly what the key changes might have been, we suspect it was a stimulation of favorable vegetation (especially cow parsnip, *Heracleum lanatum*) that has flourished in only a few sites.

The failure of mountain beavers to repopulate at sites F and G would be expected if these areas had single individuals, same-sex individuals, or individuals that failed to reproduce for some other reason. The total loss of mountain beaver activity at site H was expected since it was on an exposed south-facing slope, completely atypical of most mountain beaver habitat at Point Reyes. After the fire, the area became completely unsuitable for mountain beavers.

There are two additional factors that would tend to retard population recovery, 1) slow dispersal of mountain beavers between suitable sites and 2) post-fire changes in vegetation that could make some areas unsuitable for mountain beavers. While the extremely limited immigration was a bit surprising, it appears that post-fire changes in vegetation have played a more significant role in slowing the recovery of mountain beavers.

The lack of recovery is likely related to shifts in both plant species composition and the physical structure of thickets. We have no pre-fire vegetation descriptions, but we can determine at least the dominant species. For example, at site Z, the vegetation has undergone a significant change from a high density of sword ferns (which are common in areas inhabited by mountain beavers at Point Reyes) to thimbleberry and blackberry. Post-fire, sites E and Y were largely overgrown with blue-blossom ceanothus (*Ceanothus thrysiflorus*), a species not typically associated with mountain beavers, and thus unlikely to have been the dominant plant before the fire.

Though it is difficult to make exact predictions, we estimate that it will take 15 – 20 years for mountain beavers to reach the pre-fire estimate of 5,000 individuals. The primary factor limiting recovery seems to be vegetation. We expect it will take 10-15 years or more for sufficient successional changes to take place. As the vegetation becomes more suitable, an increase in the mountain beavers will likely occur due to population growth and, to a lesser extent, immigration from outside the burn area.

Management Recommendations

Wildfires have a strong, negative impact on mountain beaver. This is of particular concern for the two small, geographically isolated populations along the California coast, both of which are distinct subspecies. The Point Arena mountain beaver (*A. r. phaea*) is Federally listed as Endangered (U.S. Fish and Wildlife Service, 1991). Its entire range encompasses approximately 60 km^2. While some of the habitat at Point Arena would not easily carry a fire, many populations occupy coyote brush thickets are similar to those that we studied at Point Reyes. We recommend that fires in the vicinity of Point Arena or Point Reyes mountain beaver not be allowed to burn substantial portions of areas occupied by mountain beaver. Periodic small fires would allow for normal changes in mountain beaver habitat by mimicking what was probably the natural fire regime with which these animals evolved.

Acknowledgements

Reginald Barrett, Joan Fellers, David Graber, Mietek Kolipinski, Joe McBride, and Julie Yee provided useful comments on the manuscript. Our research was funded by the National Park Service and the USGS. We thank the following individuals for assistance with various aspects of the field work: Sarah Allen, Roni Clark, Debbie Cooper, John Dell'Osso, Kathleen Freel, Russ Lesko, Don Neubacher, John O'Connor, Dale Steele, Bob Stewart, Armando Quintero, and Diane Williams.

Literature Cited

Camp, C. L. 1918. Excavations of burrows of the rodent *Aplodontia*, with observations on the habits of the animal. Univ. Calif. Publ. Zool. 17 (18): 517-536.

Grinnell, J. and T. Storer. 1924. Animal life in the Yosemite. Univ. Calif. Publ. Berkeley, CA. 752+xvii Pp.

Lovejoy, B. P. 1972. The capture-recapture analysis of a mountain beaver population in western Oregon. Ph.D. Thesis. Oregon St. Univ., Eugene.

Lovejoy, B. P. and H. C. Black. 1979. Movements and home range of the Pacific mountain beaver, *Aplodontia rufa pacifica*. American Midland Naturalist. 10:393-402.

Lyon, M. W. Jr. 1907. Notes on mammals collected at Mount Rainier, Wash. Smithsonian Misc. Coll. 50: 89-92.

Martin, P. 1971. Movements and activities of the mountain beaver (*Aplodontia rufa*). J. Mamm. 52(4): 717 – 723.

Nungesser, W. and E. Pfeiffer. 1965. Water balance and the maximum concentrating capacity in the primitive rodent, *Aplodontia rufa*. Comp. Biochem. Physiol. 14: 289-297.

Pfeiffer, E. 1954. Reproduction in a primitive rodent, *Aplodontia rufa*. Unpubl. Ph.D. Thesis. Univ. Calif., Berkeley, CA.

Pfeiffer, E. 1958. The reproductive cycle of the female mountain beaver. J. Mamm. 39(2): 223-235.

Sperber, I. 1944. Studies on the mammalian kidney. Zoologiska Bidrag Fran Uppsalla. 22: 249-431.

Steele, Dale T. 1989. An ecological survey of endemic mountain beaver (*Aplodontia rufa*) in California, 1979-83. Wildlife Manage. Div. Admin. Report 89-1, Calif. Fish and Game. 58+iv Pp.

Sugnet, Paul W. and Robert E. Martin. 1985. Fire History and Post-Fire Stand Dynamics of the Inverness Bishop Pine at Point Reyes National Seashore. Unpubl. report to the National Park Service.