VII. FIRE RESEARCH

A. Summary of previous fire research directly related to Rocky Mountain National Park or to Front Range ecosystems similar to those found in the park

Of the many disturbance types found in natural systems, perhaps the most widespread is that of fire. The current structure, species composition, and dynamics of many ecosystems are often the direct result of past fires or in other cases, the result of other processes that have themselves been affected by fire. In general, fire regimes in the southern Rockies can be thought of as following an elevational gradient (Peet 1981, Romme and Knight 1981, Romme et al. 2003). The lower montane is often characterized by more frequent surface fires, while forests in the subalpine typically experience infrequent stand replacement fire events. However, fires of any intensity can occur in both elevational zones (Veblen 2000).

On the east side of the park, forest types in the montane zone include ponderosa pine, Douglas-fir, and lodgepole pine communities. These three species often intermingle in ecotonal areas, forming mixed stands. Ponderosa pine tends to dominate the lower portions of the montane, increasing in density with increased elevation and gradually giving way to Douglas-fir, particularly on moist north-facing slopes (Marr 1961, Mast et al 1998, Clements 1910). Following disturbance, upper montane sites are often pioneered by dense even-aged stands of lodgepole pine on drier sites and aspen on more mesic sites. In the absence of further disturbance, these lodgepole and aspen stands may gradually be replaced by Douglas-fir at lower elevations and Engelmann spruce and subalpine fir at higher elevations (Peet 1978, Veblen 1991, Clements 1910, Whipple and Dix 1979). In contrast to the variety of forested communities found on the east side, montane forests on the west side of the park are composed almost exclusively of lodgepole pine.

There is an increasing body of evidence that suggests ponderosa pine and mixed conifer communities in the upper montane zone of Rocky Mountain National Park are characterized by a mixed-severity fire regime, including both stand replacing and surface fire events (Laven et al. 1980, Veblen and Lorenz 1986, Brown et al. 1999, Arno 2000, Veblen et al. 2000, Brown and Shepperd 2001, Ehle 2001, Sibold 2001, Romme et al. 2003). This highly variable fire regime is reflected in reported fire return intervals for ponderosa pine (which frequently include a component of Douglas-fir and lodgepole pine in the upper montane), ranging from 1-125 years for low intensity fires and 200-300 years for stand replacing fires (Rowdabaugh 1978, Laven et al. 1980, Skinner and Laven 1982, Skinner and Laven 1983, Goldblum and Veblen 1992, Hadley 1994, Mast et al. 1998, Ehle 2001). This contrasts with the fire regime typical of ponderosa pine ecosystems at lower elevations on the Front Range and other areas of the west, in which stand replacement fires were rare and open “park-like” stand structures were maintained through frequent low intensity surface fires (Veblen et al. 2000). Comparison of fire scar and climatic evidence recorded in tree rings suggests that fire occurrence in the montane zone of the northern Colorado Front Range is strongly associated with climatic variation. Fires tend to occur in years with below average spring precipitation that are preceded by 2-3 years of above average spring precipitation (Veblen et al. 2000).

In a study of disturbance patterns and stand structure, Ehle (2001) found widespread evidence of small crown fires that resulted in the regeneration of dense even-aged ponderosa stands in the park. Over time, subsequent surface fires reduced overall tree density in these stands and created sites for post-fire seedling establishment. This process resulted in a highly variable mosaic of stand structures, densities, and ages across the landscape. Stand densities decreased for a period of about 200 years, after which tree density became relatively stable.

Although the study did not determine the spatial extent of crown fires in ponderosa, in only one instance did crown fires occur in separate plots in the same year. These two plots were located less than 2 miles apart. Study sites were located in Beaver Meadows, Upper Beaver Meadows, Hondius Park, and the south facing slopes of Deer Mountain and Eagle Cliff. This mixed severity fire regime is consistent with research conducted in ponderosa pine communities the Wild Basin area (Sibold 2001). In contrast to the pattern of increased tree density following the adoption of

fire suppression policies documented in the southwest, Ehle (2001) suggests that fire exclusion has greatly limited turnover (both mortality and recruitment) of ponderosa pine in the park.

The lodgepole pine dominated forests of the park are typically characterized by a stand replacement severity fire regime with fire return intervals in the 50-150+ year range (Clements 1910, Peet 1981). These stands tend to self-perpetuate in the presence of frequent disturbance. Depending on site conditions, lodgepole seedling reestablishment may take 30-100 years following stand replacing fire (Peet 1981). Fire frequencies in lodgepole are often higher and may include low severity fire events where stands are in proximity to ponderosa pine or mixed conifer forests that experience more frequent fire (Peet 1981, Veblen and Lorenz 1991). Sibold (2001) found evidence of low severity surface fire in 22% of the lodgepole stands in Wild Basin.

Although evidence of occasional surface fires also has been found in the Engelmann spruce and subalpine fir (spruce-fir) dominated subalpine zone, fires in this zone typically experience large, infrequent stand replacement fire events (Kipfmueller and Baker 2000, Veblen 2000, Sherriff et al. 2001, Sibold 2001, Buechling 2003, Romme et al. 2003). These large fires typically coincide with drought years and occur at intervals of well over a century (Veblen 2000). In Wild Basin, Sibold (2001) found spruce-fir stands that had not burned in over 400 years. Given the long interval fire regime typical of the subalpine, it appears that these forests are still within their natural range of variability and have not been considerably impacted by fire suppression efforts in the last century (Clagg 1975, Sherriff et al. 2001, Sibold 2001, Romme et al. 2003, Veblen 2003). The following fire-related research publications may be applicable to Rocky Mountain National Park and are listed by general topic area:

Fire History/Ecology

Alexander, M.E. 1975. A preliminary reference list on the significance of fire in the forest communities of the Colorado Rockies. Colorado State University, unpublished report.

Alexander, M.E. and D.V. Sandberg. 1976. Fire ecology and historical fire occurrence in the forest and range ecosystems of Colorado: a bibliography. Department of Forest and Wood Sciences, Colorado State University, Occasional Report.

Baker, W.L. and K.F. Kipfmueller. 2001. Spatial ecology of pre–Euro-American fires in a southern Rocky Mountain subalpine forest landscape. The Professional Geographer. 53(2):248-262.

Barrows, J.S., E.W. Mogren, K. Rowdabaugh and R. Yancik. 1977. Final report: The role of fire in ponderosa pine and mixed conifer ecosystems. Colorado State University, Fort Collins, CO.

Crane, M.F. 1982. Fire ecology of Rocky Mountain region forest habitat types. USDA Forest Service, Final Report Contract No. 43-83X9-1-884.

Franklin, T.L. and R.D. Laven. 1991. Fire influences on central Rocky Mountain lodgepole pine stand structure and composition. Proceedings Tall Timbers Fire Ecology Conference: No. 17: High intensity fire in wildlands: management challenges and options:183-196.

Kaufmann, M.R., L.S. Huckaby and P. Gleason. 2000. Ponderosa pine in the Colorado Front Range: long historical fire and tree recruitment intervals and a case for landscape heterogeneity. In: Neuenschwander, L.F., K.C. Ryan, G.E. Goldber and J.D. Greer, eds., Proceedings, Joint Fire Science Conference and Workshop (Boise, ID: University of Idaho, International Journal of Wildland Fire): 153-160.

Keane, R.E., K.C. Ryan, T.T. Veblen, C.D. Allen, J. Logan and B. Hawkes. 2002. Cascading effects of fire exclusion in Rocky Mountain ecosystems: a literature review. USDA Forest Service, General Technical Report RMRS-GTR-91.

Kipfmueller, K.F. 1997. A fire history of a subalpine forest in southeastern Wyoming. M.S. thesis. Laramie, WY: University of Wyoming. 48 p.

Sherriff, R.L. 2000. Fire history at high elevation in the Colorado Front Range. M.A. thesis. Boulder, CO: University of Colorado. 85 p.

Veblen, T.T. and T. Kitzberger. 2002. Inter-hemispheric comparison of fire history: the Colorado Front Range, U.S.A., and the Northern Patagonian Andes, Argentina. Plant Ecology. 163(2):187-207.

Stand Development/Dynamics

Aplet, G.H., R.D. Laven and F.W. Smith. 1988. Patterns of community dynamics in Colorado Engelmann spruce - subalpine fir forests. Ecology. 69(2):312-319.

Ashton, R.E. 1930. Preliminary observations on revegetation of the Twinsisters burn in Rocky Mountain National Park. Journal of the Colorado-Wyoming Academy of Science. 1(2):13.

Billings, W.D. 1969. Vegetational pattern near alpine timberline as affected by fire-snowdrift interactions. Vegetatio. 19:192-207.

Bollinger, W.H. 1973. The vegetation patterns after fire at the alpine forest-tundra ecotone in the Colorado Front Range. Ph.D. dissertation. Boulder, CO: University of Colorado. 74 p.

Donnegan, J.A. and A.J. Rebertus. 1998. Rates and mechanisms of subalpine forest succession along an environmental gradient. Ecology. 80(4):1370–1384.

Huckaby, L.S. 1991. Forest regeneration following fire in the forest-alpine ecotone in the Colorado Front Range. M.S. thesis. Fort Collins, CO: Colorado State University. 102 p.

Huckaby, L.S., M.R. Kaufmann, P.J. Fornwalt, J.M. Stoker and C. Dennis. 2003. Identification and ecology of old ponderosa pine trees in the Colorado Front Range. USDA Forest Service, General Technical Report RMRS-GTR-110.

Mast, J.N. and T.T. Veblen. 1999. Tree spatial patterns and stand development along the pine-grassland ecotone in the Colorado Front Range. Canadian Journal of Forest Research. 29:575-584.

Moir, W.H. 1969. The lodgepole pine zone in Colorado. The American Midland Naturalist. 81(1):87-97.

Nelson, R.A. 1934. Further observations on the Twinsisters burn in Rocky Mountain National Park. Journal of the Colorado-Wyoming Academy of Science. 1(6):51-52.

Nelson, R.A. 1954. The Twinsisters burn after twenty years. Journal of the Colorado-Wyoming Academy of Science. 4(6):45.

Peet, R.K. 1975. Forest vegetation of the east slope of the northern Colorado Front Range. Ph.D. Dissertation. Ithaca, NY: Cornell University. 661 p.

Rebertus, A.J., B.R. Burns and T.T. Veblen. 1991. Stand dynamics of *Pinus flexilis*-dominated subalpine forests in the Colorado Front Range. Journal of Vegetation Science. 2:445-458.

Romme, W.H., M.R. Kaufmann, T.T. Veblen, R. Sherriff and C.M. Regan. 2003. Part 2: Historical (pre-1860) and current (1860 – 2002) forest and landscape structure. In: Graham, R.T., ed. Hayman Fire Case Study, General Technical Report RMRS-GTR-114 USDA Forest Service: 196-203.

Romme, W.H., C.M. Regan, M.R. Kaufmann, L. Huckaby and T.T. Veblen. 2003. Part 4: Forest succession. In: Graham, R.T., ed. Hayman Fire Case Study, General Technical Report RMRS-GTR-114 USDA Forest Service: 220-227.

Shankman, D. 1984. Tree regeneration following fire as evidence of timberline stability in the Colorado Front Range, U.S.A. Arctic and Alpine Research. 16(4):413-417.

Shankman, D. and C. Daly. 1988. Forest regeneration above tree limit depressed by fire in the Colorado Front Range. Bulletin of the Torrey Botanical Club. 115(4):272-279.

Stahelin, R. 1943. Factors influencing the natural restocking of high altitude burns by coniferous trees in the central Rocky Mountains. Ecology. 24(1):19-30.

Veblen, T.T. 1986. Age and size structure of subalpine forests in the Colorado Front Range. Bulletin of the Torrey Botanical Club. 113(3):225-240.

Wyant, J.G., P.N. Omi and R.D. Laven. 1986. Fire induced tree mortality in a Colorado ponderosa pine/Douglas-fir stand. Forest Science. 32(1):49-59.

Fire/Fuels Management

Axtell, C. 1989. Fuel and fire behavior inventory for Glacier Gorge, Glacier Knobs, East Inlet and Colorado fire management units, RMNP. Rocky Mountain National Park, unpublished report.

Baker, W.L. and D.S. Ehle. 2003. Uncertainty in fire history and restoration of ponderosa pine forests in the western United States. In: Omi, P.N. and L.A. Joyce, eds., Fire, fuel treatments and ecological restoration: conference proceedings USDA Forest Service, Proceedings RMRS-P-29: 319-333.

Butts, D.B. 1974. Fire management in Rocky Mountain National Park. Proceedings, Tall Timbers Fire Ecology Conference, No. 14, (Missoula, MT):59-75.

Kalabokidis, K.D. and P.N. Omi. 1998. Reduction of fire hazard through thinning/residue disposal in the urban interface. International Journal of Wildland Fire. 8(1):29-35.

Kaufmann, M.R., L.S. Huckaby, P.J. Fornwalt, J.M. Stoker and W.H. Romme. 2003. Using tree recruitment patterns and fire history to guide restoration of an unlogged ponderosa pine/Douglas-fir landscape in the southern Rocky Mountains after a century of fire suppression. Forestry. 76(2):231-241.

Laven, R.D. 1980. Natural fire management in Rocky Mountain National Park: a case study of the Ouzel fire. Proc. Second Conf. Sci. Res. Natl. Parks:37-45.

Omi, P.N. and E.J. Martinson. 2002. Final report: Effect of fuels treatment on wildfire severity. Western Forest Fire Research Center, Colorado State University.

Omi, P.N. and K. Ogle. 1988. Final report: fuel and fire behavior study for the Forest Canyon, Jackstraw and Paradise Fire Management units, RMNP. Colorado State University, Department of Forest and Wood Sciences, unpublished report.

Skinner, T.V. and R.D. Laven. 1984. Background data for natural fire management in Rocky Mountain National Park - II. Department of Forest and Wood Sciences, Colorado State University, Fort Collins, CO.

Soils

Ballesteros, M.W. 1981. The effect of fire on chemical and physical properties of soils in high elevation mixed conifer ecosystems in Colorado. Honors thesis (B.A.). Williamstown, MA: Williams College. 129 p.

Benavides-Solorio, J. and L.H. MacDonald. 2001. Post-fire runoff and erosion from simulated rainfall on small plots, Colorado Front Range. Hydrological Processes. 15(15):2931-2952.

Huffman, E.L., L.H. MacDonald and J.D. Stednick. 2001. Strength and persistence of fire-induced soil hydrophobicity under ponderosa and lodgepole pine, Colorado Front Range. Hydrological Processes. 15(15):2877-2892.

McMillan, M.E. 1990. Soil development on a pinedale moraine and erosion ten years after a burn, Rocky Mountain National Park, Colorado. M.S. thesis. Boulder, CO: University of Colorado. 91 p.

Morris, S.E. and T.A. Moses. 1987. Forest fire and the natural soil erosion regime in the Colorado Front Range. Annals of the Association of American Geographers. 77(2):245-254.

Moses, T.A. 1982. Erosional response of hillslopes after forest fire in the Colorado Front Range. M.A. thesis. Boulder, CO: University of Colorado. 217 p.

Disturbance Interactions

Baker, W.L. and T.T. Veblen. 1990. Spruce beetles and fires in the nineteenth-century subalpine forests of western Colorado, U.S.A. Arctic and Alpine Research. 22(1):65-80.

Bebi, P., D. Kulakowski and T.T. Veblen. 2003. Interactions between fire and spruce beetles in a subalpine Rocky Mountain forest landscape. Ecology. 84(2):362-371.

Benedict, J.B. 2002. Eolian deposition of forest-fire charcoal above tree limit, Colorado Front Range, U.S.A.: potential contamination of AMS radiocarbon samples. Arctic, Antarctic, and Alpine Research. 34(1):33-37.

Hadley, K.S. and T.T. Veblen. 1993. Stand response to western spruce budworm and Douglas-fir bark beetle outbreaks, Colorado Front Range. Canadian Journal of Forest Research. 23(3):479-491.

Kulakowski, D. 2002. Interactions among natural disturbances in subalpine forests in northwestern Colorado. Ph.D. dissertation. Boulder, CO: University of Colorado. 132 p.

Kulakowski, D., T.T. Veblen and P. Bebi. 2003. Effects of fire and spruce beetle outbreak legacies on the disturbance regime of a subalpine forest in Colorado. Journal of Biogeography. 30(9):1445-1456.

Nesvacil, K. and C.E. Olmsted. in press. The effects of prescribed fire and ungulate herbivory 6 and 7 years post-burn in the upland bitterbrush (*Purshia tridentata*) communities of Rocky Mountain National Park, Colorado. USDA Forest Service, General Technical Report PSW-GTR-xxx.

Swetnam, T.W. and A.M. Lynch. 1989. A tree-ring reconstruction of western spruce budworm history in the southern Rocky Mountains. Forest Science. 35(4):962-986.

Veblen, T.T., K.S. Hadley, E.M. Nel, T. Kitzberger, M. Reid and R. Villalba. 1994. Disturbance regime and disturbance interactions in a Rocky Mountain subalpine forest. Journal of Ecology. 82:125-135.

Veblen, T.T., K.S. Hadley, M.S. Reid and A.J. Rebertus. 1991. The response of subalpine forests to spruce beetle outbreak in Colorado. Ecology. 72(1):213-231.

B. Summary of Ongoing fire-related research

Sibold, Jason S., Thomas T. Veblen (in progress) Subalpine fire history

Fire history will be mapped in all of subalpine forest stands in the southern two thirds of Rocky Mountain National Park (i.e. generally south of Trail Ridge Road) to determine the effects of changes in fire regimes on forest structure and related ecosystem conditions.

The two major objectives of the study are to determine fire history for the subalpine forest patch types (polygons of uniform cover type and forest structural type) identified by the existing vegetation layer of the park's GIS and to determine the effects of past fires and of fire suppression on forest structure and composition through detailed reconstruction of tree population age structures and disturbance history in representative forest patches.

Jehle, Gretchen, Natasha B. Kotliar, and Julie A. Savidge (in progress) Avian response to prescribed fire in the upland shrub/ponderosa pine system of Rocky Mountain National Park, Colorado

This study will assess avian and vegetation community response to prescribed fire in the upland shrub/ponderosa pine system. First, avian point surveys are being performed in burned and unburned study sites to evaluate differences in avian species diversity and densities. Sites burned in different years have been selected to investigate the changes in avian community composition over time. Second, to evaluate the effect of prescribed burning on nesting success of shrub-dependent species, nests will be located and monitored in burned and unburned study sites. Green-tailed Towhees have been identified as a focal species for this study because of their strong association with upland shrub habitat. Third, to assess the changes in vegetation structure resulting from prescribed fire, standardized vegetation measurements are being recorded at all avian point survey locations, at all nest sites, and at randomly located points in each study site. These data will be analyzed to observe patterns of avian habitat preference in relation to burn severity, and to quantify the effect that prescribed burning has on vegetation structure, avian community composition, and nesting success.

Fuels and vegetation mapping project (NPS and USGS)

The primary objective of this study is to develop a fuels database and vegetation map for Rocky Mountain National Park that will accurately describe tree canopy as well as understory vegetation. This information will be used to generate the spatial data layers that are required to run the Fire Area Simulation (FARSITE) model and the Rare Event Risk Assessment Process (RERAP). This database will also include information about the physical characteristics of the fuels, thereby allowing utilization of fire effects models as well as smoke production and transport models.

The vegetation and fuels mapping uses standards, procedures and contracts established by the USGS Biological Resources Division, and the NPS Inventory & Monitoring program. The work includes acquisition of new aerial photography, air photo interpretation, statistical accuracy assessment and GIS database creation.

C. Needed fire research

At the time of preparation of this plan, the following research topics have been identified by park staff as important to ongoing progress in wildland fire and fuels management at Rocky Mountain National Park:

- Effectiveness of fuelbreaks and fuel reduction zones.
  Fuelbreaks are not regarded as impenetrable barriers to fire, but they should, at least, alter fire behavior in such a way that control is easier. In particular, the fuels programs should reduce the likelihood of crown fire and the propensity for spotting in key areas of the park. Research of this type would also be useful in the design and engineering of future fuel treatments in a variety of vegetative cover types. It would be useful to test the projects against simulated fires -

originating both from within and outside the park -- to better determine how they will influence wildland fire behavior.

- Fire ecology, as related to deer, elk, and bighorn sheep habitat. The relationship of fire to forage is not well-understood in the park. However, some prescribed fires will influence the habitat of these ungulates, and the near-permanent removal of natural (and historic) fires from many areas of the park argues for some enlarged program of prescribed burning. The timing and extent of such burning, however, needs to be determined.

- Smoke production from on-going fires. Smoke management will probably be the most difficult part of the park's fire management program. Some capacity to project the quantity of particulate emissions (particularly those of 10 microns or less in size) will be helpful.

- Wind climatology and spot-fire potential. The range of spotting is, effectively, the boundary for natural fire. In some portions of the park considered as sites for natural fire, the wind regime is unknown. Before these areas can be classified as Fire Use Zones, some data on the pattern and intensity of wind flow is essential. This can be combined with the spot fire module in BEHAVE to simulate the potential for long-range spotting as well as simulations using FARSITE.