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Historical Range of Variability Assessment for Caribou Ranch Open Space, Boulder County Colorado Phase 2: Fire History and Stand Structure in Ponderosa Pine Woodlands at Caribou Ranch

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Phase 2:

Fire History and Stand Structure in Ponderosa Pine Woodlands at Caribou Ranch

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Introduction

Changes in lower-montane ponderosa pine (*Pinus ponderosa*) forests of the western US in general and the Colorado Front Range in particular over the past century are well documented (e.g., Cooper 1960, Covington and Moore 1994, Fulé et al. 1997, City of Boulder 1999, Kaufmann et al. 2000). Historically open forests with scattered trees and relatively high understory biomass and diversity were maintained by frequent, episodic, surface fires that killed ponderosa pine seedlings and saplings before they were able to reach the forest overstory (Brown et al. 1999, 2000, Veblen et al. 1996, 2000, Brown and Shepperd in review). Fire cessation resulted from changes in land use that included livestock grazing (that removed grass fuels through which fires spread), fragmentation of landscapes by roads and fences, and, beginning in the early 20th century, fire suppression by land managers. Fire exclusion has, in turn, led to often profound changes in forest structure, including formation of large areas of young, dense, relatively slow-growing trees that are susceptible to high-severity crown fires (Covington and Moore 1994, Arno et al. 1995).

However, applicability of these patterns to upper montane ponderosa pine forests in the Front Range requires site-specific data to quantify historical patterns in the upper montane zone. Environmental factors that control plant demography across elevation gradients also influence the occurrence and spread of fires (e.g., Barton 1993, Peet 1981, Brown et al. 2001). Changes in precipitation and temperature with elevation effect both fuel quantity and its ability to burn. Moister conditions in upper-elevation forests result in fewer years when fuels are dry enough to permit fire to spread after ignition. With increased elevation, a general pattern is that fire frequency decreases while fire severity may increase because of higher fuel loadings and longer periods between fires (Peet 1981). Longer periods between fires also may lead to more extensive fires since fuels and forest structure may be more continuous across a landscape.

In this study, we reconstructed fire history in ponderosa pine woodlands at Caribou Ranch in the Colorado Front Range. Fire history was reconstructed using fire-scar and tree age data from three stands. Forests at Caribou Ranch are transitional between upper montane and subalpine forests (Stevenson 1998), and ponderosa pine is restricted to mostly south-facing slopes and valley bottoms. This study provides the highest elevation fire history data yet developed from a ponderosa pine ecosystem in the Front Range (Goldblum and Veblen 1992, Veblen et al. 1996, 2000, Brown et al. 1999, 2000, Brown and Shepperd in review). Areas of ponderosa pine at Caribou Ranch are generally open woodlands with well-developed grass and herbaceous understories, often intermixed with Douglas-fir (*Pseudotsuga menziesii*) and aspen (*Populus tremuloides*). Much of the subalpine forest at Caribou Ranch is dense, post-fire lodgepole pine (*Pinus contorta*) forest (Stevenson 1998), large portions of which apparently established after extensive human-set fires during the early settlement period of the middle to late 19th century (Veblen and Lorenz 1986, 1991, Veblen et al. 2000). Our goals with the study are: 1) to document fire frequency, season of fire occurrence, and spatial patterning within the ponderosa pine woodlands; and 2) to infer the possible long-term role of surface fires, crown fires, and climate variability in structuring ponderosa pine communities at Caribou Ranch.

Methods

Two general types of tree-ring evidence have been used to reconstruct fire history: 1) fire scars formed during burning that does not kill a host tree; and 2) dates of tree establishment that postdate forest stands killed by catastrophic fires (Johnson and Gutsell 1994, Brown et al. in press). Typically, surface fires are reconstructed from fire scars and crown fires are reconstructed from forest age structure. For this study, we used both types of evidence to reconstruct fire occurrence and behavior in ponderosa pine woodlands at Caribou Ranch.

We sampled fire-scarred trees and forest age structure in two stands (CR1 and CR2) to document fire frequency, timing, and season of fire occurrence (Figure 1, Table 1). Fire-scarred trees were sampled in an additional stand to examine possible spatial extent of fires across the meadows along Delonde Creek (CR3; Figure 1). Sites were selected based on presence of fire-scarred trees. Trees sampled included stumps, logs, snags, and living trees. Full cross sections were typically cut from stumps and logs while partial cross sections were removed from living trees and snags to avoid felling them. To determine stand age structure, variable radius plots were established. The nearest 30 trees within 50 m radius of plot center were selected for aging. Increment cores were removed from approximately10 cm height above ground level on living trees and cross sections were cut from stumps, logs, and snags such that one surface was at an estimated 10 cm height above root crown. Cores sampled had to be no more than a field-estimated 10 years from pith. Tree distance from plot center was measured and tree diameter at 10 cm height was measured on living trees or estimated for remnant trees missing bark, sapwood, and often heartwood. Notes also were recorded for each tree that included species, presence of fire scars, wood char, and state of decay of remnant trees.

All cores and cross sections were prepared and crossdated using standard dendrochronological procedures (Brown et al. in press). Sample preparation involved sample stabilization and surfacing with hand planers, belt sanders, and hand sanding until cell structure was visible in tree-ring series. Crossdating involved cross matching of climatically controlled ring characteristics between trees and sites. Both visual matching of ring characteristics and correlated ring widths were used to assure crossdating. After crossdating of tree rings was completed on fire-scarred cross sections, dates were assigned to fire scars. Intra-annual positions of fire scars also were noted to assess seasonal timing of past fires. On increment cores or cross sections that did not include pith but inside ring curvature was visible, pith dates were estimated using overlaid concentric circles of varying diameters that take into account both average inside ring widths and an estimated distance to pith. Once crossdating was verified on trees at each site, composite fire chronologies were compiled from all fire dates recorded (Brown et al. in press). Composite age and fire chronologies also were compiled for plots sampled for forest structure.

Results and Discussion

Fire scars were generally rare on trees at Caribou Ranch and most trees recorded only one or two fires (Figure 2). Only three fire dates were recorded on trees at all three stands: 1654, 1706, and 1859. Few other fire dates were recorded consistently within stands and none between stands. Fire frequency is difficult to calculate with so few fire dates but intervals between these three fires were 52 and 153 years for a mean interval of just over 100 years. Fire scars during1654 and 1859 were recorded at most sites that have been collected for fire history studies in the Front Range (Brown et al. 1999, Veblen et al. 1996, 2000, Brown and Shepperd in review; see especially Figure 10 in Veblen et al. 2000 for patterns of burning that occurred during 1859 in the Boulder County area). Fires during these two years burned over large portions of Front

Range montane (and probably subalpine) forests with likely mixed severity patterns that included both surface and crown fire (Veblen et al. 2000). Fire scars also were recorded during 1706 in many ponderosa pine stands sampled in these previous studies, suggesting that this was also a regional fire year across the Front Range. All three of the widespread fire years at Caribou Ranch were very dry years in tree-ring based precipitation reconstructions, and, in the case of 1654 and 1859, followed extended wet periods (Woodhouse in press, Woodhouse and Brown 2001) during which few fire scars were recorded at sites across the Front Range (Brown et al. 1999, Veblen et al. 2000, Brown and Shepperd in review). Extended wet conditions likely promoted increased fuel buildups in stands, especially when coupled with lessened fire frequency during these periods.

An increase in fires was noted in stand CR1 during the early settlement period after 1859 (Figure 2). The mining boom in the Front Range began with the discovery of gold on Clear Creek and in the Central City area beginning during the winter of 1858-1859 (Pettem 1980, Veblen and Lorenz 1991, Veblen et al. 2000). Increased fire frequency during this early settlement period fits well with patterns recorded at other sites in Boulder County (Veblen et al. 1996, 2000). Fire scars recorded in 1859 at Caribou Ranch were almost exclusively dormant season scars (occurring between rings for 1858 and 1859) and suggest that burning took place before tree growth began in late spring of 1859. Fire in 1859 may have been promoted by increased ignitions set by miners to clear off vegetation to look for ore pockets at the very beginning of the mining boom in Boulder County (Veblen and Lorenz 1991). However, fire during 1859 and the 1860s also likely was promoted by extended drought conditions that began in the 1840s and lasted through the middle 1860s (Woodhouse in press, Woodhouse and Brown 2001). Two fires also were recorded at site CR1 in 1906 and 1909, and also may have been result of ignitions by miners at the nearby Bluebird Mine. [Dave and Alan: when was the Bluebird Mine in operation?] Other fire scars were recorded on single trees in the stand in 1436 and 1834.

In stand CR2, an increase in fires was not seen during the early settlement period, although one tree recorded a fire scar in 1860 in addition to fire scars in 1859 recorded on most of the other trees at the site (Figure 2). Why this site did not record frequent fires during the early settlement period is unknown. Other lower-elevation montane stands in the Front Range also did not record increased fire frequency during the early settlement period, leading to a conclusion that increased burning as a result of human ignitions was a site-specific historical factor in Front Range forests (Brown and Shepperd in review). It is likely that certain areas were more prone to early-settlement fires because of proximity to development or they were in areas with indications of mineralization and thus more likely to be burned over.

Two trees in stand CR2 recorded more frequent fires than other trees at the site during the pre-settlement period. One tree recorded very closely spaced scars during the 1680s while another recorded nine fire scars during a 447 year-long period (1444 to 1890; Figure 2). Closely-spaced scars seen on the first tree during the 1680s may not all be fire scars. If they are, however, we do not have any explanation for why this one tree would have recorded frequent fires in the 1680s. The second tree is located on a slight rocky promontory above the rest of the trees collected in this stand. It is possible this area was more prone to lightning strikes that started fires that did not spread beyond a local point of ignition. However, the fire frequency (ca. 40 years between fires) recorded on this tree was not representative of fire history recorded on other trees at Caribou Ranch.

Age structure in stands does not document pulses of tree recruitment into the overstory that may be related either to stand opening by crown fires or to optimal climate conditions for seedling establishment (Figure 2). Tree ages in both CR1 and CR2 document apparently continuous but low-level recruitment of trees into the overstory, especially during the fire-free period of the 1700s and early 1800s. Ponderosa pine forests often have evidence of even-aged cohorts of trees that corresponded to wet conditions that promoted seedling establishment and growth (e.g., Pearson 1933, Peet 1981, Savage et al. 1996, Kaufmann et al. 2000, Brown in review). Wetter conditions also result in fewer surface fires that allows for more trees to reach canopy status and thereby become more "fire-proof" during subsequent fires. Age data from the Black Hills documents pulses of recruitment in ponderosa pine stands that correspond temporal to both wet periods in northern Plains precipitation reconstructions and reduced surface fire frequency at both stand and landscape scales (Brown in review). Abundant tree establishment in many southwestern ponderosa pine forests during the early 1800s also is related to both wet conditions and a period of reduced fires in this region (Swetnam and Betancourt 1998, Grissino-Mayer and Swetnam 2000).

Finally, seven stumps sampled from stands CR1 and CR2 had cutting dates in the early 1900s. Other stumps had eroded outside surfaces and death dates could not be determined. Fourteen of 48 trees collected from CR2 and only three of 34 trees collected from CR1 were stumps, suggesting that harvest in the area has been selective and not complete within stand boundaries. Logging in the stands appears to have been of a size class mostly between about 30 to 50 cm in diameter.

Summary and Management Implications

Fire history data from high-elevation ponderosa pine woodlands at Caribou Ranch document that fires were generally not frequent disturbances in this area. The post-settlement fire-free period of ca. 140 years between the present and the last fire in 1859 that burned over the entire landscape is less than the previous interval of 153 years from 1706 to 1859. This suggests that in terms of fire intervals *per se*, the post-settlement period is within a historical range of variability. This result is in contrast to lower-elevation montane forests where episodic surface fires were keystone ecosystem processes (*sensu* Holling 1992) that strongly effected both forest structure and ecosystem function. The three widespread fire dates recorded at Caribou Ranch occurred during years when fire was recorded at many sites in the Front Range. Regional burning during these years emphasizes out the role of climate as a forcing of large-scale forest disturbances in this area, rather than buildup of fuels that may result from time since last fire (Bessie and Johnson 1995). It is likely that fire behavior in the subalpine forests surrounding the more open woodlands was severe and resulted in extensive stand opening during these fire years, but that surface fires burned in the more open ponderosa pine communities. Future extensive fires in Front Range forests undoubtedly will be driven primarily by regional climate variability, such as the 1988 fires in the Yellowstone area and the widespread fires in the northern Rocky Mountains this past summer.

A general paucity of surface fires in the Caribou Ranch ponderosa pine stands begs the question of why these woodlands are present on the landscape and what maintains them and the meadows along the stream bottoms. Opening of either subalpine or upper montane forests by crown fires may have formed the initial conditions for establishment of ponderosa pine in these high elevation areas (e.g., Peet 1981). Open ponderosa pine stands and woodlands likely have been maintained by drier conditions on south-facing slopes, possibly coupled with browsing and grazing of tree seedlings by native ungulates during the presettlement period and livestock after settlement. Competition from grass and herbacous layers in the meadow areas and on more mesic hillsides also may preclude tree establishment in these areas. Episodic or even extensive mortality from other disturbances, such as pathogens and insects, also may contribute to keeping these woodlands open through time. Tree establishment through time appears to be fairly uniform but of low intensity, with no apparent pulses of establishment that may have been in response to climate variability or stand opening by crown fires. It would appear, therefore, that these stands have been in more-or-less equilibrium conditions for at least the past few centuries in terms of their demography and response to natural disturbances.

Human disturbance has occurred in the ponderosa pine woodlands in the form of logging and, at least in stand CR1, increased burning during the early settlement period. However, larger and older ponderosa pine trees are still present in plots (Figure 2), suggesting that old-growth conditions necessary for wildlife habitats (e.g., presence and recruitment of logs and snags) are still present as well. The oldest living tree we sampled was over 425 years old, and many other trees were > 200 years old. We saw very little regeneration of trees of any species in the more open stands which fits with observations made by Stevenson (1998). A view suggested by Stevenson is that some of the open ponderosa pine and Douglas-fir stands may need more regeneration to ensure dominance in these areas, but age data suggest that continuous but low-level establishment has occurred in the past in at least the ponderosa pine and there is no reason to suspect such will not be the case in the future.

Finally, intensive management of ponderosa pine forests at Caribou Ranch in the form of stand thinning or prescribed fire does not appear to be needed at this time. Some intensive management including thinning and prescribed burning may be necessary to protect structures and other sensitive areas within the ponderosa pine (and other forest types), but these can and likely should be relatively local efforts with specific goals of creation of defensible space and fuel management. Prescribed fires on a larger scale may be needed in the future to maintain open forest conditions if abundant ponderosa pine establishment is seen in the woodland or meadow areas, or if less fire tolerant species, such as Douglas-fir, become better established in the ponderosa pine zone. The ponderosa pine forest at Caribou Ranch - along with the surrounding subalpine forest - appears to be recovering from human disturbances that were at their peak during the early settlement period, and current forests are likely structurally and functionally similar to many of the pre-settlement conditions.

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Table 1. Sites sampled for fire history and age structure at Caribou Ranch.

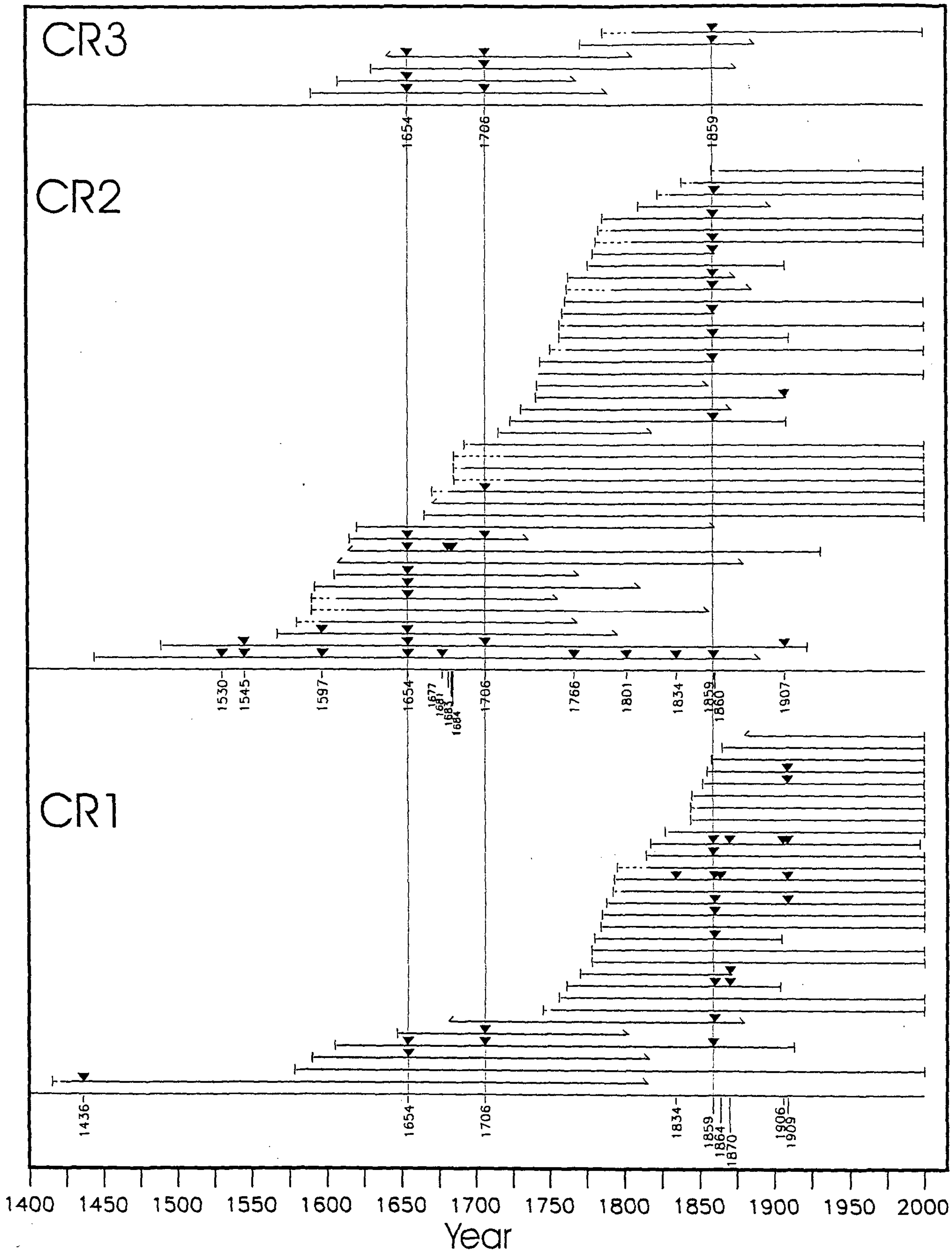
Site	Elevation Range	Slope %	Aspect	No. of Trees Sampled/Crossdated
CR1	9150-9280 ft (2788-2829 m)	40	S	34/30
CR2	8820-8840 ft (2688-2694 m)	10	SE	48/42
CR3	8590-8620 ft (2618-2627 m)	5	E	6/6

Figure Captions:

Figure 1. Location of fire history sites collected at Caribou Ranch Open Space.

Figure 2. Fire and age chronologies for fire history sites. Time spans of individual trees are noted by horizontal bars with fire scars represented by inverted triangles. Dashed lines are estimated number of years to pith. Vertical lines to left on tree chronologies are pith dates with inside dates (i.e., unknown number of years to pith) marked by slanted lines. Vertical lines to right on tree chronologies are bark dates (= death dates) with outside dates (i.e., unknown number of years to death date) marked by slanted lines.

Figure 2.


CR3
CR2
CR1
1654
1706
1859
1530
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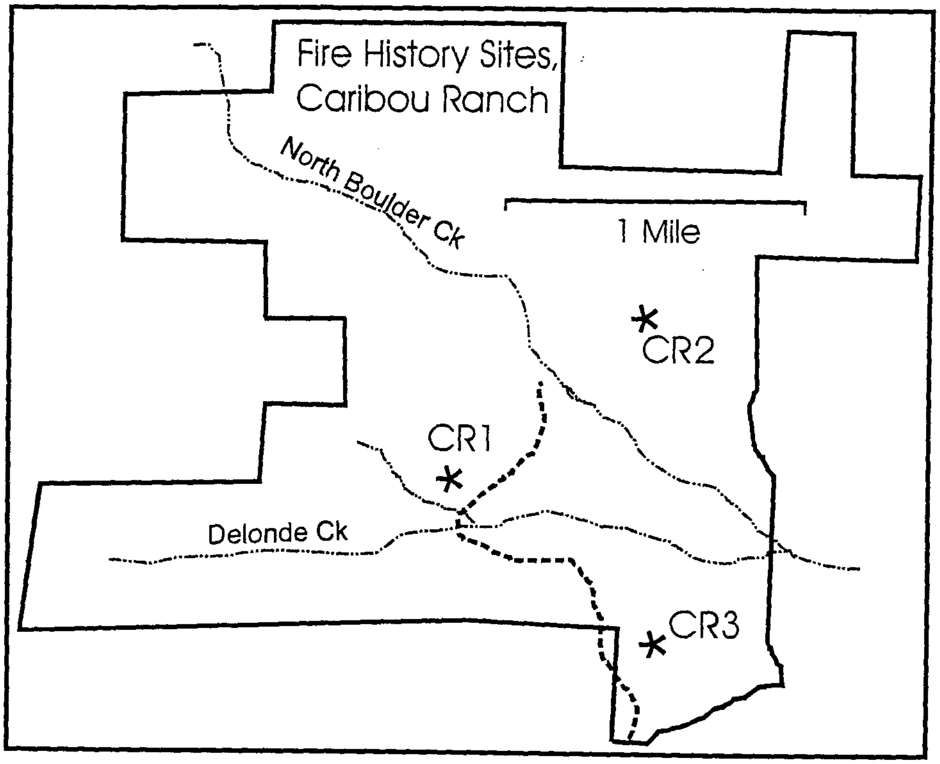
Year

Figure 1.


Fire History Sites,
Caribou Ranch
North Boulder Ck
1 Mile
CR2
CR1
Delonde Ck
CR3