Bartos, Dale L., James K. Brown and Gordon D. Booth. 1994. Twelve Years Biomass Response in Aspen Communities Following Fire. Journal of Range Management 47:79-83.

This study continued earlier work on Breakneck Ridge in the Gros Ventre Range in northwestern Wyoming to evaluate changes in vegetation following a prescribed fire in aspen. Plots were located in 10 aspen clones, nine of which burned with one unburned control. Sucker (stems <2m height) densities in the control ranged from 8,500/ha initially to a maximum of 18625/ha after three years and declined to 5,150 after 12 yeaars. The low intensity burn area contained 4,000/ha prior to burning. This increased to a maximum of 17,727 two years following burning and declined to 1,518 at 12 years after burning. The moderate intensity burn contained 5962/ha prior to burning, increased to 30,692 two years after burning and declined to 1,854/ha 12 years following the burn. The high intensity burn contained 8,417 suckers/ha prior to burning, increased to 36,458 two years after burning and declined to 2,400/ha 12 years following burning. The burned areas declined in sucker numbers from 29% to 38% after 12 years, while the control declined 39%. The authors attributed the decline in control area numbers due to elk browsing due to its location in close proximity to the burn area. The results of this study reflected similar results cited where sucker numbers declined below pre-burn levels, but biomass was higher.

While cattle grazed the area three out of four years, the area did not seem overly impacted by this grazing and the cattle seldom appeared to use the suckers. The original objective of producing more suckers than the elk could suppress was not realized [remember 2,000 to 5,000 elk use the elk winter range and are fed here]. In this case, fire treatment may have hastened the demise of the aspen. Other prescribed burns in the area were considered successful, but were not as heavily browsed by elk.

Undergrowth vegetation production was dominated by forbs before and after the treatments. Before burning forbs were 66%, grasses 21% and shrubs 13%. For the burn areas, forb increased rapidly during the first three years to a range of 82% to 94% of production. The greatest portion of this increase was from fireweed. This represented a doubling of initial biomass for the treatments, while the control area experienced a 25% increase during the same period. At the end of 12 years, total biomass in the treated areas was not significantly different from the control. In addition, in the treated areas, the percent grasses were 20% or less and shrubs 5% or less which were about half the values for the control and pretreatment measures. Livestock grazing pressure during the study may have distorted the observed production values, especially for grasses. Figure 1 showing the trend in understory vegetation is shown below.

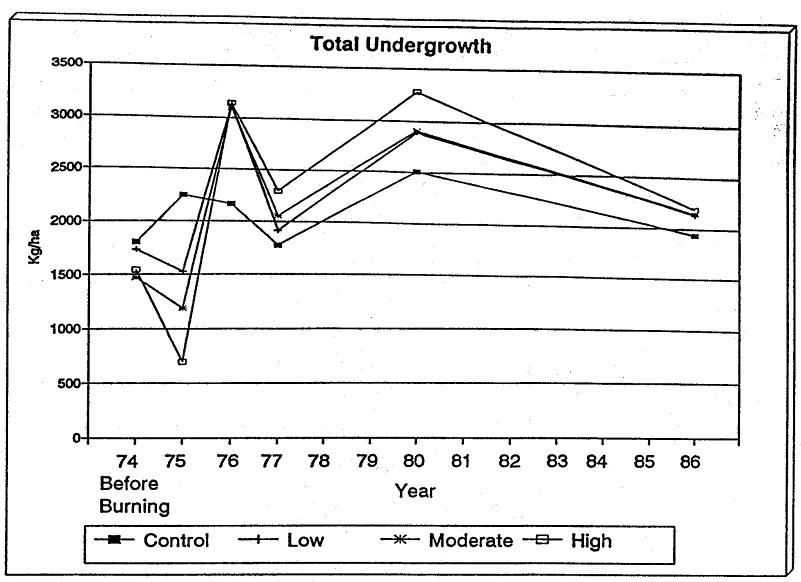


Fig. 1. Total undergrowth production for sampled years during a 12-year time span following burning in 1974 at 3 burn severities.

Shrubs were harmed by burning and did not regain pre-burn production levels even after 12 years. Burn severity did not significant. Snowberry production was reduced to half or less of pre-burn levels, for the high severity and moderate severity burns it was as low as 20% of pre-burn levels. Wild rose and aspen suckers were producing about the same as preburn levels, except at the high intensity burn site which was about half for the aspen.

The authors "question the continued use of fire to regenerate aspen stands that are subjected to heavy ungulate use. Such action could speed the elimination of aspen stands under these conditions."

Bartos, Dale L. and Robert B. Campbell, Jr. 1998a. Decline of Quaking Aspen in the Interior West – Examples from Utah. Rangelands 20(1):17-24.

Bartos and Campbell analyzed distribution of aspen in Utah National Forests. They found that of 2,100,000 acres that contained aspen, most has been converted to conifer and sagebrush, leaving 800,000 acres today. This represents a 60% decline in aspen cover across the six National Forests in Utah. They attribute loss of aspen to a combination of successional factors, fire suppression and long-term overuse by ungulates. [overuse by ungulates didn't occur prior to introduction of livestock, otherwise the larger extent of aspen documented wouldn't have occurred in the first place.] They state' "Changes in the abundance of aspen dominated landscapes have occurred over the past 125+ years partly as a result of livestock grazing, wildlife use and a reduction in fires. The historical fire regime was altered in the mid-1800's after European settlement. Fire exclusion resulted from a combination of excessive grazing, timbering, and people extinguishing wildland fires. Grazing removed the fine fuels which generally carried the fires."

For every 1,000 acres of aspen that convert to conifer, between 250 and 500 acre-feet of water is transpired and not available for streamflow or undergrowth production and an estimated 500 to 1,000 tons of undergrowth biomass is not produced. Further, numbers and kinds of plants and animals in the area decline appreciably. They provide five risk factors for aspen dominated landscapes. These are: (1) conifer cover >25%, (2) aspen canopy cover <40%, (3) dominated by aspen trees > 100 years of age, (4) aspen regeneration <500 stems per acre (5 – 15 feet tall), or (5) sagebrush cover >10%. They present photographic evidence of livestock preventing regeneration of aspen in fenceline contrast photos which show previously burned and logged area that in the presence of livestock is barren and not regenerating, but in the area where livestock are excluded, dense regeneration is evident. They state, "Actions (treatments) to induce suckering must not be initiated until excessive browsing is controlled."

Bartos, Dale L. and Robert B.Campbell, Jr. 1998b. Water Depletion and Other Ecosystem Values Forfeited When Conifer Forests Displace Aspen Communities. Proceedings of American Water Resources Association Specialty Converence, Rangeland Management and Water Resources. American Water Resources Association, Herndon, Virginia TPS-98-1. 474 p.

Application of transpiration rate studies for aspen and conifer trees provided a basis for estimating the water losses due to replacement of aspen with conifer. A statewide survey of all Utah woodlands revealed that about 2.9 million acres of forested habitat have aspen present, but only about 1.4 million acres of these are dominated by aspen. The remainder are classified as conifer forests.

The authors point out the various ecosystem values of aspen including important water yields, rich biodiversity, luxuriant undergrowth, excellent watershed protection, aesthetics, recreation, favored wildlife habitat for big-game and non-game species, valuable livestock forage and wood fiber. These aspen systems have been affected in a major way by fire control and livestock grazing. A fire history study indicates that during the 400 years prior to settlement, fire-free cycles ranged between 20 and 60 years, increasing as elevations increased. They predict that if these conditions continue, most aspen will be replaced by conifers, sagebrush or other shrub communities. Treatment alternatives mentioned include fire, cutting, fencing, spraying, ripping and chaining. They caution, however, that treatments must be pursued with caution, especially due to excessive animal pressure. Clones that are burned and then repeatedly browsed usually only hasten their demise. Therefore, treatments to induce suckering must not be initiated before relief from excessive browsing is obtained.

Various studies cited show declines of aspen due to grazing and fire suppression of near 50 % during the recent past. This includes a 50% decline in Utah since settlement, 47% in the Beaverhead National Forest Gravelly Range in Montana during a 45-year period between 1947 – 1992 and others which indicate similar patterns of decline across the West. Aspen clones that are suggested to have persisted on the same sites since the Pleistocene have been eliminated in the last 150 years.

Using figures from research by Gifford et al (1984) of 2.83 inches of water lost when fir forests replace aspen and 7.32 inches lost when spruce replaced aspen, the authors calculated that 250 to 500 acre-feet of water/1,000 acres was lost through transpiration annually, depending on the conifer species replacing aspen. Since about 1.5 million acres of aspen have been converted to conifers in Utah, this translates to an annual loss of water for streamflow and plant production of 375,000 to 750,000 acre-feet per year.

Using figures for undergrowth production in aspen (1,500 lb/ac) as opposed to conifer forest (200 lb/ac), a difference of approximately 1,300 lb/acre, this calculates to a loss of understory vegetation of 975,000 tons of herbaceous production per year.

Several authors cited have shown that aspen has biodiversity second only to riparian areas. Bird diversity and density was greater in aspen than conifers and bird species diversity increased as the size of aspen stands increased. Plant species occurrences in aspen understory (approx. 30) are nearly double those of conifer forests.

Bartos, Dale L. and Walter F. Mueggler. 1979. Influence of Fire on Vegetation Production in the Aspen Ecosystem in Western Wyoming. North American Elk Ecology, Behavior and Management. Mark S. Boyce and Larry Dl. Hayden-Wing eds. University of Wyoming, Laramie, Wyo.

One hundred and sixty hectares of aspen and 300 ha of adjacent sagebrush-grass vegetation on the Gros Ventre elk winter range were burned to improve forage production and rejuvenate the decadent aspen. Due to variations in fuel load and moisture, the burn was uneven, with high intensity and medium intensity burns. These areas were monitored prior to and for three years following the burn. Data were collected for forage production and aspen regeneration.

Total understory production on the control area varied during the four years of measurement, but changes were not significant, ranging between 1,770 kg/ha and 2,246 kg/ha. The moderate intensity burn decreased from 1,379 kg/ha pre-burn to 880 kg/ha the first year following the burn and then rebounded to 2,885 kg/ha the second year. The High intensity burn decreased even more the year following the burn. It decreased from 1,776 kg/ha before to 473 kg/ha after, but then increased to 3,717 kg/ha two years after the burn. Before burning, annuals composed about 10% of understory vegetation. On the moderate intensity burn this increased to 35% the first post-burn year and 60% on the high intensity burn.   The annuals retained dominace during the three-year monitoring period.

Aspen sucker numbers in the control area ranged between 10,000 and 20,000 during the 4-year period. Most were less than 1 meter high and were suppressed by a combination of elk browsing and the aspen overstory [note: it is mentioned that high levels of cattle grazing affected understory production in 1997 – this may indicate that elk were not the only factor suppressing aspen, certainly other studies by the authors have documented cattle impacts on aspen regeneration]. Initial high numbers of suckers produced on the moderate intensity burn were 27,000/ha the first year, 66,000/ha the second year, but declined to 30,000 the third year. On the high intensity burn, sucker numbers reached 30,000 during the second year and remained at that level the following year. After three years, both the moderate and high intensity burns resulted in about 30,000 suckers/ha.

Belsky, A. Joy and Dana M. Blumenthal. 1997. Effects of Livestock Grazing on Stand Dynamics and Soils in Upland Forests of the Interior West. Conservation Biology 11(2):315-327.

This review article investigates the causes and effects of fire history in ponderosa pine and mixed conifer forests of the interior west. It points out that these forests were historically widely-spaced fire tolerant trees underlain by grass and that recent “forest health” problems characterized by dense stands of fire sensitive and disease susceptible trees have been mainly laid at the feet of fire suppression and selective logging of fire-tolerant trees while a third factor, livestock grazing, is seldom discussed.

The authors cite literature as early as the 1920’s that suggested livestock played a role in altering these forests. Their review of livestock grazing effects focuses on literature for the “more arid low and mid-elevation forests of the western interior United States, which include forests from Washington south to New Mexico and from the Rocky Mountains west to the eastern Cascade-Sierra Nevada Range."

In presettlement times these forests were composed of widely spaced trees growing in even-aged and uneven aged stands with understories of grasses, forbs and shrubs. On drier sites at low elevations and south facing slopes, the forests were dominated by widely dispersed ponderosa pine. On north-facing slopes, wetter sites and sites at mid-elevation were dominated by Douglas fir, western larch, grand fir and white fir. These mature forests were altered periodically by intense fire, causing them to be opened up and replaced by ponderosa pine and western larch which were maintained for long periods by low-intensity ground fires that eliminated the more fire-sensitive fir seedlings. At higher elevations, mature forests were dominated by subalpine fir and mountain hemlock.

Pre-settlement, these mature trees were maintained at low densities by competitive exclusion of tree seedlings by dense understory grasses and thinning of understory trees by frequent low-intensity ground fires. These fires were ignited by lightning and Native Americans and were fueled by grasses, forbs, low shrubs and pine needles. They were cool, slow burning and non-lethal to larger fire-tolerant trees with their thick bark such as Douglas fir. Seedling and saplings of ponderosa pine and other species suffered high mortality during these fires. Mean fire return intervals of these low-intensity fires were 5 – 12 years across the west, ranging from 4-5 years in the Southwest, and in the northern Rockies 5-20 years in ponderosa pine stands and 15-30 years in mixed conifer stands.

As settlement of the West occurred, forest changes occurred including increases in tree density, insect and disease, fuel buildup and increased fire intensity. Early authors have suggested these changes began shortly after livestock were introduced into these areas. "As the numbers of livestock increased the biomass and vigor of the grasses and sedges they grazed declined.." This reduced the competitive dominance of the understory and allowed more tree seedlings to become established, thus generating thickets of saplings and pole-sized trees. Livestock reduced the frequency of surface fire by consuming the herbaceous vegetation which would otherwise have become a source of fine fuels.

These effects combined with Agency fire prevention efforts increased densities of trees. These more dense, shadier forests allowed establishment of more shade-tolerant and fire-sensitive species such as Douglas fir and white fir. As a consequence, forests shifted from fire-tolerant species such as ponderosa pine to fire-sensitive species. During dry periods, these densely spaced young and larger trees became stressed for water and increasingly susceptible to a variety of insect and disease infestations. Higher tree densities have led to more frequent and widespread disease outbreaks. As mortality increases, fuel loads increase. Examples of forests where fuel loads have increased by a factor of 10 during the fire suppression period are given.

Four case studies on grazed and ungrazed forest stands provide further insight into the effects of livestock grazing on stand dynamics. Isolated plateaus in central Washington were studied. One had never been grazed by livestock, the other had been grazed for 40 years. Neither had ever been logged. The ungrazed forests were covered with open, park-like ponderosa pine and mixed conifer forest. There was low tree regeneration and thick, lush grasses in the understory. The grazed forests had sparse grass understory and 8000 ponderosa pine, Douglas fir and western larch saplings and seedling per hectare. Since neither area had burned in 125 years and except for livestock grazing, other conditions were similar. Another case study in Utah compared two adjacent mesas, one of which was grazed and the other ungrazed. This study showed an increase in tree recruitment of 10 times greater on the grazed mesa compared to the ungrazed mesa. Tree recruitment on the grazed mesa corresponded to livestock grazing pressure, with the highest recruitment occurring during the heaviest period of grazing. As grazing was reduced, tree recruitment declined and when grazing was eliminated, tree recruitment returned to the low rates that occurred prior to grazing. Because fire had not occurred to thin the stands on the ungrazed mesa, the vigorous understory vegetation was determined to be the factor inhibiting tree recruitment.

The authors cite exclosure studies in these forests demonstrating that livestock substantially reduce vegetative cover of herbaceous vegetation, especially native grasses. This reduced plant litter and ground cover and associated soil compaction which decreases water infiltration, increases erosion rates and destabilizes soils and nutrient cycles. This leads to increased water stress and tree mortality during dry periods contributing to increased fire intensity in western forests.

Carter, John G., Brandon Chard and Julie Chard. 2000. Analysis of Ground Cover in Forest Openings in the Bear Hodges Analysis Area. Willow Creek Ecology, Inc. Mendon, Utah.

Carter, John G and Brandon Chard. 2001. An Assessment of Upland and Riparian Condition for Rich County, Utah BLM Lands. Western Watersheds Project Utah. Mendon, Utah.

GAO. 1999. Western National Forests. A Cohesive Strategy is Needed to Address Catastrophic Wildfire Threats. Report to the Subcommittee on Forests and Forest Health, Committee on Resources, House of Representatives. United States General Accounting Office GAO/RCED-99-65

GAO recognizes that the National Forest of the western United States have become much more dense, with fewer large trees and many more tightly spaced small trees and underbrush. They state that tree stands in the interior West differed from those found elsewhere due to the dry climate and varied elevations. In this region, frequent, low-intensity ground fires removed undergrowth and smaller trees from these areas. In recent years, changes in tree stand density, greater percentage of fire-tolerant species, overall species composition, insect and disease have led to concerns over forest health and the ability of the Forest Service to meet its mission of multiple use of recreation, rangeland, timber, watersheds, water flows, wilderness, wildlife and fish and protection of the lands' undiminished ability to produce these uses for future generations.

The Forest Service has estimated 39 million acres are at high risk of catastrophic wildfire due to fire suppression efforts which have allowed accumulations of high fuel levels. In 1997 it announced a goal of improving forest health through monitoring, increasing the number of acres on which fuels are reduced and restructured its budget to provide funds for those efforts. Congress authorized and funded a multi-year effort to better assess problems and solutions.

GAO provides maps of "frequent fire interval" forests which occurred at the warmer, lower elevations with fire return intervals of 5 to 30 years before settlement. These frequent fires kept the forests clear of undergrowth by consuming largely grasses and undergrowth. The figure showing these areas is reproduced on the following page. In the cooler, more moist forests at higher elevations which are generally dominated by lodgepole pine, fires historically occurred at 40 to 200 year intervals which killed nearly all the trees due to the more dense stands.

GAO points out that because the Forest Service lacks a cohesive strategy for addressing barriers to improving health of the national forests by reducing fuels, efforts may leave large areas of the West still susceptible to uncontrollable wildfire after 2015. Some of these barriers are that prescribed fires may get out of control, smoke produced can cause significant air pollution, and mechanical methods have institutional problems. These include a lack of contracting mechanisms that allow removal of timber with little commercial value and incentives focus on areas and acreage that may not present the highest fire hazards. Others are the costs which have risen as more fuels have accumulated and fires have increased in intensity. These costs have increased 70% in seven years to $661 million annually. Forest Service officials agree that the increased fire suppression efforts will not be successful and that large, intense wildfires are generally impossible for fire fighters to stop.

In 1997, the Forest Service adopted recommendations to increase the number of acres on which fuels are reduced to 3 million annually by 2005 to run until 2015. This will fall 10 million acres short of the estimated 39 million high hazard acres. The Joint Fire Science Program was authorized by Congress in 1998 to develop consistent information on accumulated fuels and ways to reduce them. This process will take up to 10 years and that is added to time required to modify Forest Plans to incorporate changes.

The Environmental Protection Agency and Forest Service are involved in a 3-year experiment to reconcile controlled burning and air quality standards. Mechanical harvesting has adverse effects on wildlife habitat and water quality in many areas which makes large-scale timber harvest infeasible. However, because the timber sale program provides funds for other activity, commercially valuable lands may be harvested while less commercially valuable lands with greater fire hazards may not be addressed. "Currently, managers are rewarded for the number of acres on which they reduce fuels, not for reducing fuels on the lands with the highest fire hazards."

GAO estimates that the cost of reducing fuels on the 39 million at-risk acres could be $12 billion between now and 2015. Forest Service officials agreed with a 1997 obseravtion by the Secretary of the Interior that efforts to reduce fuels will have to be repeated three to five times over several decades. They recommend the Forest Service develop a cohesive strategy for reducing and maintaining accumulated fuels on national forests of the interior West at acceptable levels. That strategy should include specific steps for acquiring data and assessing performance, reconciling fuel reduction strategies with other objectives and changing contracting procedures to better accomplish fuel reduction goals.

In 1997, the Forest Service identified a goal of achieving healthy and sustainable ecosystems throught conserving and restoring ecosystem structures. A specific objective was restoring or protecting the ecological conditions of forested ecosystems to maintain their components and their capacity for self-renewal. Forest Service scientists believe that a useful method of assessing forest health is comparison with the historical range of variability. "Examining the historical range of variability of a forest's tree stands is believed to be an especially useful starting point for analyzing the forest's overall health and functioning because (1) tree stands are the defining biological structures of forested versus other kinds of ecosystems and (2) the conditions of these structures greatly determine the capacity of a forest not only to produce timber, but also to maintain soils, watershed conditions, wildlife and fish habitats.

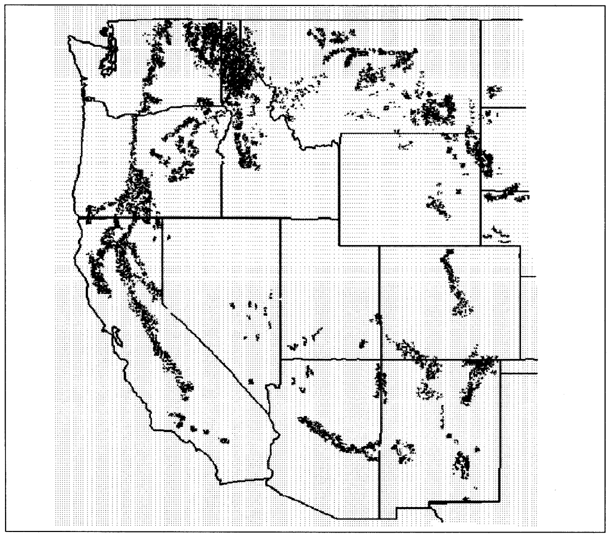
The Forest Service cites increased density of stands, accumulations of dead materials on the ground as important symptoms of poor health. Examples are given where tree stand density has increased over 50% of national forest lands with levels of increase in stems of over 15 times in the past century. Numerous figures are cited regarding increased incidence and areas of damage by insects and disease as well as large increases in noxious weeds. GAO summarizes the causes of these problems as due to extensive livestock grazing beginning in the 1800's which eliminated much of the grass that historically carried fire through the forest's undergrowth, timber harvest practices of selective logging larger trees or clearcutting and increases in nonnative plants, insects and diseases. These factors generally changed the forest's ecologies and the primary factors compounding the damage was fire suppression.

According to the Fish and Wildlife Service, of the 146 threatened, endangered, or rare plant species found in these states for which there is conclusive evidence on fire effects, 135 species benefit from wildfire or are found in fire-adapted ecosystems.

According to the Forest Service, virtually all of the 39 million acres of the lands threatened by uncontrollable, catastrophic wildfire are located in the lower-elevation, frequent fire forests of the interior West historically dominated by ponderosa pine. "These forests are particularly susceptible to such fires because, as stated in a 1995 internal agency report, far more cycles of fire (up to 10) were suppressed in these forests than in the higher elevation, lodgepole-dominated forests – where generally only one or no fire cycle was suppressed." Areas experts outside the Forest Service have identified as at medium or high risk were also shown. Those at medium risk are included because additional fuels can accumulate so over time they become high risk.

In 1995, the Forest Service announced its intention to refocus its fire management program to reducing accumulated fuels. In fiscal 1998 it announced that funds appropriated for reducing fuels would be prioritized to protect high-risk urban interface areas subject to frequent fires, areas adjacent to and within wilderness areas and lower expected long-term costs of suppressing wildfires by restoring and maintaining fire adapted ecosystems. Several reports have been issued by the Forest Service to address forest health and reduction of fuels.

Figure 1.2: Location of Frequent Fire Forests in the Interior West



The Joint Fire Science Program previously mentioned called for the Forest Service and Interior Department to conduct research and analysis to better understand the location and extent of problems with accumulated fuels, effects on other resources of different approaches to reducing these fuels, relative cost-effectiveness of these approaches, interagency approaches to monitoring and reporting efforts to reduce fuels.

Gifford, Gerald F., William Humphries and Richard A. Jaynes. 1984. A Preliminary Quantification of the Impacts of Aspen to Conifer Succession on Water Yields – II. Modeling Results. Water Resources Bulletin. American Water Resources Association (20)2:181-186.

Using heat pulse velocity techniques, water losses from aspen and subalpine fir were measured in replicated trees for one year. These data were used to modify the plant activity index and crop coefficient within the ASPCON model. Results of modeling indicated net losses to streamflow when aspen were replaced by subalpine fir. The losses were nearly three times greater for subalpine fir than for aspen.

Holechek, Jerry L., Rex D. Pieper and Carlton H. Herbel. 1998. Range Management Principles and Practices. Prentice Hall, 542 p

This range management text provides detailed information regarding the use of areas at various distance from water and on different slopes by livestock.

Kay, Charles E. 2001. The Condition and Trend of Aspen Communities on BLM Administered Lands in Central Nevada – with Recommendations for Management. Final Report to Battle Mountain Field Office, Bureau of Land Management. Battle Mountain, Nevada.

This report summarizes field studies in the Shoshone, Simpson Park, Diamond, Desatoya and Roberts Mountains on BLM lands in central Nevada. Aspen in these areas are found to be in poor condition and many stands have not successfully regenerated in 100 years or more.

No evidence of elk presence was found in or near any of the stands, so elk were not contributors to the problem. Forest succession was not a problem as conifer invasion had not taken place in the communities studied. Other than pinyon pine, conifers were absent from the study area. Kay observes that where aspen in central Nevada has been protected from grazing, aspen has maintained its position in the vegetation community and, in fact, has actually replaced sagebrush, contrary to the opinion of some that say sagebrush naturally replaces aspen. He cites other exclosure studies that have found that aspen stands have expanded and eliminated sagebrush.

Exclosure studies have also suggested that climate has little impact on aspen in central Nevada. Aspen inside exclosures regenerated without fire or other disturbance while aspen in adjacent, unprotected areas did not. Numerous papers are cited that demonstrate that climatic variation does not account for observed declines in aspen.

Fire exclusion was examined. It is noted that BLM has suppressed fires for a long period and none of the study areas contained evidence of fires with few exceptions. In fact, only a few out of the hundreds of clones studied had experienced fire during the past 20 years. Aspen age data suggest that few aspen stands in central Nevada have burned during the past 100 years. He points out that while the burned stands did regenerate, in all cases where aspen were protected from grazing, aspen regenerated. So, whle fire can benefit the species, aspen declines cannot be attributed to absence of fire.

Exclosure data indicated that herbivory hah a major influence on aspen stem dynamics and understory composition in central Nevada. Most herbivory was from livestock. Pellet counts were used and showed that 59.3% were from domestic sheep, 40.2% from cattle and 0.4% from deer. Exclosures that exclude cattle but not deer including canyons closed to livestock had all aspen stands that regenerated. When fallen trees blocked livestock access, aspen were able to regenerate in the protected spaces. Reductions in livestock numbers also resulted in aspen regeneration.

Distance to water and slope were also factors that related to aspen regeneration or the lack of regeneration. Cattle use is generally related to distance from water and slope. Steeper slopes or areas further from water receive less use. Aspen stands further from water and on steeper slopes were in better condition than those nearer water or on more gentle slopes, again indicating that grazing by livestock was the operative factor causing declining health of aspen clones.

While Kay cites other research indicating that wildlife have impacts on aspen regeneration, he states that in all cases where aspen is protected, it successfully regenerates and formed multi-aged stands without fire or other disturbance. He concludes by saying, “The single, stem-aged stands seen in central Nevada and found throughout the West are not a biological attribute of aspen, but a result of excessive ungulate herbivory. … In central Nevada, however, domestic livestock are the predominate ungulate herbivore.”

Kay, Charles E. and Dale L. Bartos. 2000. Ungulate Herbivory on Utah Aspen; Assessment of Long-term Exclosures. Journal of Range Management 53:145-153.

Krebill, R.G. 1972. Mortality of Aspen on the Gros Ventre Elk Winter Range. USDA Forest Service Research Paper INT-129. Intermountain Forest and Range Experiment Station, Ogden, Utah.

The 84,000 acre Gros Ventre elk winter range in the Teton National Forest was thought to contain between 2,000 and 5,000 elk, which were fed at supplemental feeding stations during winter. Obviously deteriorating aspen stands coupled with signs of elk damage from browsing, highlining and barking occurred in areas close to winter feeding grounds. [*The study did not emphasize cattle grazing, but in one casual mention near the end of the paper was mentioned along with elk, deer, moose, rodents as causing browsing damage. This lack of attention to livestock is found in many papers that find big-game as culprits without addressing the competition effect of livestock which decrease available forage for wildlife and cause wildlife to excessively browse areas which may not have been historically over browsed*.]

100 sample plots were placed in the 3,330 acres of aspen so that one plot was in each 33.3 acres. Stand and understory data were collected. The majority of trees were in the 80 – 120 year class (71%). Across all sample locations, the mean number of live trees were 466.4 per acre, dead trees 336.8 per acre and those that died in the current year 17.1 per acre. Of the live trees, 42% were less than 6” DBH, 55% between 6.1” and 12” and 2% greater than 12.1”. Aspen sprouts were not included in the populations figures, but were present at 653/acre. Most showed indications of being browsed down to less than 2 feet in height annually. An annual mortality of 3.6% per year was calculated, indicating that aspen populations would decline by 2/3 in 30 years. Ranges of mortality cited were 1% per year in Colorado and 2.7% per year in Utah’s Ephraim Canyon. These rates are two to four times higher than those found in similar studies in New York. [*It could be suggested that the absence of livestock grazing in aspen in*

New York might account for some of the differences.] Occurrence of sagebrush and Balsomorhiza sagittata in aspen understory along with conifer saplings indicated a state of browsing disclimax. Fungi and insects were diagnosed as the major cause of death of mature trees and were suggested to invade trees injured by elk.

McDonough, W.T. 1979. Quaking Aspen – Seed Germination and Early Seedling Growth. USDA Forest Service Intermountain Forest and Range Experiment Station. Ogden, Utah.

Suckering of aspen for regeneration has been widely studied, but propagation of aspen by seed has been considered of minor importance. Reproduction of seed has many important attributes including assuring genetic variability, widespread dissemination and new colonization by wind dispersal. Yearly seed production of mature trees is estimated at 1.6 million. Seed capsules were collected from two healthy and two deteriorating aspen clones in Logan Canyon in the Wasatch National Forest to study the effects of differences in ability to germinate under varying environmental conditions.

Germination tests at a range of temperatures revealed between 80 and 100% of seeds were able to germinate. These numbers declined as temperatures reached around 30º C and became very low at 40º C. There were no significant differences between healthy and deteriorating clones. Germination success declined under increasing water stress, ranging from 97% success at a water potential of –0.6 bars to 0% at –7.7 bars. The implications of this regard the effects of direct solar insolation on dark soil surfaces and the raising of soil temperatures above atmospheric and limit seedling establishment. Soil drying under these conditions would increase water stress and also lower germination success and ability of shoots to grow.

Because of the exacting requirements for germination and growth, the author suggests that seeding as a management tool might be too difficult and expensive and have doubtful value. It is suggested that under favorable weather and site conditions, natural seeding and establishment might be sufficient to provide the benefits of reproduction by seed.

Mueggler, Walter F. 1989. Age Distribution and Reproduction of Intermountain Aspen Stands. Western Journal of Applied Forestry 4(2):41-45.

Stand age and sucker reproduction was measured in 713 aspen-dominated forest plots on nine National Forests in Utah, SE Idaho and western Wyoming. Ninety-five percent were dominated by mature or over-mature trees. Approximately one-third of the pure stands, not invaded by conifers, may experience regeneration problems because they contain less than 500 suckers per acre.

Aspen woodlands are important for wildlife, fuelwood, flakewood, scenic beauty and summer range for livestock.

Aspen is a clonal species that regenerates almost exclusively from root suckers. It usually reproduces vigorously following fire. This method of reproduction gives it an advantage over conifers, which rely on seed for reestablishment. Aspen is a relatively short-lived and shade-intolerant species that rapidly declines in abundance as conifers regain dominance in the overstory. Because of the reduced incidence of fire, many of these even-aged aspen stands are gradually reverting to conifer dominance.

As much as one-third of the aspen groves and woodlands in the region are believed to be relatively stable communities that occupy sites unsuited for conifers or remote from a conifer seed source. The presence of both even-aged and uneven aged stands in these areas suggests that under some conditions, aspen can persist as a "stable self-perpetuating woodland community without the need for periodic disturbances like fire or clearcutting to stimulate sucker regeneration."

Stand age distribution data from the sites sampled showed that 78% of the stands contained dominant trees older than 80 years. 22% contained dominant trees younger than 80 years. Aspen reproduction data showed 19% with less than 200 suckers per acre, half with fewer than 800 suckers per acre, while 27% contained greater than 2000 suckers per acre. Sucker production was weakly, but positively correlated with herbaceous understory vegetation and negatively correlated with stand age. Aspen reproduction percentiles for all National Forest sites in the study were 33% contained 1482 suckers, 50% contained 812 suckers and 66% contained 412 suckers.

Sixty-two percent of the stands sampled were in the 80 to 120 year age class and only 2% over 160 years. In this and previous studies, only 2 of more than 1500 trees measured were more than 200 years old. Mueggler concluded that western aspen matures at between 60 and 80 years and deteriorates rapidly after about 120 years.

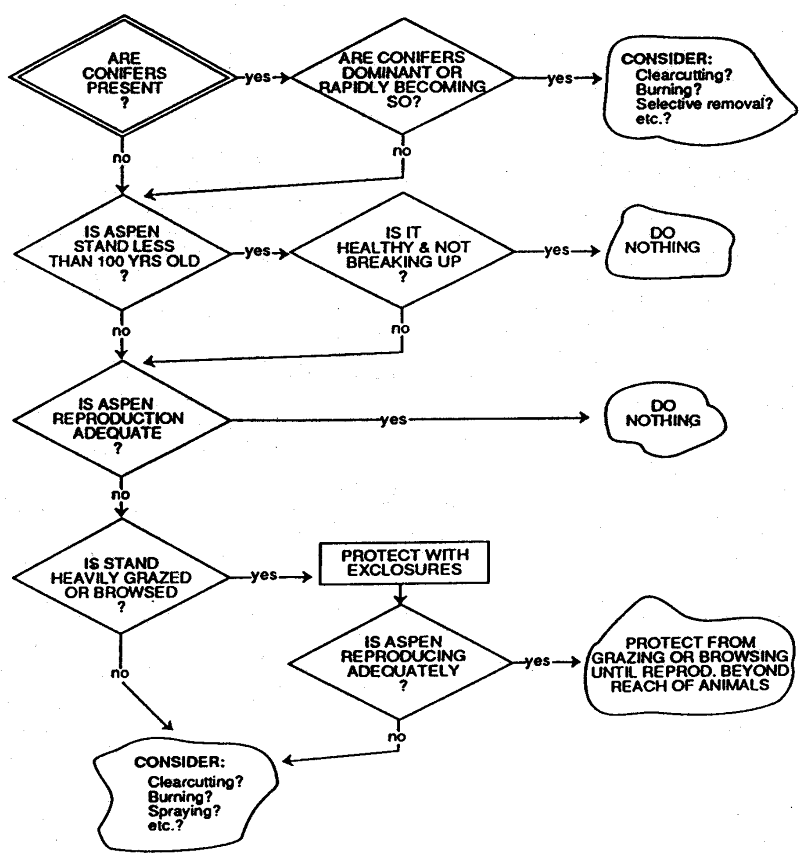
Mueggler states, “This does not necessarily mean, however, that the stands dominated by rapidly deteriorating trees will lose their identity as aspen-dominated communities. This is amply demonstrated by the existence of multi-age aspen communities. Scattered root suckers develop under existing stands, and more are frequently formed as the old canopy gradually breaks up. These suckers have the demonstrated potential to gradually replace a deteriorating even-aged canopy with a multiaged replacement stand.”

Mueggler concludes that if while not definitive, the number of suckers in an aging stand in the absence of conifer invasion may indicate the ability of the stand to replace itself. If conifers are invading, the number of aspen suckers is irrelevant and unless wildfire or management activities intervene, the conifers will suppress the aspen. If conifers are not invading, the stand has potential for natural replacement.

While the number of suckers required for stand replacement is not well defined, numbers can far exceed mature tree stocking requirements of 400 to 600 per acre. Other researchers have reported 4,000 to 60,000 suckers per acre following burning, while clearcutting increased has suckers from 930 per acre to 17,800 per acre in northern Utah and as much as 31,000 to 50,000 per acre. These numbers decline rapidly due to disease, browsing and snow breakage is high, reducing numbers to less than 10,000 per acre after periods of a few years.

Based on their analysis, the authors conclude that at least a third of mature and overmature aspen stands in the Intermountain Region which are not being replaced by conifers may also have regeneration problems without some type of management intervention such as burning, clearcutting, herbicide spraying or some other mangement action to alter the control of apical dominance over sucker production. They note, however, that an abundance of suckers does not ensure successful regeneration of the stand if the suckers are unable to grow due to browsing animals, particularly sheep, but also cattle and wildlife.

Management recommendations include two major considerations, the status of aspen to conifer succession and the status of aspen regeneration in deteriorating stands. If the stand is threatened by conifers, the conifers must be reduced by burning, clearcutting or selective removal. If conifer invasion is not an issue, then conditions must be promoted to encourage growth of the suckers needed to replace the aging trees. They note that burning is not always an option due t ... ıded here. In mature stands over 10 ... per acre, the first question to ask ... inherent to the clone. Exclosures are ... :ker production is taking place, tl ... d, then other options such as clearcı



The figure is reproduced from Mueggler (1989).

Mueggler, Walter F. 1994. Sixty years of Change in Tree Numbers and Basal Area in Central Utah Aspen Stands. USDA Forest Service Intermountain Research Station Research Paper INT-RP-478.

Paired plots of aspen in three locations at the Great Basin Experiment Station on the Wasatch Plateau in Central Utah were measured over 64 years to determine changes in stand characteristics in thinned and unthinned plots. No information was given on the presence or absence of livestock during this time. Thinning consisted of removing dead, depressed and intermediate trees. Results are shown in the following table.

Stand Name	No. Trees/acre at Beginning Age	No. Trees/acre at End of Study (63 years)
Willow Creek Unthinned	2,220 @ 40 years	164 @ 104 years
Willow Creek Thinned	1,458 @ 40 years	282 @104 years
Dusterberg Hill Unthinned	1,037 @ 70 years	54 @ 133 years
Dusterberg Hill Thinned	656 @ 70 years	190 @ 133 years
Potato Patch Unthinned	3,007 @ 50 years	259 @ 113 years
Potato Patch Thinned	1,378 @ 50 years	313 @ 113 years

In each case, thinned stands had more trees per acre than unthinned stands after the 63 year period. Other data collected showed that basal area of the stand peaks around 80 years and declines appreciably by age 100. Stands thinned from below (removing smaller trees) will contain more, but smaller stems at maturity and greater total basal area than those not thinned. Removing 33% of the intermediate and suppressed aspen in the 40-year old Willow Creek Stand resulted in 1.75 times more aspen at age 104 than if thinning had not occurred. At Dusterberg Hill, 47% of the trees were removed at age 70 and the thinned stand at age 133 contained 3.5 times more aspen than the unthinned plot. The Potato Patch stand which was succeeding to white fir at the time of thinning, was thinned at about the same rate as Dusterberg Hill, yet at age 113, there were only slightly more aspen than in the paired unthinned stand.

Mueggler, W.F. and D.L. Bartos. 1977. Grindstone Flat and Big Flat Exclosures – a 41-Year Record of Changes in Clearcut Aspen Communities. USDA Forest Service Research Paper INT-195. Intermountain Forest and Ragne Experiment Station, Ogden, Utah.

This study was conducted on the Beaver Mountain plateau on the Fishlake National Forest in Utah. A history provided shows that deer were abundant in 1865 when Beaver County was first settled. Then the ranges were heavily stocked with sheep and cattle, which overgrazed the range and that factor coupled with unrestricted hunting resulted in a decline in deer numbers to a low in about 1910. Beaver Mountain was placed under National Forest Administration in 1906 and better regulation of forage coupled with enforcement of hunting regulations in 1913 allowed deer numbers to increase. By 1926, heavy use of aspen suckers and palatable shrubs was attributed to high populations of deer and by 1934 aspen regeneration was poor over large areas. Overuse of the livestock summer range was a serious problem by the early 1930's. Cattle and sheep as well as deer were considered too numerous. Proposed reductions in livestock were protested by ranchers who claimed the deer were too numerous and responsible for depleted forage. [*These reports attest to the fact that declines in aspen were related to the combined pressure of livestock and deer, although before livestock numbers were introduced these problems apparently weren't reported*]. This resulted in establishment of study plots in aspen to evaluate the relative effects of deer and cattle grazing on aspen and forage production. Two study plots consisting of small exclosures (30 x 60 m) to exclude all ungulates, a similar one to exclude livestock, but not deer and an adjacent area open to both deer and cattle was monitored. Three-fourths of each exclosure were clearcut to allow measurement of successional change after cutting. Livestock have continued to graze the area during the study period.

Aging of aspen in the study plots indicates that very few aspen were able to escape browsing and become trees from suckers that arose between 1905 and 1934. Sucker occurrence on the uncut plots under use by deer and cattle was persistent over the years, ranging between 3,000/ha and 30,000/ha. Few of those survived to reach the 5.1cm DBH size class by 1975 (41 years later). Clearcutting stimulated sucker production in ungrazed plots to levels 19 to 26 times greater than those in uncut and ungrazed plots. After 8 years numbers surviving were similar between cut and uncut plots that were not grazed. Deer use in the plots reduced sucker numbers to 3% and 10% of the numbers in the ungrazed plots. After 5 years, neither plot contained suckers or saplings. In uncut portions of the plots, suckers continued to occur but were suppressed by browsing. In the cut portions, suckers were present for only a few years after cutting, apparently because the heavily browsed suckers were not able to keep the root system alive.

Effects on understory vegetation after 41 years included an increase to over 10 times the amount of shrubs (rose and snowberry) in the ungrazed exclosures compared to the area grazed by both deer and cattle and over 3 times that grazed by deer. Cattle use hampered total forb production, but deer use did not. Overall production of herbage was greatest on areas closed to cattle, but grazed by deer.

A large burn covering 600 hectares a few miles from the study plots had abundant aspen suckers offer hundreds of hectares. Combined deer and cattle use did not appear to inhibit successful re-establishment of the aspen stands. Several studies cited indicated that management of livestock is essential for regeneration of aspen following burning or clearcutting. These studies also indicated that normal deer populations and appreciable elk browsing did not prevent establishment of a new aspen stand. The authors suggest treating areas of sufficient size to generate sufficient aspen suckers to overcome browsing pressure. They also suggest that smaller areas might fail even if livestock are excluded for 5 to 10 years due to deer being attracted to the available forage.

Schier, George A. 1975. Deterioration of Aspen Clones in the Middle Rocky Mountains. USDA Forest Service Research Paper INT-170.

When fire and other major disturbances are excluded from the environment, aspen clone ramets become mature in 80 to 100 years and then show a rapid decline in vigor with increased susceptibility to disease and insects with age. This study was designed to investigate the ability of overmature aspen to generate suckers and account for the scarcity of regeneration in deteriorating clones compared to the abundant reproduction occurring following logging or fire.

Five deteriorating clones were located and paired with adjacent healthy ones. The location was in the Wasatch National Forest in northern Utah. Deteriorating clones were determined by low densities of living ramets and large numbers of dead stems. Absence of conifers was an important characteristic. Sucker reproduction was measured on 10 m^2 circular plots. In addition, root samples were taken from both types of sites and planted in controlled greenhouse conditions to determine ability to generate suckers. Schier (1975) defined a healthy aspen clone as one having a stem density at least 75% that of fully stocked clones of the same age on similar sites. A deteriorating clone is characterized by low density of living trees and a large number of dead stems and low density of suckers in the absence of conifers or suppression caused by browsing.

Schier (1975) documented the number of suckers in healthy clones at between 930 and 2,900 per acre while deteriorating clones had 159 to 441 suckers per acre. The authors conclude that stands with less than 500 suckers per acre may have regenerative problems, while those with over 1,000 per acre have the potential to replace themselves.

Basal area of deteriorating clones ranged from 6 to 30% of healthy ones. They were visually distinguishable from healthy clones, being shorter and having poorer form than stems in healthy stands. Excavations during root collections showed that root systems in deteriorating clones were limited in extent, occurring near the isolated living stems. Dead roots were numerous, indicating they were declining in extent. “Even if all suckers in the deteriorating clones escape mortality and develop into mature trees, only a few small areas have the potential for reaching full stocking.” Mean density of sucker reproduction was 5260 suckers/ha and 2360 clumps/ha in healthy clones while in deteriorating clones, mean densities were 767 suckers/ha and 528 clumps/ha. Rooting experiments showed no significant difference in ability of the deteriorating and healthy clones to regenerate.

Schier suggested auxin transported from above ground plant parts to the roots inhibits sucker generation. When this auxin supply is inhibited, a hormonal imbalance occurs that enables other hormones such as cytokinins to initiate regenerative processes. When above ground stems weaken and die, the root system dies back due to a lack of photosynthate being furnished to the roots. Residual stems maintain auxin levels in the smaller root system and sucker inhibition continues. Reduced vigor of the clone makes it susceptible to disease and insect attack and unless some roots and above ground stems survive to produce carbohydrates, the clone will die out. Disturbances such as damage to roots by browsing animals, insect and disease and environmental changes can cause shifts in hormones and trigger sucker generation. Schier suggests that differences in genotype susceptibility to disturbances or environmental change may explain why deteriorating and healthy clones occur side by side. He points out that abundant sucker production following major disturbance such as logging or fire that kills most stems within a short time demonstrates that regeneration is usually no problem because the rapid death of stems eliminates apical dominance while the original root system is still capable of producing suckers. He provides examples sucker regeneration under diseased mature trees as a result of leaf blight (Marssonina populi) or insect attacks.

Scheir notes that management to stimulate suckering in deteriorating clones by killing stems using methods such as clearcutting, herbicide spraying or burning. He also notes that important regeneration problems are caused by livestock, wildlife and competing vegetation. Heavy browsing can totally suppress regeneration and speed up succession to conifer or shrub types.

Schier, George A. 1976. Physiological and Environmental Factors Controlling Vegetative Regeneration of Aspen. In: Utilization and marketing as tools for aspen management in the Rocky Mountains. Proceedings of the Symposium p. 20-23. Also USDA Forest Service General Technical Report RM-29, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado.

This paper reviews the factors important to aspen regeneration. It recognizes the importance of aspen and the importance of root suckering as a regeneration mechanism. It notes that under existing environmental conditions in the Rocky Mountains, aspen rarely reproduces from seed. Several papers are cited that provide evidence that the transport of auxin from aboveground parts to roots suppresses the generation of suckers which arise from meristems on the root system. This is known as apical dominance. As long as the transport of auxin to maintained, suppression continues. Interference with the auxin supply by cutting, burning, girdling or defoliation decreases the auxin concentration in roots, initiating suckers. This effect appears proportional to the aboveground disturbance. Examples of logging in which clearcuts generate the highest numbers of suckers and the number of suckers generated is proportional to the number of stems removed.

"Sucker formation does not require anything as drastic as logging or fire. This is evident from the occurrence of thousands of shoot primordial and numerous suckers in various stages of development on the roots of relatively undisturbed aspen clones … . Elongating suckers also produce auxins which can inhibit initiation of additional suckers. Carbohydrate reserves provide the energy for growth of suckers following the hormonal imbalance that initiates suckering. The density of regeneration is related to the levels of reserves. More energy is required to reach the soil surface from deeper roots, therefore more reserves would be needed for deeper rooted clones as opposed to shallow rooted clones. Repeated destruction of new suckers by burning, cutting, spraying or heavy grazing can exhaust carbohydrate reserves and cause a drastic reduction in sucker production … . Defoliation by insects can deplete root reserves and reduce the amount of regeneration when aspen are cut."

Schier, George A. and Robert B. Campbell. 1978. Aspen Sucker Regeneration Following Burning and Clearcutting on Two Sites in the Rocky Mountains.

Data was collected from four clones each in a controlled burn area on Breakneck Ricge in the Gros Ventre Wyoming and four clearcut areas in the Chicken Creek Watershed of the Davis County Experimental Watershed in Utah. One year following clearcutting, sucker densities ranged from 22,000 to 77,000 stems per hectare. In the controlled burn areas, sucker density ranged between 14,000 to 45,000 stems per hectare. Observations of parent roots and suckers were made to determine differences in root and sucker characteristics as well as browsing impacts. Depth of parent roots producing suckers ranged from 0 to 28 cm. Differences in root depth were observed in both areas that were significant at the 1% level. These differences were suspected to be either genetic or due to site factors including soil characteristis or temperature. Significantly more suckers arose from deep roots on areas where burn intensity was high as opposed to those where it was low, probably due to shallow roots being killed. Although it was postulated that reduction of litter or darkening of the soil surface could have inhibited growth due to higher temperatures as well.

The ability of suckers to establish independent root systems was observed by adventitious roots forming on the shoots and new lateral roots on the parent roots near the suckers. At both sites, there were significant clonal differences in the ability to produce new roots. However, the formation of lateral roots on parent roots near suckers was only significant at the Chicken Creek sites. At the Gros Ventre sites, formation of adventitious roots occurred on between 44% and 74% of suckers with a mean of 65.5%. New lateral roots formed on 37.5% of the sucker locations. At the Chicken Creek sites, adventitious roots formed on between 14 dn 78% of suckers with a mean of 50.5 locations forming new lateral roots on parent roots.

"The condition of the clonal root system is of considerable importance in aspen management because suckers not only are initiated on parent roots but are dependent on them for a period of time afterwards. Shallow rooted clones must be given special consideration because the roots are vulnerable to logging damage. The best time to stimulate suckering by cutting and controlled burning is during ages when clones are making rapid growth. Vigorous clones have abundant small roots and these roots have a high sucker producing capacity. Once regeneration is established, thinning and other treatments that stimulate sucker growth can be used to encourage the development of independent root systems."

Schier, George A. and Robert B. Campbell. 1980. Variation Among Healthy and Deteriorating Aspen Clones. USDA Forest Service Research Paper INT-264.

The authors note that site quality is probably a major factor contributing to the timing and rate of decline of an aspen genotype. Ramets of a clone will probably start deteriorating on a poor site earlier than on a good one. Research from the Lake States was cited which has documented that environmental variables have a significant effect on aspen longevity. The research presented was to determine if there are inherent differences between healthy and deteriorating clones in morphology and capacity for vegetative propagation and if site quality is a factor contributing to deterioration of aspen clones. To test these questions, ten healthy and ten deteriorating clones were examined in the Logan Canyon area of the Wasatch National Forest. Clones were described according to stand characteristics. Environmental variables including physiographic features (slope, aspect, etc.) and soils were analyzed. Root segments were collected for sucker generation ability under controlled greenhouse conditions and suckers were also collected to evaluate the formation of adventitious roots. Sucker cuttings generated from collected roots were grown in controlled conditions in a greenhouse until two years old, then transplanted into a common garden where growth characteristics were observed over a ten year period.

The stand characteristics varied between healthy and deteriorating clones. Healthy clones were younger at an average of 66 years, while deteriorating clones were older at 98.3 years. This reflects the presence of younger age classes in the healthy clones. DBH and total height in healthy clones were 12.98 cm and 14.83 meters, respectively. Deteriorating clones had DBH of 7.1 cm and 8.87 m. Numbers of living stems per ha were 2,735 in healthy clones and 1244 in deteriorating clones. Dead stems per ha were 388 and 535 in healthy and deteriorating clones, respectively, while basal area was 39.04 m^2/ha and 5.04 m^2/ha. High variation between the number of suckers in healthy clones made the difference in numbers of suckers between healthy and deteriorating clones non-significant (healthy clones varied between 1000/ha to 21000/ha, as number of clumps – not stems).

Root suckering tests showed no significant difference between the ability of healthy and deteriorating clones to produce suckers or in sucker growth. ANOVA did show that clone and date were factors affecting ability to sucker or grow. Survival tests of rooted sucker cuttings showed that over 90% survived after two years with no significant difference between healthy and deteriorating clones. Environmental variables that differed between healthy and deteriorating clones were the mean phosphorous concentration and percent silt in the upper soil layer was greater for healthy clones. Since percent silt is an indicator of water-holding capacity of the soil, this indicates that soil water conditions are better in healthy clones.

The authors conclude that to determine whether a clone is deteriorating, evidence of high mortality should be present. Poor stocking is not sufficient evidence because some sites may support relatively few stems and low root density. Poor stocking may also be genotypic. "In other words, inherent characterisitics of a clone, such as the ability to regenerate itself, the pattern of root development, and the ability of suckers to develop independent root systems, could all affect the population structure of clones."

USDA. 2001. Draft Environmental Impact Statement Wasatch-Cache National Forest. United States Department of Agriculture. Forest Service. Intermountain Region. Wasatch-Cache National Forest, Salt Lake City, Utah.

Draft EIS supporting the proposed revision to the Wastatch-Cache National Forest Plan.

Wambolt, C.L., K.S. Walhof and M.R. Frisina. 2001. Recovery of Big Sagebrush Communities After Burning in South-western Montana. Journal of Environmental Management. 61:243-252.

Because big sagebrush communities are burned with the goal of increasing productivity of understory plants or big sagebrush, this study tested whether those goals were reached on 13 paired burned and unburned sites in southwestern Montana. Big sagebrush communities were estimated to occupy approximately 60 million acres in the west in 1960. Significant reductions in these populations have occurred by burning, herbicides and other methods of removal since then due primarily to its low preference for forage by cattle. This reduction has been negative for many native wildlife species, including the sage grouse. Burning and other treatments have eliminated millions of hectares of this habitat, without the expected increases in herbaceous production. "Where herbaceous production has increased following sagebrush reduction, the cause of the increase is often difficult to determine. In general, changes in grazing management or other improvements accompany the sagebrush treatments."

The authors cite the paradox that land managers often state objectives of increasing productivity of big sagebrush through prescribed fire when the same practice was used in the past to eliminate sagebrush, while claiming all the values of a mature sagebrush community as their rationale. Numerous cited studies found that big sagebrush recovery took long periods, sometimes as long as 30 years. Heavy browsing was seen to extend this period by suppressing recovery. Sites that were burned up to 32 seasons prior to the study were surveyed for canopy cover, plant density, production of winter forage using a strenuous statistical design.

Overall comparisons showed sagebrush canopy was significantly less on burned sites than unburned controls. Some burns nearly eliminated sagebrush, resulting in levels of 1% to 13% of controls after 9 and 16 years, respectively. On one site big sagebrush was eliminated while its paired control site almost doubled in 15 years. One site did not differ significantly in canopy cover, although the control contained greater cover after 32 growing seasons. Green rabbitbrush was benefited by burning, experiencing increases in cover. Bitterbrush canopy cover decreased on burn areas compared to controls. Heavy browsing affected both controls and treatments and the authors suggest that the loss of bitterbrush in the burns caused heavier browsing of the untreated areas.

Sagebrush density was significantly reduced by burning at all sites compared to controls. Seven of ten sites had more juvenile sagebrush than the burned areas, while the reverse was true for one burned site that occurred on a slope. Significantly more winter forage was produced by big sagebrush in the unburned sites than in the burned sites. This was true even at the oldest site after 32 seasons. Site and temporal variables had no significant correlation to canopy cover or density.

Total perennial grass cover across all sites was not different between burned and unburned areas. Even after 32 years, there was no significant difference. Perennial forb canopy cover response was similar. This research was stated to confirm earlier studies that non-sprouting shrubs like big sagebrush can take longer than 30 years to re-establish to pre-burn condition. No clear short or long term benefit to grasses or forbs could be discerned, while the shrubs used by wildlife are suppressed by burning. The authors conclude that the opportunity to increase livestock forage through prescribed burning of sagebrush communities under similar environmental conditions are minimal.

"Land managers should include all the effects of burning in their decision-making. Burning has often been prescribed for big sagebrush communities without concern for long-term monitoring for potential environmental impacts."

Wadleigh, Linda and Michael J. Jenkins. 1996. Fire Frequency and the Vegetative Mosaic of a Spruce-Fir Forest in Northern Utah. Great Basin Naturalist 56(1):28-37.

This paper analyzes causes and effects of forest health problems in the T.W. Daniel Experimental Forest managed by Utah State University. The authors state up front that, "Absence of natural fire in wildland ecosystems, due to removal of fine fuels by livestock, reduction in Native American ignitions, and a suppression policy instituted in the early 1900's has led to extensive alterations in natural vegetative succession patterns."

Photo evidence from as early as the 1870's showed that early stages of forest succession were more common than they are today. The evidence is that the absence of fire has contributed to a marked alteration of natural vegetation mosaics by favoring woody species such as shrubs and trees over grasses. Fire return intervals of 50 to 130 years were estimated for spruce-fir habitats with subalpine fir forests in Colorado with an interval of around 200 years. In lower elevation aspen and lodgepole pine forests, fire return frequency was higher.

Wadleigh and Jenkins studied the fire history in the T.W. Daniels Forest to determine if the existing vegetative mosaic is correlated with the fire history of the study area. They studied fire occurrence during presettlement (1700 – 1855), settlement (1856 – 1909) and suppression (1910 to present) eras. Overstory ages were 63 to 284 years in lodgepole pine, 106 years in aspen, 188 years in subalpine fir and 193 years in Engelmann spruce.

Across the entire study area, a fire occurred on average about every 18 years. The fire interval was shortest in lodgepole pine and longest in aspen. Results are tabulated below.

Mean Fire Return Interval

Forest Type	Presettlement 1700 – 1855	Settlement 1856 – 1909	Suppression 1910 to Present	Total 289 Years
Overall Study Area	39 (1 – 122)[1]	4.9 (1 - 30)	79[2]	18.1
Spruce – Fir	--	9 (1 – 30)	79[2]	41.3
Lodgepole Pine	39 (12 – 122)	6 (1 – 17)	--	22.2
Aspen	156[3]	13.5 (4 – 16)	--	57.8

1. Numbers in parentheses are length of intervals from which the mean is calculated. Dashes indicate no evidence of fire during period. 2. No fires occurred. 3. No evidence of fire during pre-settlement, but since oldest aspen was 106, it is assumed longer than 106 years.

It is noted that stands dominated by subalpine fir are a later successional stage and that where stands have sustained recent extensive fires, subalpine fir dominance is less. Subalpine fir is, however, a component of regeneration following those fires. Fire frequencies have declined during the suppression era which has favored the establishment of Englemann spruce and subalpine fir. Once subalpine fir ovetops other species, it is not easily replaced, requiring fire, insects, disease or logging.

The size and number of fires was related to the heaviest use period. In 1880, the census indicated that between 1% and 10% of the timbered area of Cache County burned. Heavy grazing reduced fine fuel loads, but use by loggers and sheepherders increased the sources of ignition. A report by an early forester in 1906 stated that ¾ of the area that would later become the Wasatch-Cache NF burned over in the last 20 years. “probably due to careless sheepherders”. During the suppression period, fire frequency decreased due to Forest Service efforts and a large reduction in grazing which lessened ignition hazards (from herders).

Fire hazard in lodgepole pine is highest following a fire when standing dead snags and remaining ground fuels from the previous fire and when crowns of tolerant understory species reach into the crowns of mature lodgepole, creating a ladder effect. During the period between 1877 and 1903, several non-lethal fires occurred in lodgepole pine stands due to available fuel.

The lack of fire in the T.W. Daniel Forest during the last 80 years has allowed succession to proceed toward a subalpine fir climax. Earlier periods with more frequent fires favored lodgepole pine. “The continued lack of disturbance will allow the more tolerant species of subalpine fire and Engelmann spruce to overtop the intolerant lodgepole pine and aspen. Eventually the area will lose its diverse appearance and will be similar to that in areas where fire disturbance is less frequent.”