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Fuels Inventory and Appraisal in Intermountain Quaking Aspen (*Populus tremuloides*) Communities

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FUELS INVENTORY AND APPRAISAL IN INTERMOUNTAIN QUAKING ASPEN (*POPULUS TREMULOIDES*) COMMUNITIES

by

Janet A. Beales

A thesis submitted in partial fulfillment
of the requirements for the degree

of

MASTER OF SCIENCE

in

Forest Ecology

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ABSTRACT

Fuels Inventory and Appraisal in Intermountain Quaking Aspen (*Populus tremuloides*) Communities

by

Janet A. Beales, Master of Science

Utah State University, 1998

Major Professor: Dr. Michael J. Jenkins
Department: Forest Resources

Field research was conducted in quaking aspen, *Populus tremuloides* Michx., communities. Fifty-one plots were established in seven major locations in the Bear River Range of northern Utah. The locations inventoried were divided into two age classes: young aspen (under 70 yr) and old aspen (over 70 yr). Custom fuel models were developed for each age class and the data were analyzed for relationships between fuel loads and other measurable factors, including: basal area, average diameter at breast height (d.b.h.), fuel depth, litter loads, tree regeneration, shrub loads, herbaceous loads, slope, tree height, aspect, percent aspen in the plot, grazing intensity, trees infected with disease, elevation, and stand age.

The computer program BEHAVE, fuels inventory data, and the two customized fuel models were used to predict fire behavior, including: flame length, fireline intensity, rate of spread, and heat per unit area.

Young aspen stands and old aspen stands differed significantly for most of the variables studied. The customized fuel models for the young aspen and old aspen also differed, and these fuel models predicted different fire behavior in the two aspen age classes.

When fuel loads were compared to the other stand characteristics inventoried for the 51 plots, fuel loads were most strongly correlated with average d.b.h. (P=.005). Fuel loads were also negatively correlated to grazing intensity (P=.024) for the 51 plots. No significant correlations were found between fuel loads and the other variables when analyzed for the seven locations. In general, stand conditions were not good indicators of fuel loads in aspen communities.

Most important to this study were the differences in the fuel data. When used to develop custom fuel models, the young and old aspen fuel models represented two distinct stand types and predicted different fire behavior. Neither stand type was well represented by Northern Forest Fire Laboratory (NFFL) model 8. The customized fuel models better represent aspen communities in the Bear River Range and should be used by managers for fire behavior predictions.

(61 pages)

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Fire plays an important role in the establishment and regeneration of quaking aspen, *Populus tremuloides* Michx., communities. Without periodic, stand-replacing disturbance, aspen communities are replaced with conifers, shrubs, and grasses (Jones and DeByle, 1985b). In the Bear River Range of northern Utah, the natural frequency of fire in aspen stands is 70-200 yr (Gullion, 1984). In recent history, fire occurs much less frequently in quaking aspen. Several variables have contributed to this reduced fire frequency. The removal of Native Americans stopped indigenous burning of quaking aspen stands (DeByle et al., 1987). Fires are also less frequent in aspen communities because of intense grazing by livestock that reduces fuel loadings (DeByle et al., 1987). In the past century, rigorous United States fire suppression policies have increased fire frequency intervals in aspen communities (Gullion, 1984).

Fire management policies were first established in 1905, with the creation of the Forest Service. The Forest Service created a system of fire management that emphasized fire suppression (Pyne et al., 1996). Fire suppression policies were enforced in the United States until the 1960's. In 1963, the Leopold Committee in the United States Congress stated that fire was a critical process necessary to maintain the health of certain forest ecosystems (PNFMTC, 1992). The United States then began to use fire as a tool to restore ecosystems. In 1978, the National Environmental Protection Act was instated. This act initiated extensive monitoring programs of human-induced landscape changes, including prescribed fires (PNFMTC, 1992).

When the Yellowstone fires occurred in 1988, the role of fire in ecosystems was questioned and the use of fire as a management tool decreased. After the Yellowstone fires were proven successful in regenerating forest communities, prescribed fire once again became a valuable forest management strategy. Prescribed fire is a useful method to regenerate quaking aspen communities.

Quaking aspen, a member of the willow family (Salicaceae), is the most geographically widespread tree in North America (Jellinski and Cheliak, 1992) This tree can be found from Mexico to northern Alaska (Mitton and Grant, 1996). Aspen is a clonal species, and regenerates vegetatively from the roots of a common ancestor (Graham et al., 1963).

Aspen is dioeceous, having male and female clones. These clones do not differ in vegetative growth (Sakai and Burris, 1985). The male-to-female sex ratio is approximately 1:1 for quaking aspen (Grant and Mitton, 1979). These trees do produce seeds, but seedling establishment is extremely rare (Romme et al., 1995). The 1988 Yellowstone fire was the first time in over 300 yr aspen has been documented as successfully colonizing by seed (Mitton and Grant, 1996).

In the Intermountain West, two thirds of the aspen stands are over 96 yr old and 90% of the aspen stands are at least 75 yr old. Rapid deterioration of aspen trees occurs after 120 yr and few aspen trees can live past 200 yr (Olmsted, 1979).

Although aspen trees produce some new sprouts from their roots throughout their life cycle, aspen sprouts require high levels of light to grow and are not usually successful in their own shade or in shade from other species. Toxins produced by other species also reduce regeneration. The presence of an overstory inhibits aspen sprouting (Graham et al., 1963).

As an aspen stand ages, its capacity to produce root sprouts decreases because auxin production in the shoot tips inhibits sprouting. When auxin production is reduced, cytokinins produced in aspen roots encourage suckering (Mueggler, 1985). Through overstory removal by a disturbance such as fire, auxin production is reduced and root sprouting is stimulated. The amount of light entering the forest is also increased through overstory removal, aiding aspen stand regeneration (Gullion, 1984). Prescribed fire is a means by which aspen stands can be induced to regenerate vegetatively because fire removes the inhibiting overstory.

Aspen communities currently found in most of the West are rapidly deteriorating and declining in numbers and size because of encroachment by other species, particularly conifers (Mueggler, 1985). Increasing amounts of disease in the aspen are also contributing to deteriorating aspen stands, due to the lack of disturbance. The incidence of disease in aspen stands increases with stand age (Etheridge, 1960). In older aspen trees, the major decay-causing organism is thought to be *Phellinus tremulae* Bond., a fungus that causes trunk rot (Hinds, 1985). The aspen leaf rust, *Melampsora medusae* Thuem, is very common in the Rocky Mountains but does not usually cause any serious damage to the tree (Walters, 1984). Aspen trees are also susceptible to other forms of rots, cankers, and leaf diseases that increase in frequency with age (Etheridge, 1960).

Older aspen stands differ from younger stands in other ways. A large amount of downed woody material occurs in older stands (Gullion, 1984). As canopy cover increases, the productivity and palatability of the understory vegetation decreases (Bradley et al., 1992). For wildlife managers, it is ideal to replace aspen stands every 60-90 yr for the game species elk, mule deer, and ruffed grouse. After this age a decrease in forage quality occurs (Jones and DeByle, 1985a).

Understory productivity is greatest in forests before crown closure. Once crown closure occurs, there is a decline in productivity. Certain species of wildlife, specifically the game species of ruffed grouse, mule deer, and elk, are negatively impacted in older aspen stands by decreased access and reduced food quality and availability (Gullion, 1984).

The amounts of litter and woody material on the forest floor increase with stand age. As a stand ages and mean stem size increases, the ability of a stand to produce large amounts of course woody debris increases (Sturtevant et al., 1997).

After crown closure, decomposition rates decrease with stand age (Turner and Long, 1975). Decomposition rates are also related to litter type. Hardwood litter decomposes more quickly than conifer litter. The more conifer litter present in areas with hardwoods, the lower the decomposition rates (Elliot et al., 1992). The amount of quaking aspen has been shown to decrease with stand age and the amount of conifer to increase, resulting in a decrease in decomposition rates in older aspen communities (Pare and Bergeron, 1995).

Fuel loads increase with stand age. This increase in fuel loads is associated with a decrease in nutrients because of lower decomposition rates and lower forest productivity. Dead woody debris also has lower nutrient concentration than fine litter or live plants (Kauffman et al., 1994).

Prescribed burns have been shown to increase forage availability and palatability for many wildlife species including elk, ruffed grouse, and mule deer by decreasing the canopy cover and removing excess litter, resulting in increased forest productivity, and encouraging the growth of more palatable species (Johnston and Hendzel, 1985). Ruffed grouse have been shown to prefer aspen stands 7-30 yr old (Wiggers et al., 1992). Elk and mule deer prefer young aspen stands and rely heavily on aspen stands for forage (DeByle, 1985). Prescribed fire improves diet quality by increasing the protein content and digestibility of forage and increasing the number of aspen sprouts.

Fire creates conditions that allow more light to reach the forest floor, which enhances forage growth (Hobbs and Spotwart, 1984). Aspen sprouts resulting from prescribed burns provide preferred forage for grouse and ungulate species (Carlson et al., 1993). Prescribed fires also remove excess downed woody materials that inhibit wildlife movement (Buttery and Gillam, 1984). Disease and decay within the aspen communities are additionally reduced by fires (Etheridge, 1960).

After fires, aspen suckering increases. According to Bartos et al. (1991), spring fires result in higher suckering rates than fall fires. Prior to burning, aspen suckering ranged between 3,500 and 15,000/ha in their study areas. After spring prescribed fire, average suckering was 104,200/ha while fall suckering averaged 41,200/ha (Bartos et al., 1991). Aspen suckering peaks 2 yr after a fire and gradually declines in the years following (Bartos et al., 1991).

Prescribed fire is an effective technique that can be used to accomplish this goal. The numbers of aspen suckers produced from fire are generally higher than aspen suckering resulting from clearcutting because fire reduces competition from other species (Bartos et al., 1991).

The main problem managers encounter in using prescribed fire in aspen communities is that aspen stands do not always readily burn because of their typically low fuel loads and high fuel moisture contents. However, even a light surface fire is sufficient to kill aspen trees. They are extremely sensitive to fire due to their thin bark (Bradley et al., 1992). Low-intensity fires that normally occur in aspen communities retain most of the nutrients in the stand. Less intense fires consume less biomass and cause lower amounts of nutrient to be lost than higher intensity fires (Kauffman et al., 1994). All burn intensities are successful in regenerating quaking aspen. Moderate burns (20%-80% of aspen killed) are slightly more successful than light burns (0%-20% of aspen killed) and heavy burns (80%-100%). Moderate burns result in more aspen suckering and higher shrub and grass production (Bartos and Mueggler, 1981).

Ungulate browsing is another concern that may diminish the effectiveness of prescribed fire. Populations of elk and mule deer have grown greatly in the past century, resulting in increased browsing intensity on aspen suckers. This intense browsing can reduce the success of prescribed fires in regenerating aspen by decreasing the numbers of aspen suckers (Kay, 1995).

Many aspen stands are impacted by livestock grazing. Livestock usually consume 50% or more of palatable forage in aspen communities (DeByle, 1985). Livestock grazing causes a shift in species composition in aspen communities by decreasing palatable species, particularly forbs. Species low in palatability are favored and grasses increase (DeByle, 1985). Grazing results in a decrease in fuel loads by decreasing fine fuels (DeByle et al., 1987).

Naturally occurring fires in aspen stands occur most commonly in the fall and somewhat less frequently in the spring. Fall fires can be expected to burn more successfully than spring fires in quaking aspen communities because of more suitable, drier fire weather, lower fuel moisture contents, and higher amounts of fine fuels (Jones and DeByle, 1985a). Flammability increases with increases in woody fuel loading in aspen communities (Bradley et al., 1992). Even though older stands have higher fuel loads and higher levels of flammability, they should burn less intensely, have lower rates of spread, and have shorter flame lengths than younger aspen communities because fire spreads at slower rates through larger, more densely packed fuels (Anderson, 1982).

Fire Dynamics

Fire may develop when fuels, heat, and oxygen are present. Fire has four phases: preignition, ignition, combustion, and extinction. Fire begins with preignition. During this phase, heat removes fuel moisture and the fuels are warmed to ignition temperature. Once the fuels are ignited, the heat generated by combustion can ignite adjacent fuels. Fire extinction will occur when any of the three fire requirements (fuel, oxygen, or heat) becomes limiting (Whelan, 1995).

As a fire burns, its behavior on the landscape is governed by three major factors: topography, weather, and fuels (Martin, 1979). These three components determine the rate of spread, fire intensity, and flame length, factors important in defining the success of prescribed fires (Pyne et al., 1996).

Topography includes the slope, aspect, and elevation of the landscape. Slope steepness affects both the rate of spread and the flame length of uphill fires because steeper slopes bring flames closer to adjacent fuels, and these fuels are brought to an ignition temperature quickly (Pyne et al., 1996). Aspect is associated with variations in the amounts of solar radiation and wind received by an area. Fire weather conditions conducive to more rapid combustion occur on the aspects with higher levels of solar radiation and lower humidities. In the northern hemisphere, these aspects are typically south and southwest aspects (Pyne et al., 1996). Elevation is an important component of fire behavior. The length of the fire season decreases with increasing elevation. Higher elevations typically have later snow melts, shorter growing seasons, and later curing dates (Pyne et al., 1996).

Weather also influences fire behavior. Fuel moisture is affected by temperature, relative humidity, and precipitation. Drier fuels are more easily ignited (Kozlowski and Ahlgren, 1974). Wind influences fire behavior by governing the direction and rate of spread of a fire. Wind can also cause erratic fire behavior (NWCG, 1981).

The fuels component is the most variable factor in these aspen stands because fuels vary with stand characteristics such as stand age and species composition. Fuels can vary greatly between stands. The characteristics and success of a prescribed fire are dependent on the amounts, types, and positioning of the fuels present in the stand (NWCG, 1981). Limited research has been conducted on the correlation between fuel loads and stand conditions in forest communities.

Fuels are a major component used to develop models to predict fire behavior. In developing fire models, fuels, fuel moisture, wind, and slope are considered as well as other variables such as temperature, humidity, shading, and sheltering (Burgan and Rothermel, 1984).

Fire behavior can be modeled through the use of the computer program, BEHAVE. BEHAVE has 13 standard fuel models developed at the Northern Forest Fire Laboratory (NFFL). Each one is representative of fuel loads in a different fuel type (Anderson, 1982).

BEHAVE is based on a mathematical fire spread model developed by Rothermel (1972). Fire spreads at the rate of the ratio of the heat received by fuel ahead of the fire to the heat required to ignite the fuel (Rothermel, 1972). This model incorporates wind, slope, fuels, and fire characteristics to predict fire behavior. As indicated by the fire spread model, fuel loads are needed to compute fire behavior. Fuel models therefore must be developed or chosen for an area before fire behavior can be predicted.

A wide range of fuel types exists in the United States. The 13 predesigned NFFL models attempt to describe a wide variety of fuel conditions. The NFFL models are divided into four groups based on the general vegetation type: grass, brush, timber litter, and slash (Anderson, 1982). The fuel models within these groups are further delineated by the general depth and compactness of the fuel, as well as the fuel size classes present (Anderson, 1982).

Several classes of fuel are used to develop models. Litter and duff amounts are important factors. Litter includes freshly fallen leaves, needles, bark, and other vegetative material. Duff is the layer below the litter where decomposition and fermentation of the vegetative material occur (Brown et al., 1985). Several size classes of downed woody materials (dead twigs, branches, stems, and fallen shrub and tree boles) are entered into fuel models. These downed woody material size classes are 1 hr time lag fuels (0-.635 cm in diameter), 10 hr time lag fuels (.635-2.54 cm in diameter), 100 hr time lag fuels (2.54-7.62 cm in diameter), and 1000 hr time lag fuels (greater than 7.62 cm in diameter). Information on shrub species types and densities is also collected (Rothermel, 1983).

All aspen stands are most closely represented by NFFL fuel model 8, closed timber litter. The fuels description is a closed, healthy forest stand of short-needled conifers or hardwoods with a compact litter layer of needles, leaves, and twigs that support fire. Little undergrowth is present in this model. Fire behavior in these stands is described as slow burning with short fire flame lengths (NWCG, 1981).

BEHAVE also can be used to create specialized fuel models for specific stand conditions. These site-specific models allow the user to adjust individual components such as litter and duff depths, 1 hr, 10 hr, and 100 hr fuel loads to better represent individual forest communities (Burgan and Rothermel, 1984).

BEHAVE has two programs that can be used to design site-specific (custom) fuel models. The first is NEWMDL, which builds a fuel model based solely on the data from a specific area. The second program is TSTMDL, which allows changes to be made to a previously built model or 1 of the 13 standard NFFL fuel models (Burgan and Rothermel, 1984). TSTMDL is useful if the data set for a specific area is not complete or if certain components such as surface-to-volume ratios are not available for an area. Accurate fuel models can still be designed.

Fire behavior predictions can be made using the program BEHAVE FIRE1 by inputting a specific fuel model as well as environmental factors such as fuel moisture contents, slope, and windspeed. These predictions help determine the role of fuels in fire behavior (Romme et al., 1995). The relative importance of weather and fuel in fire behavior was studied by Bessie and Johnson (1995). They found weather to account for 83% of the variability in fire intensity and fuels to account for 15% (Bessie and Johnson, 1995).

While weather plays a major role, fuel loads are an important component that helps govern fire behavior. Fuel loads determine the amount of energy available to a fire, and the horizontal and vertical spread of the fire (Whelan, 1995). A strong correlation has been shown between the fuel load and fire intensity (Stinson and Wright, 1969).

Research conducted in quaking aspen communities related to fuel loads and stand conditions appears limited. No studies have been conducted that look at a broad range of aspen stand conditions and their relationships to fuel loads. Research into fuel loadings in aspen communities and how variations in fuel loads may effect fire behavior is minimal. No papers have been published using customized aspen fuel models.

Several relationships between fuel loads and stand conditions should exist. Older stands should have heavier fuel loads than younger stands because as stands age, decomposition rates decrease and fuel loads increase (Turner and Long, 1975). Aspen disease should be positively correlated with fuel loads since these stands typically have higher mortality and lose more leaves. The higher the percentage of conifers in the stand, the larger the fuel loads should be because conifers add greatly to the fine fuels with cones and needles (Elliot et al., 1992). The larger the proportion of the understory composed of shrubs, the higher the fuel loads should be since shrubs have a large woody component and are present year round. Areas heavily grazed should have reductions in fuel loads since many of the fine fuels have been removed (Kay, 1997).

Topographic differences among the areas should influence fuel loads. Fuel loads should be heaviest on north-facing slopes and lightest on south-facing slopes since southern slopes receive greater amounts of solar radiation and have higher decomposition rates (NWCG, 1981). Fuel loads have been shown to decrease with increasing elevation in conifer forest types (Brown and Lee, 1981). Fuel loads should decrease with elevation since biomass decreases with increasing elevation.

Fuel loads should be heavier in older aspen stands. The custom fuel models for young and old aspen communities should therefore have different fuel loads and compute different fire predictions when used in BEHAVE FIRE1. The areas with heavier fuel loads, particularly 100 hr fuels, should burn with lower fireline intensity, shorter flame lengths, and lower reaction intensity because fire spread rates are slower through larger, more compact fuels (Burgan, 1987).

This study will help managers to better predict how aspen communities will respond to fire by providing correlations between stand conditions and fuels and also by identifying the stand characteristics most closely related to fuel loads. The custom fuel models designed for the two different aspen age classes should help managers predict the fire behavior in quaking aspen and will help to indicate when prescribed fire would be most successful for regenerating aspen communities. While some variation in the success of the prescribed fires in the aspen stands will most likely occur depending on the weather and the stand conditions initially present, prescribed fire should be an effective method to renew aspen communities and improve wildlife habitat quality in the Bear River Range.

ASSESSING FUEL COMPONENTS IN INTERMOUNTAIN QUAKING ASPEN (*POPULUS TREMULOIDES*) COMMUNITIES

Introduction

Fire suppression practices in the United States over the past 100 yr have resulted in changes in fire dependent ecosystems (Bartos and Mueggler, 1979). Fire frequencies in quaking aspen (*Populus tremuloides* Michx) communities have decreased compared to historic fire frequencies (Pyne et al., 1996). Livestock grazing has contributed to lengthened fire intervals by reducing fuel loads (Jones and DeByle, 1985a). Regeneration and forest health have declined and resulted in the replacement of aspen by conifers, shrubs, or grasses (Mueggler, 1985). Aspen stands are important in providing wildlife habitat for many species, including the game species of elk, mule deer, and ruffed grouse. Under a policy of fire suppression, many aspen communities are in late successional stages and are of reduced habitat quality for many wildlife species (Jones and DeByle, 1985a). Prescribed fire is one possible alternative to create younger, healthier aspen communities and improved wildlife habitat.

For prescribed fires to be used as a management tool, evaluation of existing stand conditions is necessary (Pyne et al., 1996). Fire behavior is governed by fuels, topography, and weather (Martin, 1979). Fuels are an important component of fire behavior and fuels data can be used in fuel models to predict fire behavior.

The BEHAVE computer program used to develop fuel models and fire behavior predictions includes a TSTMDL program that can be used to customize a Northern Forest Fire Laboratory (NFFL) fuel model. By using fuels inventory data, a fuel model is developed for a specific area or forest cover type that are used in the BEHAVE FIRE1 program to predict fire behavior (Burgan and Rothermel, 1984).

Thirteen standardized NFFL fuel models have been developed to represent existing fuel types in the United States (Anderson, 1982). Of these standard models, aspen is best characterized by NFFL model 8, closed timber litter. This model is described as a closed forest composed of short-needled conifer and hardwood species with a compact litter layer that supports fires. NFFL model 8 is used in fire predictions for all stands represented by this characterization (Anderson, 1982).

Fuel loads have been shown to increase with stand age in forest communities due to decreased decomposition rates and increased amounts of woody debris in older stands (Kimmins, 1996). Research is necessary to look at relationships between fuel loads and stand characteristics of quaking aspen.

The objectives of this study were to: 1) develop custom fuel models for the aspen communities in the Bear River Range, Utah, 2) use the customized fuel models for fire behavior predictions using potential weather conditions, and 3) correlate fuel loadings with stand conditions in these aspen communities.

The fuels data collected from aspen stands in the Bear River Range were used to develop custom fuel models for two aspen stand types, young aspen (under 70 yr) and old aspen (over 70 yr). The locations were divided at 70 yr because western aspen usually mature between 60 and 80 yr of age (Mueggler, 1989). The two custom models were compared to NFFL model 8 and were utilized to predict fire behavior using the BEHAVE FIRE1 program.

Fuel loads were measured and comparisons made to aspen stand characteristics, including stand age, disease, slope, aspect, grazing intensity, elevation, percent of trees that are aspen, litter depth, number of shrub stems in two circular shrub plots, cm of shrubs intersecting a transect, litter weight, herbaceous weight, regeneration, basal area per hectare, and average diameter at breast height (d.b.h.).

Methods

Seven areas were established in the Bear River Range of northern Utah for data collection during 1996 and 1997. These areas are located on the Logan and Ogden Ranger Districts of the Wasatch-Cache National Forest (Figure 1). Aerial photos and maps were used to designate private, state, and other land boundaries and to select the locations where treatment of aspen communities to improve wildlife habitat and stand quality were desirable. Treatment areas were outlined and numbered, and acreage was calculated using a dot grid and located on maps. Areas were visited and a reference point (RP), typically a large tree, was marked

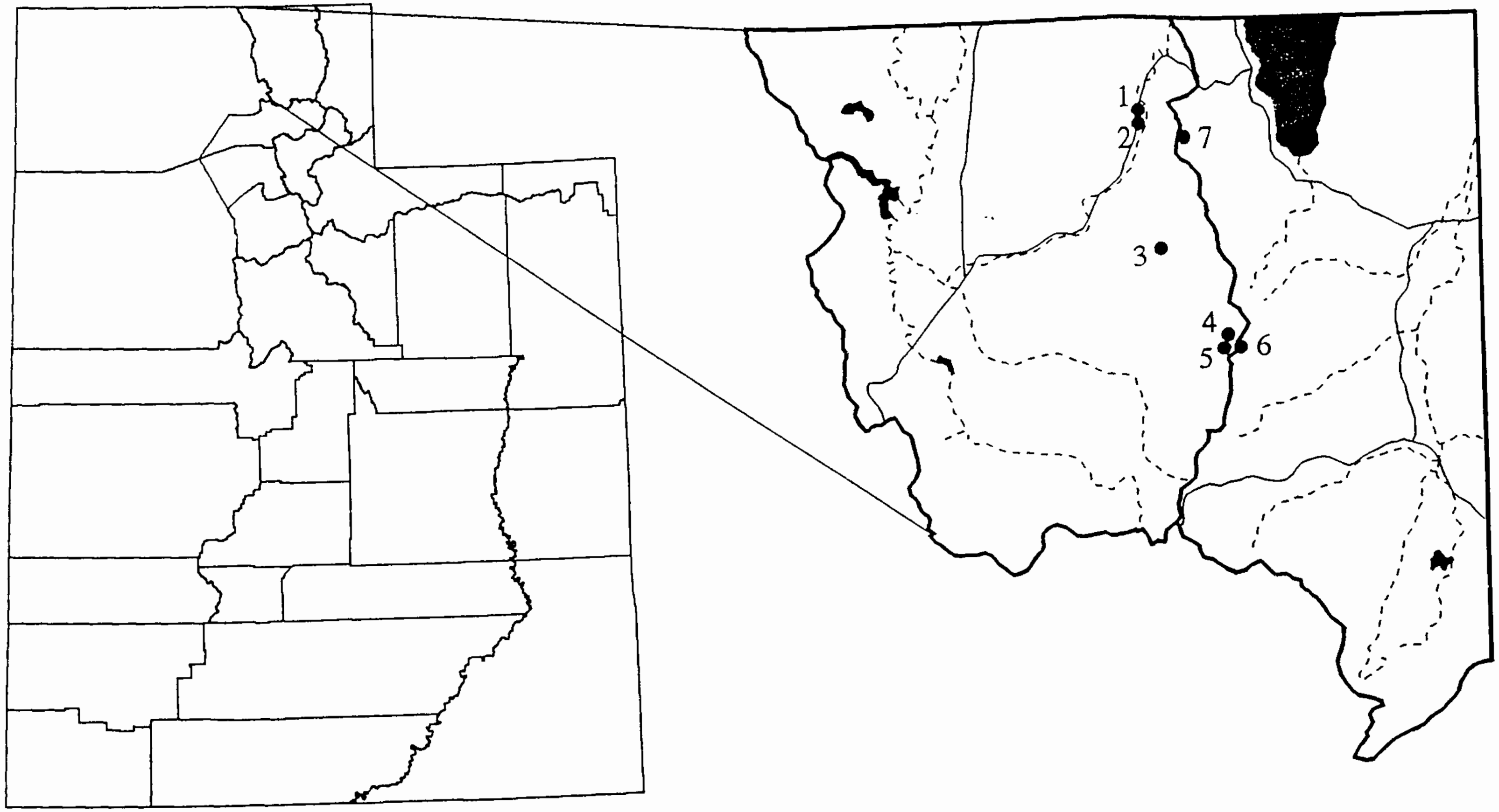

Figure 1. Map of seven study locations in the Bear River Range in northern Utah.

with an aluminum tag and stake. The RP was marked on the aerial photos and pictures were taken from the stake in the cardinal directions.

One plot per 4.05 hectares was established in these areas, resulting in approximately 8-10 plots per location. Each plot was permanently staked with a fence post and pictures were taken at each plot in the cardinal directions. All plots were marked on the aerial photos and the azimuth and distance from the RP to each of these points were recorded. Data collected were used to compare fuel load inventory data to aspen disease, slope, aspect, grazing intensity, elevation, percent of trees that are quaking aspen, litter depth, number of shrub stems in two shrub circle plots, cm of shrubs intersecting a linear transect, litter weight, herbaceous weight, regeneration, basal area per hectare, and average diameter at breast height (d.b.h.).

Habitat typing was done for each area using the "Aspen Community Types of the Intermountain Region" Report INT-250 (Mueggler, 1988). Fuel load classes were determined using INT-205, "Appraising Fuels and Flammability in Western Aspen: A Prescribed Fire Guide" (Brown and Simmerman, 1986). At plot #1 of every 10 plots or at plot #1 in each area, the field location form was completed. At plots #2-10, the point location description form was completed. At all plots, a timber inventory, understory vegetation inventory, fuels inventory, and shrub intercept inventory were completed. Notes were taken at each point about any cultural, wildlife, or other unusual features. Stand age was estimated by coring a few trees at each plot. Herbaceous material and litter were also collected from each point and dried in an oven at 60 C for 48 hr, according to the fuels inventory instructions. Copies of all data collection instruction sheets and data recording sheets are in the Appendix.

Data at 51 plots in the seven area locations were collected during 1996 and 1997 and analyzed using SPSS 7.5 for Windows. Stand age was used to group the aspen areas into two stand types with different fuel load characteristics. The first group included young aspen, stands under 70 yr. The second group was old aspen, stands over 70 yr.

Once the stands were grouped into young and old aspen, comparisons were made between the two age classes for all the variables analyzed from the field data. Independent t-tests were used to look for statistically significant levels of variations for all variables between the two age groups. Equal variance was not assumed.

The fuels inventory data were used to create custom fuel models using "BEHAVE: Fire Behavior Prediction and Fuel Modeling" INT-167 (Burgan and Rothermel, 1984). One hr, 10 hr, and 100 hr fuel loads, grass, shrub, slash loads and litter depths were entered into BEHAVE TSTMDL to create site-specific fuel models, (Anderson, 1982). BEHAVE TSTMDL used the parameters from NFFL model 8, closed timber litter, as the base for the custom models. The 1 hr, 10 hr and 100 hr fuel loads were changed as well as the live woody and live herbaceous entries. The fuels inventory data used to create the custom fuel models were averaged among the plots for each category for each of the two groups, young aspen and old aspen. NFFL model 8, closed timber litter (the standard model for aspen communities), was also used. The environmental parameters entered were constant in both custom models and in NFFL model 8, with the medium standard environmental parameters chosen. Zero slope was used for all models. Standard environmental values were used.

BEHAVE FIRE1 was used to compute fire behavior predictions in the two custom models and NFFL model 8. FIRE1 uses a fuel model, weather conditions, and slope to predict fire behavior. Two sets of initial weather conditions were used to make fire predictions. Each set of initial conditions was entered with each of the three fuel models. Weather conditions were chosen according to Burgan (1987). The FIRE1 fire behavior outputs were compared for the three models. The fire behavior outputs include flame length (m), fireline intensity (btu/m/s), rate of spread (m/hr), heat per unit area (kj/sq.m), reaction intensity (kw/sq.m), and effective windspeed (km/h).

Fuel load data and other data collected at the 51 plots in the seven locations were then analyzed using SPSS 7.5 for Windows. Variables analyzed included: fuel load (m tons /ha), litter depth (cm), basal area per hectare (sq.m/ha), number of aspen and conifer regeneration in a 2.07 m radius circle, number of shrub stems in two .46 m radius circle plots, cm of shrubs intersecting a 15.2 m linear transect, oven dry herbaceous weight (g/.18 sq.m), oven dry litter weight (g/.09 sq.m), slope (%), aspect (degree), average tree height (m), average d.b.h. (cm) of trees, percent of trees that are aspen, percent of diseased trees, grazing intensity (scale of 0-4 with 0=no grazing and 4=extremely heavy grazing), and elevation (m). Spearman's correlation test was used to test for significant correlations between fuel loadings and each of the other variables (alpha=.05) over the 51 plots. The equation used in Spearman's correlation test (Langley, 1970) is:

$$Z= n-1 * 1-D +T/(.5(n -n)$$

where n=number of pairs of measurements

D =the sum of the squares of the differences between the rank values of each pair of observations.

T=correction factor for observations of equal value.

Data were also grouped by location (into the seven areas). The same variables were analyzed and Spearman's correlation test was again used to make correlations between fuel loads and the other variables for the seven locations.

Results

The stands were grouped by age into young aspen stands (under 70 yr) and old aspen stands (over 70 yr) as shown in Table 1. The following variables were analyzed for young and old aspen: fuel load, aspen disease, slope, aspect, grazing intensity, elevation, percent of aspen, estimated stand age, litter depth, number of shrub stems in two circular plots, cm of shrubs intersecting a

Table 1. The average stand age of the seven locations and the custom fuel model incorporating each location.

Stand number	Stand age (yr)	Component of young or old aspen custom fuel model
Location 1	50-65	young
Location 2	70-85	old
Location 3	55-70	young
Location 4	75-90	old
Location 5	80-95	old
Location 6	45-60	young
Location 7	85-100	old

linear transect, litter weight, herbaceous weight, regeneration, basal area per hectare, and average d.b.h. (Table 2). Table 2 showed the levels of variability within each age class.

The results of the independent t-tests showed several variables with significant differences between young and old aspen stands (Table 3). Three variables were highly significant with $\underline{P}<.01$. The percent of aspen in the young stands was significantly higher than the percent of aspen in the old stands ($\underline{P}=.000$). The older stands were at a significantly higher elevation ($\underline{P}=.006$) than the younger stands. Herbaceous weight was significantly different ($\underline{P}=.007$), with young aspen stands having larger amounts of herbaceous materials than old aspen stands.

Table 2. Summary of variables when separated into young aspen and old aspen.

	Young aspen (under 70 yr)			Old aspen (over 70 yr)		
Variable	N	Mean	S.D.	N	Mean	S.D.
Fuel load (m ton/ha)	25	4.86	4.02	26	7.59	7.34
Average d.b.h. (cm)	25	15.90	7.54	26	21.01	8.73
% trees aspen	25	90.55	20.69	26	61.58	31.90
Aspect (degree)	25	160.60	125.76	26	146.48	127.59
Basal area per hectare (sq.m/ha)	25	7.62	4.24	26	11.36	5.56
% trees with disease	25	29.56	29.49	26	40.15	24.69
Elevation (m)	25	2211.63	148.82	26	2343.44	175.06
Grazing intensity (scale range 0-4)	25	1.98	.77	26	1.83	.42
Herbaceous weight (g)	23	20.96	14.82	17	10.53	7.61
Litter depth (cm)	24	1.07	1.00	26	1.63	1.00
Litter weight (g)	22	28.45	12.82	17	100.65	193.77
Number of regeneration	25	2.60	2.97	26	5.73	5.96
Shrub stems in circle	25	26.00	23.11	26	17.77	22.37
Shrub line intercept (cm)	25	364.13	236.63	19	199.72	251.97
Slope(%)	25	20.50	13.42	26	13.68	9.05
Tree height (m)	25	9.65	3.54	26	12.40	4.91

Table 3. Results of independent t-test analyses of young and old aspen stands.

Variable	t value	D.F.	Sig. (2-tailed)
Fuel load (m ton/ha)	-1.66	39.04	.106
Average d.b.h. (cm)	-2.25	48.46	.029*
% trees aspen	3.86	43.08	.000**
Aspect (degree)	.394	47.99	.695
Basal area per hectare	-2.69	46.51	.010**
% trees with disease	-1.39	46.83	.172
Elevation (m)	-2.90	48.29	.006**
Grazing intensity (scale range 0-4)	-1.66	39.04	.106
Herbaceous weight (g)	2.90	34.46	.007**
Litter weight (g)	-1.75	16.11	.145
Litter depth (cm)	-1.93	47.65	.059
Number of regeneration	-2.39	37.04	.022*
Shrub stems in circle	1.29	48.74	.203
Shrub line intercept (cm)	2.20	37.56	.034*
Slope(%)	2.11	42.08	.041*
Tree height (m)	-2.31	45.51	.026*

* Significant at 0.05 level

**Significant at 0.01 level

Several variables were significant at the .05 level of probability. Older stands had a significantly higher basal area per hectare than younger stands (P=.010). Regeneration (including both aspen and conifer) was significantly greater in older stands (P=.022). Average tree height (P=.026) and average d.b.h. (P=.029) were both significantly higher in old stands. Young aspen stands had significantly greater shrub line intercept amounts (P=.034). Young aspen stands were also in areas with significantly steeper slopes (P=.041) than old aspen stands.

Fuel loads were not significantly different for the two age groups at the .05 probability level, but with P=.106, there was strong evidence for differences in fuel loads between the aspen age classes, with young aspen stands having lower fuel loads than older aspen (Table 3).

Table 4 lists the fuel data entered for the young aspen fuel model and old aspen fuel model developed with BEHAVE TSTMDL and the fuel data for standardized NFFL model 8. When the data were averaged for the older stands and younger stands, the older stands had greater fuel loads. The fuels data used in the standard model, NFFL model 8, had higher fuel loads than the young aspen stands but lower fuel loads than old aspen stands.

The old aspen stands had greater 1 hr, 10 hr, and 100 hr fuel loads than young aspen stands. The young aspen model had greater live herbaceous and live woody fuel loads than the old aspen model. NFFL model 8 had no live

Table 4. Standard values for NFFL model 8, and values computed from fuel inventory data for the custom fuel models, young aspen (under 70 yr) and old aspen (over 70 yr).

Variable		NFFL model 8	Young aspen	Old aspen
Fuel loads	1 hr	3.36	.29	.74
(m ton/ha)	10 hr	2.24	1.39	4.91
	100 hr	5.60	4.39	7.48
	Live herbaceous	0	.90	.34
	Live woody	0	.56	.25
S/V ratios	1 hr	66	66	66
(1/cm)	Live herbaceous	6	6	6
	Live woody	6	6	6
Other	Depth (cm)	6.1	6.1	6.1
	Heat content (j/g)	18595	18595	18595
	Extinction moisture (%)	30	30	30

herbaceous or live woody loads. The 1 hr fuel loads for NFFL model 8 was much higher than the loadings found in either the young or old aspen age class aspen communities in this study. The 10 hr and 100 hr fuel loads in NFFL model 8 were intermediate to the fuel loads in young and old aspen.

When BEHAVE FIRE1 was run with the same weather, topography, and fuel moisture conditions (fire model 1) with each of the three fuel models, the fire behavior predictions differed for both custom fuel models and for the standard model 8 (Table 5). When changes were made to the wind speed, live woody fuel moisture and live herbaceous fuel moisture components for the second run of BEHAVE FIRE1 (fire model 2), and each of the fuel models was used with this set of weather and fuel moisture conditions, fire behavior outputs again differed for all three models.

In the first fire prediction, fire model 1, with lower wind speeds (6 km/hr), higher live herbaceous fuel moisture (120%), and higher live woody fuel moisture (120%), the young aspen fire outputs were much greater than the fire outputs in old aspen or model 8 (Table 6). Almost all of the young aspen output variables were approximately twice those of the old aspen model and NFFL model 8. The old aspen fire was the least intense, but it was not much different from the NFFL model 8 fire. The old aspen fire did release more heat per unit area than the standard model.

In the second fire prediction, live woody fuel moisture content and live

Table 5. The standard weather conditions entered into BEHAVE FIRE1 for fire behavior predictions.

Environmental parameters	Fire model 1* (first fire prediction)	Fire model 2** (second fire prediction)
Fuel moisture (%)		
1 hr	6	6
10 hr	7	7
100 hr	8	8
Live herbaceous	120	60
Live woody	120	60
Wind speed (km/h)	6	50
Slope (%)	0	0

herbaceous fuel moisture were decreased to 60%. Wind speed was increased to 50 km/hr. The predicted fire behavior was similar to the first fire prediction. The main difference shown in the second fire prediction was that the fires predicted by all three models were greater. The rates of spread increased by a factor of two for all three fuel models.

For both fire models, the fire behavior predictions differed between the two custom fuel models and NFFL model 8 (Table 6). The outputs for the young aspen model were much greater than the outputs for NFFL model 8 or the old aspen model. The custom fuel models should be used instead of NFFL model 8 to predict fire behavior in aspen.

The descriptive statistics of the variables analyzed for the 51 plots were

Table 6. Output from BEHAVE FIRE1, indicating predicted fire spread for NFFL model 8, young aspen, and old aspen, using conditions listed in Table 5 for two fire predictions.

	Fire model 1 predictions			Fire model 2 predictions		
Output	Model 8	Young aspen	Old aspen	Model 8	Young aspen	Old aspen
Rate of Spread (m/hr)	24	30	12	120	150	60
Heat per unit area (kj/sqm)	2142	5460	2513	2142	5796	2522
Fireline intensity (kw/m)	17	37	11	58	215	25
Flame-length (m)	.3	.4	.2	.5	.9	.3
Reaction intensity (kw/sqm)	176	257	141	176	273	142
Effective windspeed (km/h)	6.0	6.0	6.0	15.3	23.7	12.3

summarized in Table 7. The ranges of variation for all variables were high. This high level of variation was visible in and among all the aspen stands analyzed. The variables with the largest standard deviations included litter weight, number of regeneration, and number of stems in circle shrub plots. These variables had standard deviations larger than their means. Fuel loads, percent of trees with disease, herbaceous weight, and litter depth had standard deviations that were at least 80% the size of the variable means. The smallest standard deviations were grazing intensity, tree height, elevation, percent of trees that were aspen, and average d.b.h. These variables had standard deviations less than 50% the size of their means.

When Spearman's correlation tests were run to compare fuel load and other aspen stand characteristics, including disease, slope, aspect, grazing intensity, elevation, percent of trees that are aspen, litter depth, number of shrub stems in two 0.46 m circles, cm of shrub stems over 15.24 m, litter weight, herbaceous weight, regeneration, basal area per hectare, and average d.b.h., only two variables were statistically significant, and only one variable at the .01 level (Table 7). Average d.b.h. was significantly correlated to fuel load ($\underline{P}$=.005). Grazing intensity was less significantly correlated to fuel load ($\underline{P}$=.024). Although not statistically significant, percent aspen may be correlated to fuel load ($\underline{P}$=.174). No other variable showed any significant relationship to fuel loads over the 51 plots (Table 7).

Table 7. Summary of variable descriptive statistics and the results of Spearman's correlation test of fuel load versus the other variables analyzed for the 51 plots.

Variable	N	Mean	S.D.	Spearman coefficient	P value
Fuel load (m tons/ha)	51	6.25	6.08	1.00	-------
Average d.b.h. (cm)	51	18.49	8.48	.389**	.005
%trees aspen	51	75.78	30.58	-.193	.174
Aspect (degree)	50	153.5	126.00	-.086	.554
Basal area per hectare (sq.m/ha)	51	9.53	5.28	.146	.295
% trees with disease	51	34.96	27.40	.137	.308
Elevation (m)	51	2278.80	174.31	-.212	.337
Grazing intensity (scale 0-4)	51	1.90	.62	-.316*	.024
Herbaceous weight (g)	40	16.53	13.23	.113	.489
Litter weight (g)	39	59.92	131.21	-.058	.726
Litter depth (cm)	50	1.35	1.04	.169	.239
Number of regeneration	51	4.2	4.95	.04	.781
Shrub stems in circle	51	21.80	22.89	-.007	.961
Shrub line intercept (cm)	44	293.14	254.20	.002	.988
Slope (%)	50	17.09	11.84	-.025	.864
Tree height (m)	51	11.05	4.47	.093	.515

* Correlation significant at 0.05 level.

**Correlation significant at 0.01 level.

When the plots were grouped into stands and the variables were compared for the seven locations, wide variations were visible in the variables among the stands (Table 8). The standard deviations seen among the stands appeared lower than the standard deviations among the plots. Only one variable in the area descriptives, litter weight, had a standard deviation greater than its mean. All standard deviations were lower for location comparisons rather than plots, with the exception of grazing intensity. The standard deviation for grazing intensity was only .03 higher in the location data than the plot data.

Spearman's correlation tests between fuel loads and the other area variables showed that no correlations at $\underline{P}<.05$ exist (Table 8). Three variables, with $\underline{P}<.30$, appeared more closely correlated to fuel loads than the other variables: the amount of regeneration in a location ($\underline{P}=.119$), the percent of diseased trees ($\underline{P}=.215$), and average d.b.h ($\underline{P}=.294$).

Discussion

NFFL model 8, the standard fuel model designed to represent aspen communities, had characteristics very different from the characteristics seen in quaking aspen communities in the Bear River Range. NFFL model 8 was not representative of aspen stand fuel load conditions. The fuel loads in NFFL model 8 were unlike either the young aspen (under 70 yr) or old aspen (over 70 yr) custom fuel models for 1 hr fuel loads, live herbaceous loads, and live woody loads. The aspen age classes in this study, young aspen and old aspen, had large

Table 8. Summary of variable descriptive statistics and the results of Spearman's correlation test of fuel load versus the other variables for the seven locations.

Variable	N	Mean	S.D.	Spearman coefficient	P value
Fuel load (m tons/ha)	7	6.88	2.73	1.00	--------
Average d.b.h. (cm)	7	18.87	4.48	.464	.294
% of trees aspen	7	71.53	28.55	-.321	.482
Aspect (degree)	7	196.00	102.29	.321	.482
Basal area per hectare (sq.m/ha)	7	9.89	3.25	.143	.760
% of trees with disease	7	37.18	12.28	.536	.215
Elevation (m)	7	2278.8	174.31	-.283	.538
Grazing intensity (scale 0-4)	7	1.80	.65	-.468	.289
Herbaceous weight (g)	6	15.87	10.08	-.143	.787
Litter weight (g)	6	67.16	96.26	-.086	.872
Litter depth (cm)	7	1.32	.66	.286	.535
Number of regeneration	7	4.85	2.88	.643	.119
Shrub stems in circle	7	22.83	14.96	.000	1.000
Shrub line intercept (cm)	6	261.44	183.16	.071	.879
Tree height (m)	7	11.16	3.94	.107	.819
Slope (%)	7	18.28	8.31	.086	.872
Average stand age (yr)	7	73.21	15.66	-.107	.819

differences in fuel loads. The two custom fuel models were much more accurate indicators of aspen stand conditions and should provide more accurate fire behavior predictions.

The fire predictions made by BEHAVE FIRE1 differed between the young aspen model, the old aspen model, and NFFL model 8. The young aspen had higher fire behavior outputs than the other models and the fire moved more quickly through the lighter, less densely packed fuel loads. Higher live woody and herbaceous loads increased reaction intensity, flame length, and the rate of spread in the young stands. Spread rates were slower in the older aspen stands and this caused shorter flame lengths and lower reaction intensities. NFFL model 8 fire predictions differed from the old aspen fire outputs, with higher rates of spread, larger flame lengths, and greater reaction intensities (Table 5).

The custom fuel models should more accurately predict fire behavior in quaking aspen communities than NFFL model 8. The usefulness and effectiveness of the young aspen and old aspen custom fuel models for predicting fire behavior can be assessed when prescribed fire is used in quaking aspen communities in the Bear River Range and also for fires in other areas of quaking aspen.

The statistical analyses of the young and old stands showed older aspen stands had greater downed woody fuel loads than younger aspen stands while younger aspen stands had greater amounts of live herbaceous and live woody fuel loads than older stands (Table 4). When independent t-tests were used to compare these two age groups, the stands were shown to be significantly different in 9 of the 17 variables analyzed. For all variables except aspect, noticeable differences existed between the young and old aspen stands (Table 2).

With the exception of regeneration amounts, the differences in stand conditions between the young and old areas in this study were supported by several studies (DeByle, 1985; Graham et al., 1963; Kimmins, 1996; Mueggler, 1989). Regeneration rates were expected to be higher in younger stands, but the analysis of the young and old stands showed regeneration was higher in the older stands (Table 2). This difference can be explained by the conifer encroachment occurring in the older stands. Most of the regeneration in the older stands resulted from conifer species. The younger aspen stands had little conifer encroachment, and therefore lower amounts of regeneration.

High levels of variability existed in the data collected for the 51 plots. The high standard deviations were expected because each location studied encompassed a large range of aspen stand characteristics. When the data were grouped into locations, extreme values were averaged out and as a result, locations had lower standard deviations. Plot data were important to analyze because the degrees of freedom were larger than for location data, allowing for more statistically significant correlations between fuel loads and other variables. The location data, having smaller degrees of freedom, did not provide statistically significant correlations with fuel loads.

Many of the correlations expected between fuel loads and the other variables were not significant. The high variability seen in the data might be influenced by several factors. The data in this study were collected over the summer and fall seasons in two consecutive years and several different technicians were involved in the data collection. Interactions between the variables and other stand conditions may also influence the results. Stand ages were calculated in this study for locations but not used as a variable in the plot comparisons because many aspen trees had rotted at the pith and tree ages could not be determined at all plots. Fuel loads were not correlated with most variables studied. Stand conditions were not good indicators of fuel loads.

According to the literature reviewed, correlations were expected to exist between fuel loads and all-variables studied. Average d.b.h. was the only variable correlated with fuel loads at the .01 significance level (Table 7). Correlations between d.b.h. and fuel loads have also been found in Douglas-fir communities (Turner and Long, 1975).

Grazing intensity was significantly correlated with fuel loads at the .05 significance level (Table 7). Sheep graze heavily on forbs and shrubs in many areas of this study, reducing the amounts of fine fuels in these stands. As a result, fuel loads were decreased in grazed areas. Livestock grazing not only reduces fuels, but also decreases wildlife habitat quality by reducing forage for wildlife species (DeByle, 1985).

Aspen communities provide habitat for many species, including elk, mule deer, ruffed grouse, and cavity-nesting birds (DeByle, 1985). The two most important habitat characteristics influencing wildlife abundance are food and cover (Gullion, 1984). Young aspen stands, with greater amounts of forbs, grasses, and shrubs, provide better forage for wildlife than older aspen stands. The dense shrubs in many young aspen stands provide cover for ruffed grouse. Ruffed grouse also prefer young aspen stands because in older aspen stands, the greater amounts of downed woody fuels can conceal predators (DeByle, 1985). Older aspen stands have larger trees and greater amounts of conifer that provide better cover for elk and mule deer. The greater amounts of diseased and insect infested trees in old aspen communities are preferred by cavity-nesting and insectivorous birds (Gullion, 1984).

Both young and old aspen communities provide important wildlife habitat. In general, young aspen stands provide better forage and old aspen stands provide better cover. The quality and quantity of forage are highest in forest communities in the first 10 yr after a fire and gradually decrease over time (Carlson et al., 1993).

Most important to this study were the differences in the fuel data. When used to develop fuel models, the young and old aspen fuel models represented two distinct stand types and predicted different fire behavior. Neither stand type was well represented by NFFL model 8. The customized fuel models more accurately represent aspen communities in the Bear River Range and should provide better fire predictions.

This research showed fuel loads in the Bear River Range were most significantly related to average d.b.h. and grazing intensities. Stands grouped into young and old age classes differed for many variables. Both young and old aspen stands in the Bear River Range have important wildlife habitat characteristics. Management strategies such as prescribed fire can create an even greater mosaic of aspen communities to support wildlife.

SUMMARY

In this study, seven quaking aspen communities were designated for prescribed fire in 1997 and 1998. Fifty-one plots were placed in these areas. Several inventories were taken at each plot, including a point location description, timber inventory, understory vegetation inventory, fuels inventory, and shrub intercept inventory.

Customized fuel models were designed for two age groups, young aspen (under 70 yr) and old aspen (over 70 yr), using BEHAVE TSTMDL. Comparisons were made between these custom fuel models and NFFL model 8 (closed timber litter). All three models differed in fuel loads, with young aspen having the lowest fuel loads and old aspen the heaviest fuel loads. When used in BEHAVE FIRE1, the models differed in fire behavior predicitions.

The custom fuel models are more accurate representatives of aspen communities found in the Bear River Range in Utah than NFFL model 8. The young aspen fuel model and old aspen fuel model should provide much more accurate fire predictions in quaking aspen communities and should be used by managers instead of NFFL model 8.

From the data collected in this study, the following variables were analyzed: fuel loads, percent of aspen with disease, slope, aspect, grazing intensity, elevation, percent of trees that are quaking aspen, litter depth, number of shrub stems in two shrub circle plots, cm of shrubs intersecting a linear transect, litter weight, herbaceous weight, regeneration, basal area per hectare, and average diameter at breast height (d.b.h.).

The t-tests showed the young and old aspen differed for many stand characteristics. Sixteen of the 17 variables differed between the young and old stands ($\underline{P}<.15$). These areas were significantly different ($\underline{P}<.05$) for 9 of the 17 variables analyzed.

Comparisons were made between fuel loads and other variables over the 51 plots, using Spearman's correlation test to look for potential relationships. No relationships existed between fuel loads and most stand characteristics. Fuel load was significantly correlated with average d.b.h. ($\underline{P}=.005$) and with grazing intensity ($\underline{P}=.024$) for the 51 plots. No significant correlations were found when Spearman's correlation tests were conducted between fuel loads and the other variables when the plots were grouped into the seven locations.

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APPENDIX

INT 4801-14

POINT AND TREE DATA ITEMS

PAGE ____ OF____

TOPO NAME______________ AREA #_____ TRACT #_____ CREW NAMES:______________________________DATE(S)________

POINT NUMBER	POINT HISTORY	TREE NUMBER	AZIMUTH	SLOPE DISTANCE	TREE HISTORY	SITE TREE/MORTALITY	SPECIES/HABITAT TYPE	PAST DBH/DRC	CURRENT DBH/DRC/COUNT	RADIAL GROWTH	TREE AGE/LOC STAND AGE	PAST HEIGHT	CURRENT HEIGHT	CROWN RATIO UNCOMPACTED	CROWN RATIO COMPACTED	CROWN CLASS	PRIMARY DAMAGE/COD	SECONDARY DAMAGE	TREE CLASS/COVER CLASS	MISTLETOE CLASS	RELATIVE CROWN POSITION	I & D INCIDENCE	NUMBER OF STEMS	ROTTEN & MISSING VOLUME	DEAD VOLUME	POSTS-LINE	POSTS-CORNER	XMAS TREE GRADE		COMMENTS
57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	77	75	76	81	82	85	86	87	88	89	90		
XX	XX	XX	XXX	XX	XX	X	XXX	XXX	XXX	XX	XXX	XXX	XXX	X	X	X	XX	XX	XX	X	XX	XX	XX	X	X	X	X	X	XX	
	01																													

POINT #

HERBS										
% STAND				% DEAD				% COV.		BASE WT.
1	2	3	4	1	2	3	4	1	2	

read entire rectangle

LITTER				
% STAND				BASE WT.
1	2	3	4	

read right half only

POINT #

HERBS										
% STAND				% DEAD				% COV.		BASE WT.
1	2	3	4	1	2	3	4	1	2	

read entire rectangle

LITTER				
% STAND				BASE WT.
1	2	3	4	

read right half only

POINT #

HERBS										
% STAND				% DEAD				% COV.		BASE WT.
1	2	3	4	1	2	3	4	1	2	

read entire rectangle

LITTER				
% STAND				BASE WT.
1	2	3	4	

read R half only

POINT #

HERBS										
% STAND				% DEAD				% COV.		BASE WT.
1	2	3	4	1	2	3	4	1	2	

read entire rectangle

LITTER				
% STAND				BASE WT.
1	2	3	4	

read R half only

POINT #

HERBS										
% STAND				% DEAD				% COV.		BASE WT.
1	2	3	4	1	2	3	4	1	2	

read entire rectangle

LITTER				
% STAND				BASE WT.
1	2	3	4	

readR half only

POINT #

HERBS										
% STAND				% DEAD				% COV.		BASE WT.
1	2	3	4	1	2	3	4	1	2	

read entire rectangle

LITTER				
% STAND				BASE WT.
1	2	3	4	

read R half only

POINT #

HERBS										
% STAND				% DEAD				% COV.		BASE WT.
1	2	3	4	1	2	3	4	1	2	

read entire rectangle

LITTER				
% STAND				BASE WT.
1	2	3	4	

read R half only

POINT #

HERBS										
% STAND				% DEAD				% COV.		BASE WT.
1	2	3	4	1	2	3	4	1	2	

read entire rectangle

LITTER				
% STAND				BASE WT.
1	2	3	4	

read R half only

NT 4801-13

FIELD LOCATION DESCRIPTION ITEMS

1Topo	XX		32 SLOPE	XX		123 SOIL TEXTURE	X
2Area #	XXXX		33 CURVATURE CLASS	X		124 SOIL GROUP	X
3Tract	XXXX		34 PHYSIOGRAPHIC CLASS	XX		125 PERCENT BARE GROUND	XX
9Point #1	XXX					128 SOIL EROSION	X
10 Crew Names:	XXXX		35 PRIM HABITAT TYPE	XXX			
			36 SEC HABITAT TYPE	XXX		131 WATER PROXIMITY	X
11 PAST DATE	XXXX		37 FIELD LOC HISTORY	XXX		132 WATER TYPE	X
12 CURRENT DATE	XXXX						
14 CREW NUMBER	XX		40 NO SEED/SAP SUBPLOTS	XX		133 LAND USE IMPACT	XXX
			41 SEED/SAP PLOT SIZE	XX		129 LAND USE IMPACT DISTANCE	XXX
15 SAMPLING FACTOR	XX		42 NUMBER OF POINTS	XX		134 CONDITION SIZE	X
16 SAMPLE KIND	X		43 NUMBER OF RECORDS	XXX		135 FOREST AREA SIZE	X
19 PAST GLU	XX		48 UTM ZONE	XX		136 BURN HISTORY	X
20 CURRENT GLU	XX		49 UTM EASTING	XXXX		137 CUTTING HISTORY	X
			50 UTM NORTHING	XXXXX		138 TYPE OF CUTTING	X
22 PAST OWNERSHIP	XX					139 DISTANCE TO IMPROVED ROAD	XX
23 CURRENT OWNERSHIP	XX		111 WILDLIFE COVER	XXXXXX			
			112 VEGETATIVE CONCEALMENT	X		141 SALV SNAGS 4–10.9" DBH	XX
24 LOCATION ORIGIN	X		113 BROWSING INTENSITY	X		142 NONSALV SNAGS 4–10.9" DBH	XX
25 LOC CANOPY STRUCTURE	X		114 ANIMAL TYPE	XXX		143 SALV SNAGS 11–19.9" DBH	XX
26 SEED SOURCE	X		115 GRAZING INTENSITY	X		144 NONSALV SNAGS 11–19.9" DBH	XX
27 FOREST TYPE	XX					145 SALV SNAGS 20"+ DBH	XX
28 LOC STAND–SIZE CLASS	X		118 RECREATION USE	XXX		146 NONSALV SNAGS 20"+ DBH	XX
29 CROWN COVER	XX		119 TRAILS/ROADS	X			
			120 AVAILABILITY	XX		147 DOWNED STEMS 1.0–4.9"	XX
30 ELEVATION	XXX					148 DOWNED STEMS 5.0–8.9"	XX
31 ASPECT	X		121 LITTER DEPTH (X.X)	XX		149 DOWNED STEMS 9.0–19.9"	XX
46 ASPECT AZIMUTH	XXX		122 HUMUS DEPTH (XX.X)	XXX		150 DOWNED STEMS 20.0"+	XX
44 RS COVER TYPE	XX						

GENERAL COMMENTS:

BASELINE INFORMATION:

From	To	Azimuth	Horz Gd Dist /	Photo Dist =	PSR	PSR Adjustment (if needed)

From	To	Azimuth	Photo Dist X	PSR =	Horz Gd Dist	Adjustment (if needed)
RP	LC					

UNDERSTORY VEGETATION DESCRIPTION FORM

OPO NAME:	POINT #'S.
REA #	CREW NAMES:
RACT #	DATE(S):

PART I – SPECIES LIST BY COVER CLASS AND LAYER

26.3' RADIUS

TREES			SHRUBS			FORBS			GRAMINOIDS		
ECIES	COVER	LAYER	SPECIES	COVER	LAYER	SPECIES	COVER	LAYER	SPECIES	COVER	LAYER
XXXX	X	X	XXXXX	X	X	XXXXX	X	X	XXXXX	X	X

PART II – PLANT GROUP COVER CLASS BY LAYER CARD TYPE 5

LAYER	TREES	SHRUBS	FORBS	GRAMINOIDS
	X	X	X	X
3 (6.1' +)				
2 (1.6–6.0')				
1 (0–1.5')				
3				
2				
1				
3				
2				
1				
3				
2				
1				
3				
2				
1				

List only species with 5 percent or greater cover.
The 1/20–acre plot has a radius of 26.3 ft.
5 percent of the 1/20–acre plot entails a circle 5.9 ft. radius.

COVER CODES

Percent Cover	Code
0	0 *
<5	1 *
5–25	2
26–50	3
51–75	4
76–95	5
96–100	6

LAYER CODES

Height (feet)	Code
0–1.5	1
1.6–6	2
6.1+	3

* Cover codes 0 and 1 will ONLY be used on Part II

DOWNED FUEL INVENTORY

TOPO NAME________________________ AREA#________ POINT #'S______________ DATE(S): ______________

Fuel Size Class (in): 0 - 1/1 - 3,/ 3+
Length of sample plane: 6,'/ 10,'/ 35'

CREW NAMES:

35 feet of 50' line

POINT #	Slope	No. of Intersects within the inch categories below. ----- Fuels-------			3"+		Litter Depth (Tenths of inches)			Duff Depth (Tenths of inches)		----Circular Plots---- % Cover (Code) ----Shrubs----		% Dead (Code)		Average Height (inches)		SPP species	No. of stems by diameter class (cm)							AZIMUTH
		0-.25 0-6'	.25-1 0-6'	1-3 0-10'	S. 3"+ 0-35'	R. 3"+ 0-35'	1'	10'	20'	1'	10'	1st Plot	2nd Plot	1st Plot	2nd Plot	1st Plot	2nd Plot		A	B	C	D	E	F	G	

Percent Codes

1 = 0 - 5%	2 = 6 -20%
3 = 21 - 40%	4 = 41 - 60%
5 = 61 -80%	6 = 81 - 95 %
7 = 95 - 100%	

Stem Classes

A = 0 - 0.5	B = 0.5 - 1
C = 1 - 1.5	D = 1.5 - 2
E = 2 - 3	F = 3 - 5
G = 5+	

TOPO MAP:____________ AREA#______ DATE(S):________ CREW NAMES:______

POINT #_____ POINT #_____

LINE INTERCEPT LINE INTERCEPT

					Species				
					INCHES OF INTERCEPT				
					TOTAL				

POINT #_____ POINT #_____

LINE INTERCEPT LINE INTERCEPT

					Species				
					INCHES OF INTERCEPT				
					TOTAL				

POINT #_____ POINT #_____

LINE INTERCEPT LINE INTERCEPT

					Species				
					INCHES OF INTERCEPT				
					TOTAL				