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Shrub Succession on Eight Mixed-Severity Wildfires in Western Montana, Northeastern Oregon, and Northern Idaho

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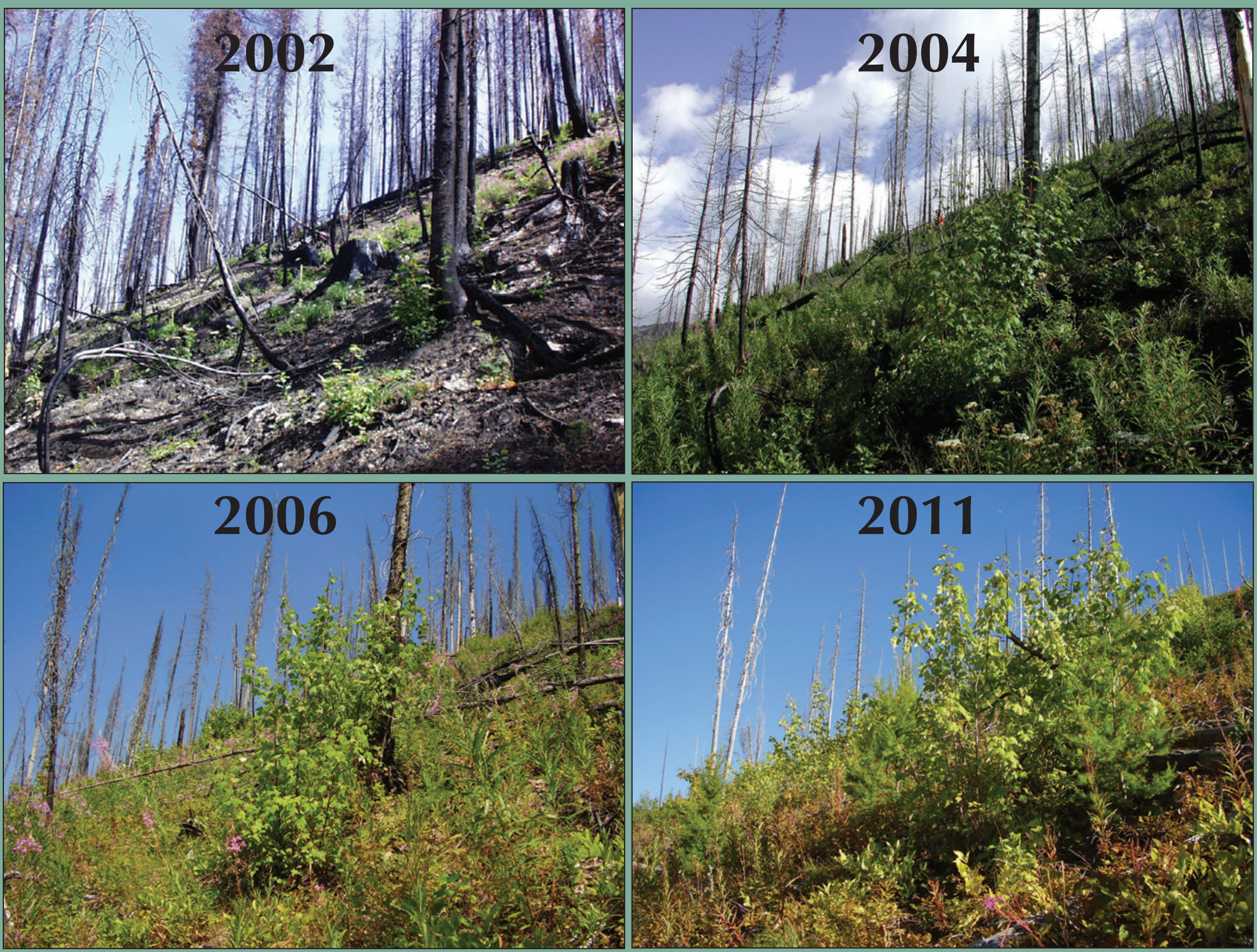

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Abstract

The response of 28 shrub species to wildfire burn severity was assessed for 8 wildfires on 6 national forests in the northern Rocky Mountains, USA. Stratified random sampling was used to choose 224 stands based on burn severity, habitat type series, slope steepness, stand height, and stand density, which resulted in 896 plots measured at approximately 2-year intervals from 1 to 11 years after the fire. For each species, mathematical models were developed to predict the probability of occurrence on 1/300-acre plots, cover on the plot, and average height. The association between burn severity and the probability of occurrence was generally negative. For most species, occurrence increased with increasing time since the wildfire. Cover decreased with increasing burn severity, except for some species that are dependent on seed for establishment. The longer it took the species to become established on the plot, the less cover could be expected. The best variable to predict shrub height was the cover of that species on the plot. Height decreased with increasing basal area and burn severity. These results can help natural resource managers predict the effects of wildfire on vegetation succession as a function of burn severity, site factors, and time. Of particular importance is the finding that percent cover of shrubs is generally low (less than 10 percent for almost all species) when the time between the wildfire and when the species was first observed on the plot is more than about 2 years. This result could be verified in other studies, either by a designed prospective study or reanalysis of previous studies where succession was followed over time.

Keywords: Forest succession, wildfire burn severity, *Acer glabrum*, Rocky Mountain maple; *Alnus viridis* ssp. *sinuata* (= *A. sinuata*), Sitka alder; *Amelanchier alnifolia*, Saskatoon serviceberry; *Arctostaphylos uva-ursi*, kinnikinnick; *Berberis* spp., Oregon grape; *Ceanothus sanguineus*, redstem ceanothus; *Ceanothus velutinus*, snowbrush ceanothus; *Chimaphila umbellata*, pipsissewa; *Ericameria nauseosa* (= *Chrysothamnus nauseosus*), rubber rabbitbrush; *Holodiscus discolor*, oceanspray; *Linnaea borealis*, twinflower; *Lonicera utahensis*, Utah honeysuckle; *Menziesia ferruginea*, rusty menziesia; *Paxistima myrsinites* (= *Pachistima myrsinites*), Oregon boxleaf; *Physocarpus malvaceus*, mallow ninebark; *Ribes cereum*, wax currant; *Ribes lacustre*, prickly currant; *Ribes viscosissimum*, sticky currant; *Rosa* spp., rose; *Rubus parviflorus*, thimbleberry; *Salix* spp., willow; *Sambucus racemosa*, red elderberry; *Shepherdia canadensis*, russet buffaloberry; *Sorbus scopulina*, Greene's mountain ash; *Spiraea betulifolia*, white spirea; *Symphoricarpos albus*, common snowberry; *Vaccinium membranaceum* (= *V. globulare*), thinleaf huckleberry; *Vaccinium scoparium*, grouse whortleberry

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NOTE: Tables and figures are numbered consecutively from the text through the Appendix. References for the text and Appendix are combined and precede the Appendix.

Introduction

The ability to predict vegetation development following forest disturbance is important for forest management decisions. Secondary succession following a wildfire proceeds through several stages: invasion, stagnation, and resumption of regeneration, eventually leading to old growth forests in the absence of another stand-replacing disturbance (Daubenmire and Daubenmire 1968). Information in the early years after forest disturbances is key to understanding secondary succession, wildlife use, competition, wildfire hazard, hydrology, and recreation opportunities.

Forest ecosystems in the Interior West are adapted to wildfire as a periodic disturbance agent (Arno 1980; Roe et al. 1971; Wellner 1970). Indeed, many forest plant species are fire dependent (Fischer and Bradley 1987; Smith and Fischer 1997). Recent wildfires in dry Interior West forests have increasingly been crown fires that kill much of the overstory, while historical low-severity ground fires have become less common (Covington and Moore 1994; Steele et al. 1986). Fire exclusion and suppression, which have resulted in increased fuel load and fuel connectivity (Auclair and Bedford 1994; Hessburg et al. 2000), may explain, at least in part, the increase in wildfire severity. Earlier spring snowmelt, increased length of the fire season, and warmer temperatures since the mid-1980s may also be contributing to increased wildfire activity (Westerling et al. 2006), which would accelerate the buildup of greenhouse gases in the atmosphere (Running 2006).

The data reported in this paper are part of an overall study to quantify secondary plant succession following wildfires in the northern Rocky Mountains from 2000 to 2003. This study was conducted in western Montana, northeastern Oregon, and northern Idaho. The study area encompasses forest types from ponderosa pine/Douglas-fir (*Pinus ponderosa*/*Pseudotsuga menziesii*) to grand fir/western redcedar/western hemlock (*Abies grandis/Thuja plicata/Tsuga heterophylla*) to subalpine fir/lodgepole pine (*Abies lasiocarpa/Pinus contorta*).

The purpose of this paper is to report shrub development for 28 species from 1 to 11 years after the wildfires. Data are reported on the probability of occurrence, shrub cover, and shrub height as a function of burn severity, site factors, and years since disturbance.

Study Design

Eight wildfires were sampled on six national forests. The wildfires occurred in 2000 through 2003 (table 1). These same stands were used by Ferguson et al. (2007) to predict spotted knapweed (*Centaurea biebersteinii*) response to wildfire, and by Ferguson and Craig (2010) to predict non-native plant species' response to wildfire. These stands were also used as part of a larger study to quantify the relationship between burn severity and forest structure in the U.S. Rocky Mountains (Jain and Graham 2007).

A stratified random sample was used to select stands within burn perimeters by using pre-fire metrics. Stands had been previously delineated and mapped by the U.S. Forest Service, National Forest System. Stratification ensured a range of conditions was sampled, by using combinations of:

- Three pre-fire habitat type series (ponderosa pine/Douglas-fir; grand fir/western redcedar/western hemlock; subalpine fir/lodgepole pine);

Table 1—Attributes of sample stands by wildfire.

Wildfire name and acronym	National Forest	Year of wildfire	Wildfire size (acres)	Number of stands sampled	Habitat type series[a] and (number of plots)	Years sampled
Bitterroot Complex, BITT-BITT	Bitterroot	2000	356,075	71	PIPO/PSME (154), ABLA/PICO (130)	1 or 2, 3, 5, 7, 10
Kootenai Complex, KOOT-KOOT	Kootenai	2000	34,600	30	PIPO/PSME (12), ABGR/THPL/TSHE (15), ABLA/PICO (93)	2, 4, 6, 9, 11
Ninemile Complex, LOLO-LOLO	Lolo	2000	24,350	18	ABGR/THPL/TSHE (9), ABLA/PICO (63)	2, 4, 6, 9, 11
Moose, FLAT-MOOS	Flathead	2001	70,975	32	ABLA/PICO (128)	1, 3, 5, 8, 10
Robert, FLAT-ROBT	Flathead	2003	57,750	13	ABGR/THPL/TSHE (20), ABLA/PICO (32)	1, 3, 6, 8
Crazy Horse, FLAT-CRAZ	Flathead	2003	11,300	5	ABGR/THPL/TSHE (8), ABLA/PICO (12)	1, 3, 6, 9
Flagtail, MALH-FLAG	Malheur	2002	8,200	45	PIPO/PSME (120), ABGR/THPL/TSHE (57), ABLA/PICO (3)	1, 3, 5, 8 10
Myrtle Creek, IPAN-MYRT	Panhandle	2003	3,450	10	PIPO/PSME (4), ABGR/THPL/TSHE (36)	1, 3, 6, 9

[a] PIPO = ponderosa pine, PSME =Douglas-fir, ABGR = grand fir, THPL = western redcedar, TSHE = western hemlock, ABLA = subalpine fir, and PICO = lodgepole pine.

- Two classes of burning index (≤75 and >75), an index of predicted fire spread and energy release (Bradshaw et al. 1984);
- Two slope steepness classes (≤35 percent and >35 percent);
- Two pre-fire canopy heights (sapling to medium size trees ≤40 feet and mature to old trees >40 feet tall); and
- Two pre-fire stand densities (≤35 percent and >35 percent conifer canopy cover).

Note that all combinations were not possible within each wildfire; for example, the Bitterroot fire does not have grand fir/western redcedar/western hemlock habitat types.

Within each wildfire and stratum, three low-density stands were randomly selected for sampling. The location of each stand center was determined by using aerial photographs. Transect lines were drawn on the photograph and the intersection at the approximate stand center was assigned a global positioning system (GPS) point. Field crews located this GPS point and installed a four-point cluster of plots. A second four-point cluster was installed in an adjacent higher-density stand that was also burned in the wildfire, which allowed Jain and Graham (2007) to quantify how fire behavior changed as it moved between differing stand structures. This second stand was chosen to represent a change in pre-fire density, burn severity, cover type, or forest structure. There were only a few instances when an acceptable adjacent stand was unavailable.

The four-point cluster plot design was similar to the sample design used by the U.S. Forest Service, Forest Inventory and Analysis program (Bechtold and Scott 2005). The center of plot 1 was at the assigned GPS point and was the basis for the location of three additional plots, which were 120 feet between plot centers at azimuths of 0 degrees, 120 degrees, and 240 degrees. Each of the four points had three associated plots. First was a 1/24-acre circular plot to record habitat type (Cooper et al. 1991; Johnson and Clausnitzer 1992; Pfister et al. 1977) and burn severity to overstory trees. The second plot was a variable radius plot for sampling overstory trees and snags. Basal area factors of 10, 20, or 40 square feet/acre were used to sample about five to seven overstory trees per point, if present. Basal area factors were not changed between points within a stand. The third plot was a 1/300-acre circular fixed-area plot to record slope, aspect, and burn severity to the forest floor, low shrubs, and tall shrubs. In addition, the 1/300-acre plot is the experimental unit used to record vegetation occurrence, cover, and height at time intervals after the wildfire. Hereafter, "plot" refers to the 1/300-acre fixed-area plot.

Elevation, the only variable recorded at the stand level, was recorded at plot 1. All other variables were recorded by plot to make them as independent as possible. Burn severity classes were used to characterize the effects of fire on vegetation and soil by using the protocol of Key and Benson (2001). Classes were recorded for each of four strata (forest floor, short shrubs, tall shrubs, and overstory trees) by using the following categories: 0 = unburned, 1 = light (blackened duff, scorched foliage, and overstory trees with predominantly green or brown needles), 2 = moderate (duff consumed, shrubs mostly consumed but stubs remaining, and overstory trees with predominantly brown or burned needles), and 3 = severe (mineral soil colored orange, shrubs consumed leaving holes in the soil, and overstory trees predominantly black). Each burn severity class was recorded by percentage of the plot that it occupied, for example, 60 percent severe burn and 40 percent moderate burn to the forest floor.

Identification of habitat types is more difficult following wildfires, but not impossible. Species of fire-killed trees could usually be identified, and some shrubs, forbs, and grasses survived the wildfire or sprouted from the roots. Field crews examined adjacent unburned stands to determine common habitat types in the area. Also at each remeasurement, crews reassessed habitat types and changed the habitat type code, if warranted.

Vegetation abundance was estimated by using Daubenmire's (1959) ocular estimate of canopy coverage method, with two differences: we used 1/300-acre circular plots instead of rectangular plots, and vegetation was recorded by percentages rather than by broad cover classes. A value of 1 percent was used to note occurrence only (trace); otherwise, percent cover classes were 5 through 100 by 5 percent increments. Each shrub species was recorded separately, and also as a lifeform. Percent cover of shrubs as a lifeform was not a summation of cover of the individual species; rather it was the percentage of the plot occupied by any shrub, which could be overlapping. Therefore, shrubs as a lifeform could not exceed 100 percent, whereas the sum of the individual shrub species covers could. Occurrence is defined as the presence of any aerial part of a species within the vertical cylinder of the 1/300-acre circular plot. Heights of shrubs, forbs, and non-native invasive species were recorded to the nearest 0.5 feet, with a minimum height of 0.5 feet.

Species identification can be difficult in the early years after wildfires, such as when sprouts and seeds produce primary leaves or when plants are too small to have produced identifying characteristics. If crews were uncertain about species identification, they added a question mark to the species code on the field sheet. The species identification was verified, or changed, during subsequent measurements.

Vegetation sampling was done in late June through September, beginning at low elevations where the growing season starts earlier and progressing upward in elevation. Vegetation dried early in 2001 on the Bitterroot National Forest, so we did not record vegetation for 25 of the 71 stands. For these 25 stands, burn severity was recorded and overstory trees were measured in 2001, and vegetation was recorded in 2002.

Nomenclature for species names was taken from the PLANTS database (USDA Natural Resources Conservation Service 2015). Several species were combined because of difficulty identifying small plants that lacked flowers. *Berberis repens* and *Berberis aquifolium* were combined as one code, as were all species of *Salix* and all species of *Rosa*.

Each plot was measured at 2- to 3-year intervals. Data collection began in year 1 or 2 after the wildfire and continued up to 11 years. Stands scheduled for remeasurement in 2008 were not sampled due to a lack of funding, which affected year 5 or 6 for some wildfires.

Data Analysis

Our analyses use techniques applicable to two-state modeling systems (Hamilton and Brickell 1983). The first step was to analyze the occurrence of species—a species either occurs on a plot or it does not. All plots were used to calculate the probability of occurrence. The second step analyzes attributes on plots where the species occurs; in this case the attributes were shrub cover and height. Analyzing data in this sequence can detect if species are expanding by becoming established on more plots (occurrence), expanding horizontally (cover), or expanding vertically (height). Conversely, species could decrease in occurrence, cover, or height over time.

Quantitative burn severity indices were calculated for each plot. The burn severity codes (0, 1, 2, and 3) were weighted by the proportion of the plot they occupied to calculate the index. Preliminary analyses showed that the forest floor burn severity was the best predictor of occurrence, cover, and height compared to burn severity for low shrubs, tall shrubs, or overstory trees. Hereafter, discussion of burn severity means forest floor burn severity on the 1/300-acre plot.

The interaction of slope and aspect was modeled as suggested by Stage (1976). This technique for modeling slope and aspect is very useful for showing how slope steepness can be beneficial, or not, depending on aspect and species. We calculated the best (optimum) aspects for species occurrence, cover, and height.

Statistical significance of independent variables in all analyses was assessed at the 0.05 significance level. Transformations of variables were explored to achieve homogeneity of error variance, normality, and to obtain additivity of effects (Kirk 1982). The significance of independent variables was evaluated by using t-ratios and F-values. Occurrence and cover models were fit by using a generalized linear mixed model (GLMM), specifically GLIMMIX in SAS® 9.4 (SAS 2015). Overall goodness of fit for each occurrence and cover model was assessed by the (generalized chi-square)/(degrees of freedom) statistic. A value of 1.0 indicates a good fit, which was generally the case for probability models, but not for cover models.

The probability of individual shrub species occurrence on a 1/300-acre plot was analyzed with logistic regression models in GLIMMIX by using a dichotomously distributed dependent variable (1 if the species occurs, 0 otherwise). The predicted probability is continuous and bounded in the interval [0,1]. The form of the logistic model is $P = 1/(1+e^{-\sum \beta_i X_i})$, where P is the probability, "e" is the base of natural logarithms, β_i is the ith regression coefficient, and X_i is the ith independent variable. Analyses in GLIMMIX specified two random effects in the model. First, the SUBJECT statement was used to account for the correlation among plots within stands, because four plots were measured in each stand. Second, the repeated measures option was used to account for measuring the same plots at successive time periods. The type of covariance option that we specified for repeated measures was the simple diagonal structure.

Before developing species' probability models, data were excluded where the species does not occur, based on habitat types (Cooper et al. 1991; Johnson and Clausnitzer 1992; Pfister et al. 1977) and sometimes geographic area. For example, grouse whortleberry (*Vaccinium scoparium*) does not occur on warm, dry habitat types. Because the probability of grouse whortleberry occurrence on warm, dry habitat types is zero, there is no need to include these habitat types in the model. Therefore, probability models predict occurrence on plots in our data where it can occur. If data were included where the species cannot occur, (1) the probability models would predict that a species could occur where it cannot and (2) the true effect of independent variables would be compromised by irrelevant data.

Data for cover and height models are from plots where the species did occur. Cover of individual shrub species was analyzed with PROC GLIMMIX by using logistic regression with a beta distribution. For these analyses, percent cover was divided by 100 to make it a proportion; therefore, the predicted cover proportion is continuous and bounded in the interval [0,1]. Repeated measures and the correlation among plots within stands were statistically accounted for in the analyses, as in the models for shrub occurrence.

Height models were developed by using PROC MIXED in SAS (Littell et al. 1996). The dependent variable was the natural log of height; when translated back to the natural scale, it always results in a positive predicted height. Repeated measures and the correlation among plots within stands were statistically accounted for in the analyses, as in the models for shrub occurrence. Akaike's information criterion (AIC: smaller is better) was used to compare model fits that had different sets of independent variables but the same dependent variable.

We calculated a variable called delay to plot occupancy. "Delay" is the number of years between the wildfire and when the species was first observed on the plot. A species that was present the first year after the fire has a delay of 0 years, a species that occurs the second year after the fire has a delay of 1 year, and so on. Our reasoning is that species established on a plot immediately after the wildfire might develop more cover for a given time period than if that same species had become established after competing vegetation was present. Similarly, cover is predicted by using the number of years the species has been on the plot ("age" in the results section), rather than the number of years since the wildfire. Because plots were not measured each year, species that occur for the first time during a non-measurement year would not be detected until the next measurement. Therefore, time since wildfire in the probability of occurrence models, and age in the cover and height models, are not as precise as if we had measured plots each year.

Graphs of the raw data use time groups (1 and 2 years; 3 and 4; 5 and 6; 9, 10, and 11) so that all stands are included as data points. This avoids trying to interpret graphs that alternate between stands measured during even years since the wildfire (2, 4, 6, 8, 10) and those measured during odd years since the wildfire. Data points for the 7 and 8 year time group are not included in the graphs because of too few data.

Results

There are 896 plots sampled from 224 stands. The stratified random sampling design ensured sampling of a variety of conditions. Overstory densities varied from 0 to 360 square feet/acre, elevations varied from 2,798 to 7,895 feet, slope steepness ranged from 0 to 92 percent, and all aspects were sampled.

In order to develop predictive models for species occurrence, cover, and height, it was necessary to collapse the various habitat types to habitat type series (table 2). The result was 290 plots in the PIPO/PSME series, 145 plots in the ABGR/THPL/TSHE series, and 461 plots in the ABLA/PICO series (table 3). Table 3 also shows the number of plots by forest floor burn severity classes and habitat type series. There is a fairly balanced distribution of plots across the combinations of burn severity and habitat type series, although it would have been desirable to sample more plots in the ABGR/THPL/TSHE group.

Table 2—Number of plots by habitat type, and habitat type series assignments for data analyses. Abbreviation codes for species names are explained in table 4 or below.

Habitat type	Number of plots	Habitat type series
PIPO/FEID	9	PIPO/PSME
PIPO/CARU	2	PIPO/PSME
PIPO/CAGE	23	PIPO/PSME
PIPO/SYAL	14	PIPO/PSME
PSME/FEID	2	PIPO/PSME
PSME/CAGE	38	PIPO/PSME
PSME/CARU	48	PIPO/PSME
PSME/CELE	10	PIPO/PSME
PSME/SPBE	3	PIPO/PSME
PSME/LIBO2	3	PIPO/PSME
PSME/SYAL	56	PIPO/PSME
PSME/PHMA	31	PIPO/PSME
PSME/VAME	51	PIPO/PSME
ABGR/CAGE	19	ABGR/THPL/TSHE
ABGR/CARU	28	ABGR/THPL/TSHE
ABGR/LIBO2	6	ABGR/THPL/TSHE
ABGR/CLUN	6	ABGR/THPL/TSHE
ABGR/VASC	10	ABGR/THPL/TSHE
ABGR/XETE	1	ABGR/THPL/TSHE
THPL/CLUN	61	ABGR/THPL/TSHE
THPL/OPHO	1	ABGR/THPL/TSHE
TSHE/CLUN	9	ABGR/THPL/TSHE
TSHE/other (not CLUN)	4	ABGR/THPL/TSHE
PICEA/LIBO2	4	ABLA/PICO
PICEA/CLUN	5	ABLA/PICO
ABLA/CARU	15	ABLA/PICO
ABLA/ARCO	7	ABLA/PICO
ABLA/CACA	9	ABLA/PICO

(continued)

Table 2—(Continued).

Habitat type	Number of plots	Habitat type series
ABLA/LIBO2	46	ABLA/PICO
ABLA/CLUN	80	ABLA/PICO
ABLA/GATR	2	ABLA/PICO
ABLA/OPHO	1	ABLA/PICO
ABLA/MEFE	31	ABLA/PICO
ABLA/XETE	180	ABLA/PICO
ABLA/VAME	23	ABLA/PICO
ABLA/VASC	27	ABLA/PICO
ABLA/ALVI	18	ABLA/PICO
ABLA/LUHI	5	ABLA/PICO
ABLA-PIAL/VASC	4	ABLA/PICO
PICO/LIBO c.t.*	1	ABLA/PICO
PICO/CARU	3	ABLA/PICO

Additional species definitions not found in table 4.

Abies grandis	ABGR	Grand fir
Abies lasiocarpa	ABLA	Subalpine fir
Arnica cordifolia	ARCO	Heartleaf arnica
Calamagrostis canadensis	CACA	Bluejoint reedgrass
Carex geyeri	CAGE	Elk sedge
Calamagrostis rubescens	CARU	Pinegrass
Cercocarpus ledifolius	CELE	Mountain mahogany
Clintonia uniflora	CLUN	Queencup beadlily
Festuca idahoensis	FEID	Idaho fescue
Galium triflorum	GATR	Sweetscented bedstraw
Luzula hitchcockii	LUHI	Smooth woodrush
Oplopanax horridum	OPHO	Devil’s club
Pinus albicaulis	PIAL	Whitebark pine
Picea sp.	PICEA	Spruce
Pinus contorta	PICO	Lodgepole pine
Pinus ponderosa	PIPO	Ponderosa pine
Pseudotsuga menziesii	PSME	Douglas-fir
Thuja plicata	THPL	Western redcedar
Tsuga heterophylla	TSHE	Western hemlock

* c.t. = Community type.

Table 3—Number of 1/300-acre plots sampled by forest floor burn severity and habitat type series.

Habitat type series	Forest floor burn severity[a]			Total
	Low	Medium	High	
PIPO/PSME	89	123	78	290
ABGR/THPL/TSHE	30	100	15	145
ABLA/PICO	98	170	193	461
Total	217	393	286	896

[a] Forest floor burn severity classes are: Low 0.0 to 0.99, Medium 1.0 to 1.99, High 2.0 to 3.0

Table 4 shows the 28 species that were analyzed in this study by scientific name, the abbreviation code that will be used throughout this paper, common name, mean percent occurrence, mean percent cover, and mean height. Species are listed in descending order of occurrence, from 98.8 percent for SHRB to 2.8 percent for SARA.

Models were developed to predict occurrence, cover, and height for each species. Models were also developed for occurrence and cover of shrubs as a lifeform (SHRB). Results and discussion for individual species are given in the Appendix.

Table 4—Scientific and common names of shrub species, their abbreviation, occurrence, cover, and height on 896 sample plots.

			Percent	Cover[a]		Height[a]	
Scientific name	**Abbreviation**	**Common name**	**occurrence**	**Percent**	**SD[b]**	**Feet**	**SD[b]**
Any shrub species	SHRB	shrub	98.8	28.1	23.7	n/a	n/a
Spiraea betulifolia	SPBE	White spirea	57.7	4.8	6.3	0.9	0.4
Vaccinium membranaceum	VAME	Thinleaf huckleberry	53.0	8.2	10.9	0.9	0.4
Salix spp.	SALX	Willow species	51.6	6.8	8.2	3.0	2.0
Vaccinium scoparium	VASC	Grouse whortleberry	33.6	8.3	12.0	0.5	0.1
Berberis spp.	BERB	Oregon grape species	32.3	4.5	8.4	0.5	0.2
Rosa spp.	ROSA	Rose species	29.7	2.9	3.3	1.2	0.7
Paxistima myrsinites	PAMY	Oregon boxleaf	29.6	2.2	3.2	0.7	0.3
Ceanothus velutinus	CEVE	Snowbrush ceanothus	27.0	24.6	26.7	1.6	1.0
Symphoricarpos albus	SYAL	Common snowberry	26.1	7.2	11.7	1.5	0.7
Rubus parviflorus	RUPA	Thimbleberry	22.0	6.3	10.1	1.3	0.8
Amelanchier alnifolia	AMAL	Saskatoon serviceberry	19.6	2.8	3.7	1.7	1.1
Ribes viscosissimum	RIVI	Sticky currant	14.8	1.5	1.5	1.4	0.6
Lonicera utahensis	LOUT2	Utah honeysuckle	14.7	2.0	2.8	1.3	0.7
Linnaea borealis	LIBO2	Twinflower	14.6	5.2	8.3	0.5	0.0
Chimaphila umbellata	CHUM	Pipsissewa	14.5	1.8	4.3	0.5	0.0
Ribes lacustre	RILA	Prickly currant	11.4	2.5	3.5	1.3	0.7
Arctostaphylos uva-ursi	ARUV	Kinnikinnick	9.4	9.5	14.6	0.5	0.0
Alnus viridis ssp. *sinuata*	ALVI	Sitka alder	8.5	11.4	13.9	4.9	2.9
Acer glabrum	ACGL	Rocky Mountain maple	8.5	7.3	12.8	3.9	2.8
Ceanothus sanguineus	CESA	Redstem ceanothus	7.8	33.0	29.9	4.5	2.5
Menziesia ferruginea	MEFE	Rusty menziesia	6.8	9.8	13.1	2.3	1.0
Physocarpus malvaceus	PHMA	Mallow ninebark	5.7	10.5	11.9	2.5	1.1
Ribes cereum	RICE	Wax currant	5.6	4.7	8.4	2.1	1.2
Ericameria nauseosa	ERNA	Rubber rabbitbrush	5.1	2.5	3.7	1.4	0.9
Holodiscus discolor	HODI	Oceanspray	4.6	5.5	8.6	2.7	1.2
Sorbus scopulina	SOSC2	Greene's mountain ash	4.4	1.5	1.3	1.5	0.8
Shepherdia canadensis	SHCA	Russet buffaloberry	3.3	5.1	5.1	1.9	0.9
Sambucus racemosa	SARA	Red elderberry	2.8	1.0	0.0	1.2	0.8

[a] Cover and height at the last measurement (8 to 11 years since the wildfire).

[b] Standard deviation.

Occurrence

Recall that data were excluded where the species does not naturally occur, based on habitat types or geographic area. These exclusions are shown in table 5. The models developed to predict the probability of occurrence for the 28 shrub species and SHRB as a lifeform are shown in table 6.

SHRB occurred on 98.8 percent of the 896 plots (table 4). Occurrence was more than 90 percent in the first measurements after the fires and there were no apparent differences among burn severity classes (fig. 1a). For presentation of results in tables and graphs, the burn severity index was classified into three categories: low (0.0 to 0.99), medium (1.0 to 1.99), and high (2.0 to 3.0); however, it is important to note that the calculated burn severity index explained in the methods section was used to develop regression models.

Table 5—Habitat types and wildfires that were excluded from the data for fitting probability equations, by species.

Abbreviation	Excluded habitat types or wildfires
ACGL	PIPO series; ABLA/CACA, MEFE, XETE; PICO series
ALVI	PIPO series; PSME series
AMAL	ABLA/VASC; ABLA-PIAL/VASC
ARUV	PIPO series; THPL series; TSHE series
BERB	ABLA/CACA, MEFE, LUHI; PICO series
CESA	No exclusions
CEVE	No exclusions
CHUM	No exclusions
ERNA	All geographic areas except the MALH-FLAG fire
HODI	PICEA series; ABLA series; PICO series
LIBO2	PIPO series; PSME/FEID, CARU, CAGE, SPBE, SYAL; ABLA-PIAL/VASC
LOUT2	PIPO series
MEFE	PIPO series; PSME series; ABGR/CAGE, CARU
PAMY	PIPO series; PSME/FEID, SPBE, CAGE; ABLA/CACA, ARCO; ABLA-PIAL/VASC; PICO series
PHMA	THPL series; TSHE series; PICEA series; ABLA series; PICO series
RICE	All geographic areas except the MALH-FLAG fire
RILA	PIPO series; PICO series
RIVI	PICO series
ROSA	No exclusions
RUPA	PIPO series; PSME/SYAL, SPBE, CARU, FEID, CAGE; ABLA/CACA, XETE, LUHI; PICO series
SALX	No exclusions
SARA	PIPO series; PSME series
SHCA	No exclusions
SOSC2	PIPO series; PICO series
SPBE	No exclusions
SYAL	ABLA/MEFE, XETE, LUHI, CACA; ABLA-PIAL/VASC; PICO series
VAME	PIPO series; PSME/FEID, CARU, CAGE, SPBE; ABLA-PIAL/VASC
VASC	PIPO series; PSME/FEID, CARU, CAGE; THPL series

Table 6—Coefficients for estimating the probability of occurrence on 1/300 acre plots following wildfire. The form of the equation is PROB = $(1 + e^{-(\sum \beta_i X_i)})^{-1}$, where "e" is the base of natural logarithms. Variables are explained in the footnote.

Species	B_0	ba	ff	time	elev	$elev^2$	cos(α)*slo	sin(α)*slo	slo	PIPO/PSME	ABGR/ THPL/TSHE	Optimum aspect	occur/n	Chi^2/df
SHRB	3.6725	-0.0072							2.2755	-1.5408	-0.9525	n.s.	3992/4155	1.21
ACGL	3.0768	0.0028	-0.7531		-0.1278				2.9546	-0.7089	0.1458	n.s.	179/2831	0.78
ALVI	-4.9084	-0.0089	-0.7909	0.0472	0.1921	-0.0024	1.7753	0.2425	0.9091	n/a	-0.7498	2	214/2729	0.93
AMAL	0.6738		-0.4605	0.0629	-0.0665		-0.7890	0.1604	2.8633	-0.0686	-0.4253	166	491/4023	0.94
ARUV	-8.4120		-1.0884		0.3384	-0.0034	0.4661	0.8050	-4.4475	0.2031	1.0810	48	278/3619	0.81
BERB	-0.7041		-0.1513	0.0425	-0.0334		-2.0034	0.6224	1.5980	1.3816	1.2647	166	1118/3917	1.00
CESA	-3.4535		0.3040									n.s.	192/4155	0.98
CEVE	-32.6343	-0.0092	1.1385		1.1066	-0.0107	-2.3558	-0.3761	1.3202	2.2082	2.6941	188	883/4155	1.05
CHUM	-10.1038	0.0065	-0.5329		0.3109	-0.0027	-0.2795	0.5061	-0.4270	-2.1938	0.4754	119	363/4155	1.06
ERNA	3.2932	-0.0137		0.1117	-0.1145				1.9090			n.s.	114/900	1.10
HODI	4.2019	0.0042			-0.1672		-2.9594	0.1759	-0.3897			181	105/2056	0.82
LIBO2	3.6029	0.0044	-0.8299	0.0540	-0.0755		0.9757	0.7410	-2.2558	-0.8029	-1.3225	45	440/3179	0.92
LOUT2	0.4809	0.0042	-0.3766	0.0374	-0.0558		0.9619	0.3535	1.5893	-1.4962	-0.9967	28	321/3915	1.03
MEFE	-4.6280		-0.6921		0.0548		3.7186	1.4366	-0.5704	n/a		19	219/2494	0.96
PAMY	-8.3537		-0.2032	0.0752	0.4216	-0.0056	-0.4497	-0.0921	2.5701	-2.8440	-0.5861	187	840/3589	0.81
PHMA	-2.0269	-0.0108			-0.0741		1.3177	1.6999	8.2426			51	113/1760	0.85
RICE	12.4470		0.4509	0.1448	-0.3130		-1.1038	-1.0286	3.8093			219	156/900	1.03
RILA	-5.5410	0.0055	-0.4328	-0.0500	0.1542	-0.0015	2.4727	0.2765	-0.2105	-1.5885	-0.7257	9	256/3895	0.97
RIVI	-5.8974	0.0050		0.0429	0.0313		0.4021	-0.3595	4.1414	-0.5551	-0.0995	319	349/4135	0.94
ROSA	1.4977	-0.0024	-0.5731		-0.0509		-0.5070	0.3750	1.6799	0.5431	0.4006	150	1054/4155	1.02
RUPA	4.6053		-0.1788		-0.1260				1.3888	n/a		n.s.	495/1769	0.95
SALX	-0.0951		0.3588	0.0745	-0.0178		0.5632	0.5346	-0.1604	-1.5044	0.1940	41	1489/4155	1.06
SARA	-5.3376				0.0366		2.2211	-0.9533	-2.1278	n/a		336	53/2729	1.06
SHCA	-4.0361						0.4769	1.1450	0.7643	-0.9325	0.0523	67	82/4155	0.97
SOSC2	-0.4849		-0.3129		-0.0601		1.5468	-0.5922	2.1833	-1.5683	-1.2697	342	103/3895	1.12
SPBE	3.3520	0.0015	-0.1082		-0.0634		-1.6540	-0.1834	1.7781	-1.0072	-1.5863	187	2000/4155	1.01
SYAL	-1.6850	-0.0055	-0.5659	0.0384			-0.6906	-0.3020	2.2713	0.9673	-0.0779	203	797/3027	1.02
VAME	-2.8091		-0.1145	0.0246	0.0946	-0.0007	0.5078	-0.4173	1.2962	-1.4782	-1.4159	328	1672/3451	1.01
VASC	-2.2881	0.0030	-0.2546	0.0721	0.0440		0.2049	0.3065	-1.3505	-2.4470	-1.8411	56	1023/3237	1.03

B_0: Intercept term
ba: residual basal area in square feet per acre
ff: forest floor burn severity index, calculated for individual plots
time: number of years since the wildfire
elev: stand elevation in 100's of feet
cos(α)*slo: cosine of plot aspect (α in radians) times slope ratio
sin(α)*slo: sin of plot aspect (α in radians) times slope ratio
slo: plot slope (slope percent divided by 100)
PIPO/PSME habitat type series. (Note: the ABLA/PICO habitat type series coefficient is part of the B_0 term)
ABGR/THPL/TSHE habitat type series
occur/n: occur = number of occurrences for the species. n = number of observations
n.s.: non-significant at the 0.05 level

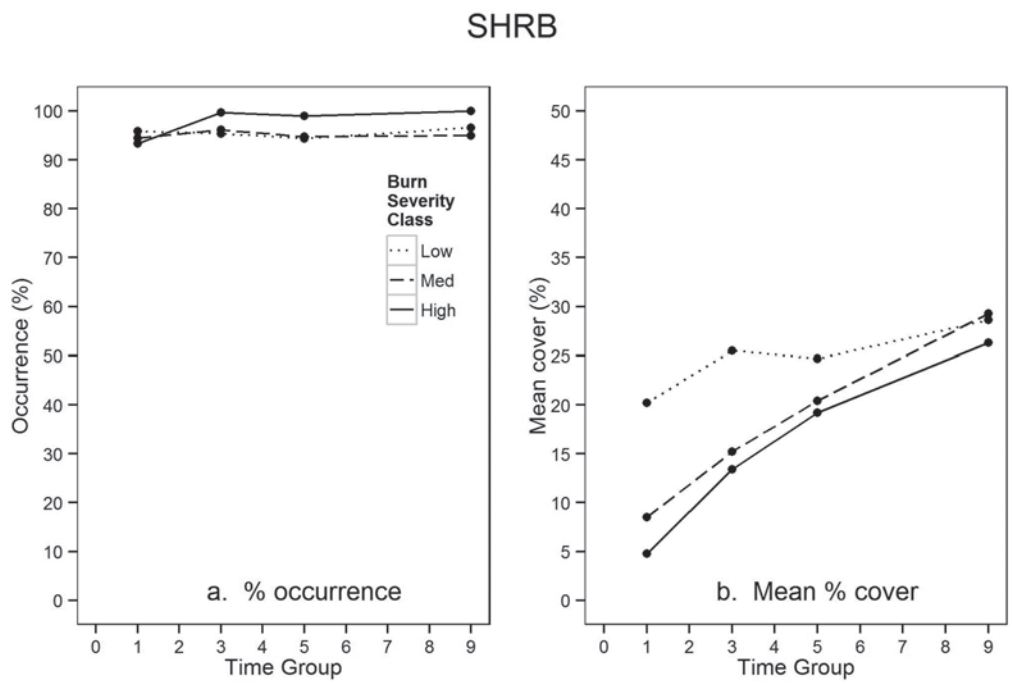

Figure 1—(a). Percent occurrence for SHRB (any shrub species) by burn severity class and time since wildfire. (b). Mean percent cover for SHRB by burn severity class and time since wildfire.

The probability of SHRB decreased with increasing basal area, and it increased with increasing slope steepness (table 6). The ABLA/PICO series had the highest occurrence of SHRB, followed by the ABGR/THPL/TSHE series, and then the PIPO/PSME series.

Some general trends are evident for the 28 species listed in table 6. The association between burn severity and probability of occurrence was generally negative (occurrence decreased with increasing burn severity), except for species that are primarily dependent on seed to become established after a wildfire. For these species (CESA, CEVE, RICE, SALX), occurrence increased with increasing burn severity. Occurrence increased with increasing time since wildfire for most species. The exception was RILA, which decreased slightly with increasing time. The predicted effects of residual basal area, elevation, slope and aspect, and habitat type series were variable, depending on the species.

The interaction of slope and aspect was significant in 24 of the 28 species models (table 6). Species differ in their optimum aspect (where they have the highest occurrence). The optimum aspect for occurrence can differ from the optimum aspect for cover or height.

Figure 2 shows three patterns for the interaction of slope and aspect. The first pattern is increasing occurrence with increasing slope steepness across all aspects, especially at the optimum aspect (fig. 2a). The second pattern is increasing occurrence with increasing slope steepness at the optimum aspect, but decreasing occurrence with increasing slope steepness that is opposite from the optimum aspect (fig. 2b). The third pattern is decreasing occurrence with increasing slope steepness across all aspects, but the decrease is less at the optimum aspect (fig. 2c).

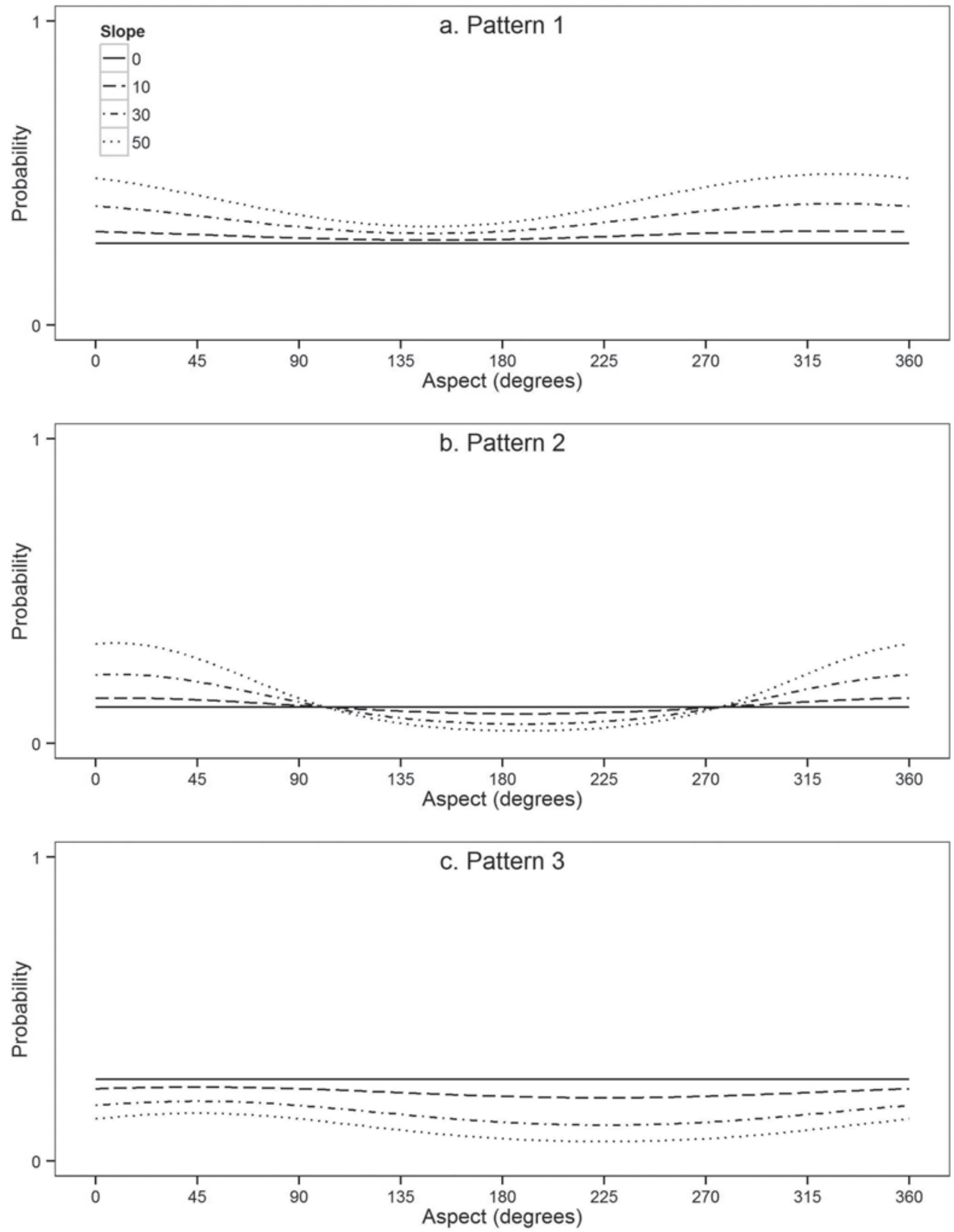

Figure 2—Example slope and aspect interactions. (a). Pattern 1. Occurrence increases with increasing slope steepness across all aspects, especially at the optimum aspect. This graph shows the probability of VAME occurrence, which had an optimum aspect of 328 degrees. (b). Pattern 2. Occurrence increases with increasing slope steepness at the optimum aspect, but decreases with increasing slope steepness that is opposite the optimum aspect (the optimum aspect + 180 degrees). This graph shows the probability of RILA occurrence, which had an optimum aspect of 9 degrees. (c). Pattern 3. Occurrence decreases with increasing slope steepness across all aspects, but the decrease is less at the optimum aspect. This graph shows the probability of LIBO2 occurrence, which had an optimum aspect of 45 degrees.

Elevation was a significant predictor of occurrence in 25 of the 28 species models (table 6). Occurrence increased with increasing elevation for 4 species and decreased with increasing elevation for 14 species. For seven species, the relationship between occurrence and elevation was quadratic; occurrence was lower at both lower and higher elevations, and highest at mid-elevations. Figure 3 shows three examples where predicted occurrence was highest at mid-elevations. When elevation has a quadratic effect, the highest probability can differ among species, as can the steepness of the curve.

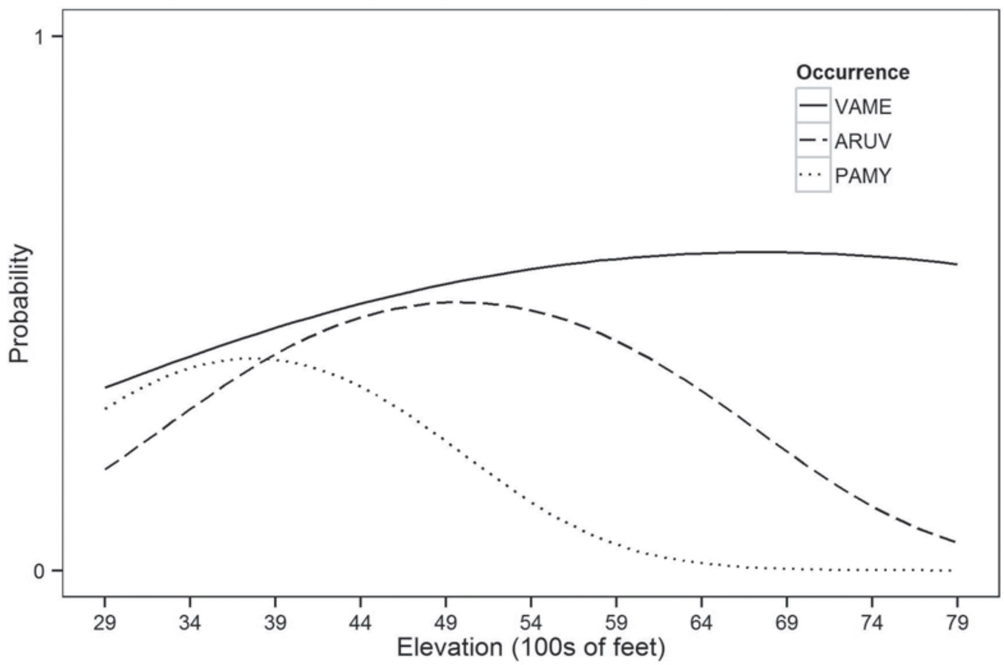

Figure 3—Examples of quadratic elevation coefficients. The upper curve is VAME occurrence, which peaked at 6,800 feet. The middle curve is ARUV occurrence, which peaked at 5,000 feet. The bottom curve is PAMY occurrence, which peaked at 3,800 feet.

Cover

A graph of percent SHRB cover by burn severity class and time shows that increasing burn severity was initially associated with decreasing cover, and that all three burn severities had increases in cover over time (fig. 1b). By the time of the last measurement, cover for all burn severity classes was between 25 and 30 percent.

Predicted SHRB cover decreased with increasing basal area, burn severity, and elevation (table 7). It increased with increasing age. SHRB cover increased with increasing slope steepness across all aspects, and was slightly better at the optimum aspect of 190 degrees (fig. 2, pattern 1). The most cover was on the ABGR/THPL/TSHE series, followed by the ABLA/PICO series, and then the PIPO/PSME series.

Table 7—Coefficients for estimating cover proportion on 1/300 acre plots following wildfire. The form of the equation is COVER = $(1 + e^{-(\sum \beta_i X_i)})^{-1}$, where "e" is the base of natural logarithms.

Species	B_0	ba	ff	age	delay	elev	$elev^2$	cos(α)*slo	sin(α)*slo	slo	PIPO/PSME	ABGR/ THPL/TSHE	Optimum aspect	n	Chi^2/df
SHRB	-0.5907	-0.0046	-0.4427	0.1283		-0.0195		-0.3095	-0.0570	0.7071	-0.2533	0.0364	190	3992	0.51
ACGL	-0.9407	-0.0058		0.0970	-0.7686	-0.0432							n.s.	179	0.32
ALVI	-19.2663		-0.9554	0.1251	-0.5557	0.6823	-0.0067	-0.5065	-2.4634	2.8468			258	220	0.44
AMAL	-1.7102		-0.2972	0.1093	-0.6416	-0.0532		0.8065	-0.5150	1.3040	0.7001	-0.6493	327	491	0.10
ARUV	-3.8848	0.0098		0.1430	-0.3880			-0.3576	1.9159	-0.4372			101	278	0.32
BERB	-3.9318							-1.6502	-0.4999	-0.3905			197	1118	0.46
CESA	-4.2751	-0.0670	0.9180	0.3639	-0.2304								n.s.	192	0.37
CEVE	-13.8531	-0.0352	0.5234	0.2957		0.3728	-0.0040	-1.0106	0.3103	-0.8924	1.2098	1.2996	163	883	0.43
CHUM	-6.7071		-1.3602		-0.3838	0.0750				-4.5994			flat	363	0.32
ERNA	-4.7759			0.2917				-4.1365	-1.3869	-4.6998			199	114	0.11
HODI	-4.7922			0.2368									n.s.	105	0.19
LIBO2	-14.8537		-0.5052	0.0690	-0.4878	0.5257	-0.0056	3.1051	1.1373	0.2078			20	440	0.34
LOUT2	-2.9153			0.1077		-0.0445		1.8724	0.4734	0.1878			14	321	0.22
MEFE	-11.7505		-1.3650		-0.3654	0.3424	-0.0026						n.s.	219	0.39
PAMY	-3.3493		-0.7549		-0.2908			-0.3378	0.9684	0.3375			109	837	0.31
PHMA	-3.6889		0.7381	0.0830	-0.8910			0.9296	0.1564	0.5669			10	113	0.28
RICE	-19.7675			0.2233		0.3075				-4.3461			flat	156	0.25
RILA	-20.1347		-1.1164			0.6919	-0.0065	6.0179	-0.6395	-6.5975			351	256	0.21
RIVI	-22.0370	0.0094				0.6268	-0.0058						n.s.	349	0.16
ROSA	-3.5631			0.0700		-0.0273		-0.0098	-0.5775	0.8570	0.3689	0.2300	269	1054	0.16
RUPA	-3.1720			0.0771	-0.6955						n/a	-0.3980	n.s.	495	0.33
SALX	-4.6964	-0.0043		0.2350	-0.2917	0.0092					0.0307	0.2734	n.s.	1489	0.24
SARA													n.s.	58	n/a
SHCA	-3.2429		-0.5533	0.1631									n.s.	82	0.12
SOSC2	-7.0763		1.4000		-0.5609			4.3143	0.8941	-0.1253			12	103	0.06
SPBE	-3.0387			0.0718	-0.3455	-0.0130		-0.0247	-0.3738	1.2029	-0.5069	-0.8998	266	2000	0.27
SYAL	-1.6817	-0.0039		0.0654	-0.3326					-2.0041	-0.3219	-1.3646	flat	797	0.36
VAME	-21.1484		-0.6384	0.1158	-0.2023	0.6386	-0.0054	-0.6955	-0.2378	0.7382	-0.3873	0.2572	199	1672	0.42
VASC	-5.2540		-0.9022	0.0567	-0.4350	0.1183	-0.0008	-0.0458	-0.6801	-0.6431	-1.3191	-0.5213	266	1023	0.36

B_0: Intercept term
ba: residual basal area in square feet per acre
ff: Forest floor burn severity index, calculated for individual plots
age: number of years the species has been on the plot
delay: number of years between the wildfire and the first occurrence of the species on the plot
elev: stand elevation in 100's of feet
cos(α)*slo: cosine of plot aspect (α in radians) times slope ratio
sin(α)*slo: sin of plot aspect (α in radians) times slope ratio
slo: plot slope (slope percent divided by 100)
PIPO/PSME habitat type series. (Note: the ABLA/PICO habitat type series coefficient is part of the B_0 term)
ABGR/THPL/TSHE habitat type series
n: number of observations used in the equation
n.s.: non-significant at the 0.05 level

There are also some general trends across species listed in table 7. For several tall shrub species (ACGL, CESA, CEVE, SALX), cover decreased with increasing basal area. The negative effect of basal area was strongest for CEVE and CESA. Cover decreased with increasing burn severity for species such as ALVI, AMAL, CHUM, LIBO2, MEFE, PAMY, RILA, SHCA, VAME, and VASC, but cover increased with increasing burn severity for CESA, CEVE, PHMA, and SOSC2. As one would expect, the longer the species was on the plot, the more cover was predicted. Conversely, the longer it took the species to become established on the plot (delay to plot occupancy), the less cover could be expected. Other independent variables (elevation, slope and aspect, habitat type series) were species-specific.

For many species, the optimum aspect for cover was close to the same aspect for occurrence (tables 6 and 7). Sometimes the optimum aspects were different; for example, the optimum aspect for VAME occurrence was 328 degrees while the optimum aspect for cover was 199 degrees, and the optimum aspect for AMAL occurrence was 166 degrees while the optimum aspect for cover was 327 degrees.

The optimum aspect is sometimes shown as “flat” in table 7. This happens when the cosine and sine terms are not significant, but the slope term is significant and has a negative sign. The negative slope term in this situation means that cover decreases with increasing slope steepness in any direction; thus, the greatest cover is on flat topography.

Height

Models predicting shrub heights are shown in table 8. The best variable to predict shrub height was the cover proportion of that same species on the plot. This is because of the strong positive relationship between cover and height. Height decreased with increasing basal area for 15 shrub species, the exception being MEFE. Height also decreased with increasing burn severity for 11 species, except RICE, where the coefficient was positive. Height increased with increasing number of years that the species was on the plot for 23 of the 28 species. Other independent variables (elevation, slope and aspect, habitat type series) were species-specific. Optimum aspects for height can differ from optimum aspects for occurrence or cover. As noted in the section above, an optimum aspect of “flat” indicates that height decreases with increasing slope steepness in any direction; thus the best heights are on flat topography.

Delay to Plot Occupancy

The number of years between the wildfire and when a species was first observed on a plot, which we call delay to plot occupancy (also called “delay” in table 7), is a significant predictor of cover (table 7). The effect of delay to plot occupancy is also to reduce shrub heights because height and cover are positively correlated. The longer it takes a species to become established on a plot, the less cover and height can be expected for a given number of years of growth.

Table 8—Coefficients for predicting shrub heights. The form of the equation is HT = exp(∑ßiXi).

Species	B_0	cover	ba	ff	age	elev	$elev^2$	cos(α)*slo	sin(α)*slo	slo	PIPO/PSME	ABGR/ THPL/TSHE	Optimum aspect	n	AIC
ACGL	0.6486	3.8170	-0.0030	-0.2222	0.0617			-0.8410	0.1046	-0.3027			173	178	400.3
ALVI	0.2751	2.1034	-0.0038		0.1207								n.s.	219	491.0
AMAL	0.1697	7.0541	-0.0023		0.0478	-0.0094		-0.0720	0.1587	0.5478			114	491	792.9
ARUV*													n.s.	278	n/a
BERB	-0.6980	0.6293			0.0028			-0.0287	0.0082	-0.0228	-0.0150	0.0223	164	1117	-1646.8
CESA	-0.4832	0.7864	-0.0058		0.1972			-0.8061	0.0647	-0.1428			175	192	340.6
CEVE	-0.0331	1.7629	-0.0016	-0.0618	0.0665	-0.0116		-0.3291	-0.0120	0.0389			182	881	921.4
CHUM*													n.s.	363	n/a
ERNA	-4.2733	3.9770	-0.0047		0.0758	0.0760		-0.5183	-0.3678	0.1015			215	114	186.7
HODI	0.6060	2.6587	-0.0038		0.1248	-0.0217							n.s.	105	180.6
LIBO2*													n.s.	440	n/a
LOUT2	-0.1184	6.9095		-0.0832	0.0376	-0.0058				0.4459			n.s.	321	460.3
MEFE	0.4622	2.2080	0.0016	-0.1327	0.0773	-0.0092							n.s.	219	355.3
PAMY	-0.6568	3.2549		-0.0427	0.0103						0.0420	0.0702	n.s.	837	86.9
PHMA	-0.2521	1.6968	-0.0058		0.0684			-0.1729	0.3515	0.4954			116	113	155.0
RICE	-0.6807	3.5028	-0.0021	0.1668	0.1149								n.s.	155	261.6
RILA	-0.2675	7.8791	-0.0009	-0.1364	0.0599					-0.4287	-0.2051	0.0063	flat	256	326.1
RIVI	-2.0071	8.6992	-0.0015		0.0804	0.0586	-0.0006	-0.3863	-0.0649	0.0946			190	349	466.6
ROSA	0.1618	4.7833	-0.0006		0.0512	-0.0185				0.5503	0.0688	0.0028	n.s.	1054	1208.4
RUPA	-0.2772	3.0368		-0.1113	0.0378			-0.2904	0.0697	0.0980			167	502	702.4
SALX	0.6650	2.6760	-0.0022	-0.0613	0.1296	-0.0180				0.4263	-0.0692	-0.1172	n.s.	1488	2595.3
SARA	1.2233			-0.2705		-0.0165							n.s.	58	107.6
SHCA	1.1280	4.1977		-0.1430	0.0735	-0.0192		-0.5605	-0.0047	-0.0994			180	82	98.1
SOSC2	-0.3296	12.292			0.0671								n.s.	102	179.1
SPBE	-0.0706	1.9987	-0.0009		0.0183	-0.0076				0.1977	-0.0502	0.0968	n.s.	2000	1949.5
SYAL	0.1055	1.5519	-0.0015		0.0442	-0.0088				0.2212	0.1943	0.0348	n.s.	797	1094.6
VAME	-2.1027	1.3821		-0.1494	0.0276	0.0671	-0.0006			-0.1691	-0.1581	0.0545	flat	1671	1299.2
VASC	-0.6927	0.1586											n.s.	1024	-1910.8

* For these species, height is always 0.5 feet.
B_0: Intercept term
cover: Cover of the same species on the plot
ba: residual basal area in square feet per acre
ff: Forest floor burn severity index, calculated for individual plots
age: number of years the species has been on the plot
elev: stand elevation in 100's of feet
cos(α)*slo: cosine of plot aspect (α in radians) times slope ratio
sin(α)*slo: sin of plot aspect (α in radians) times slope ratio
slo: plot slope (slope percent divided by 100)
PIPO/PSME habitat type series. (Note: the ABLA/PICO habitat type series coefficient is part of the B_0 term)
ABGR/THPL/TSHE habitat type series
n: number of observations used in the equation
n.s.: non-significant at the 0.05 level

The Appendix shows graphs of percent cover by delay to plot occupancy for each of the 28 species. In figure 4 we show the effects of delay for three species to illustrate a result that applies to almost all species: percent cover rarely exceeds trace or 5 percent when delay is greater than about 2 years. Figure 4a shows percent cover by delay for SPBE (which primarily sprouts from the roots or rhizomes, with a maximum cover of about 50 percent), figure 4b shows VAME (which primarily sprouts from rhizomes or root crowns, with a maximum of about 70 percent cover), and figure 4c shows CEVE (which is very dependent on seed germination following wildfire, with a maximum cover approaching 100 percent). We used a “jitter” feature in R (R Core Development Team 2014) in these figures to show the density of observations at a given intersection of percent cover and year.

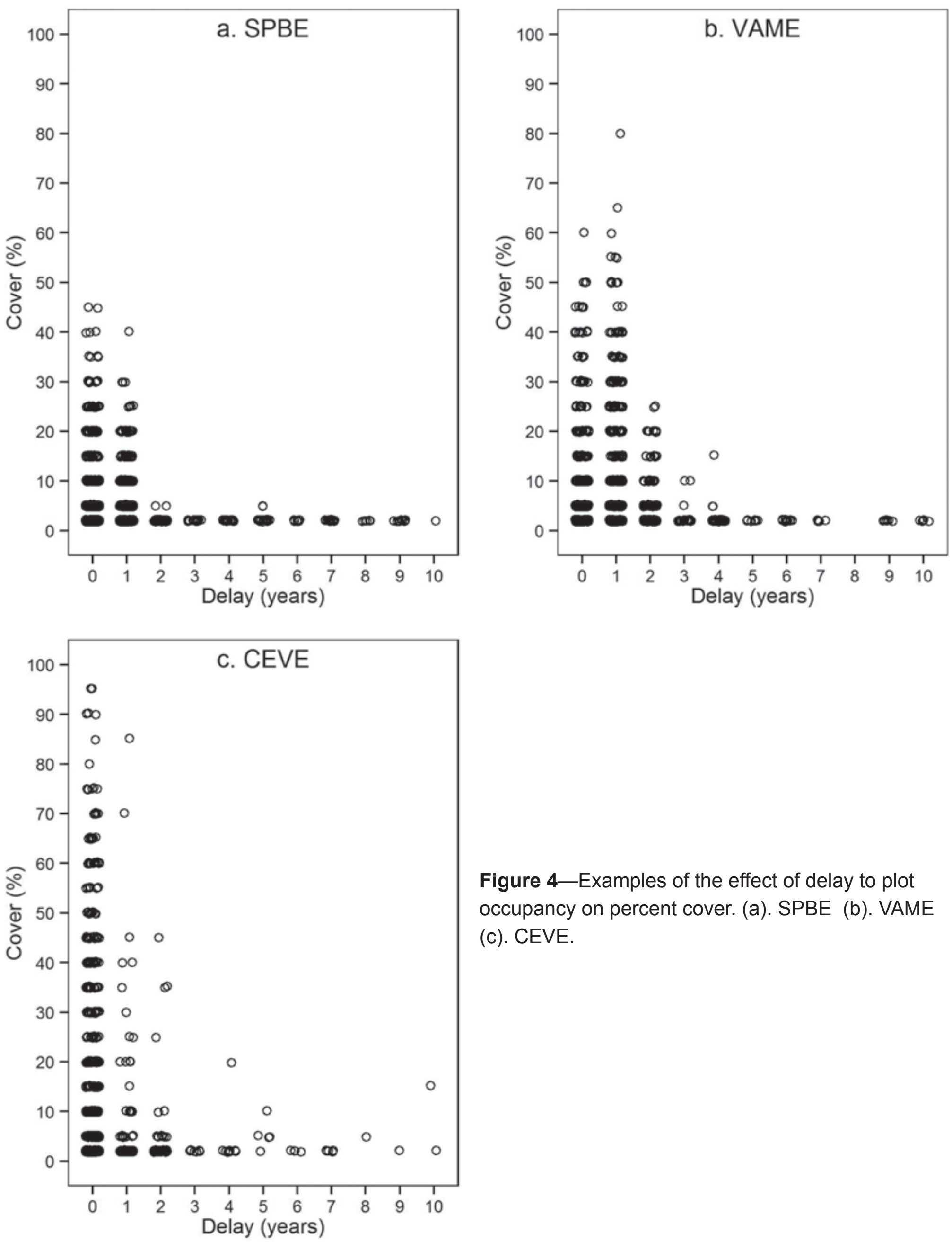

Figure 4—Examples of the effect of delay to plot occupancy on percent cover. (a). SPBE (b). VAME (c). CEVE.

Discussion

The objective of this study was to predict shrub response to wildfire as a function of burn severity, site factors, and time since wildfire. Models developed from this study predict shrub occurrence, cover, and height as a function of burn severity, residual overstory density, elevation, slope steepness, aspect, habitat type series, and time since wildfire. These models are suitable for developing a shrub response model similar to COVER (Moeur 1985) in the Forest Vegetation Simulator (FVS; Crookston and Dixon 2005). In the COVER model, the disturbance that triggers vegetation response is management activity (harvesting or site preparation). Models presented in this paper could be used to develop a model where wildfire is the disturbance that triggers vegetation response. Our models may also be useful in the Understory Response Model (Sutherland and Miller 2005).

We used the (generalized chi-square)/(degrees of freedom) statistic that is reported in GLIMMIX to assess goodness of fit for the occurrence and cover models. A chi^2/df value of 1.0 indicates a good fit. The probability of occurrence models have good values ranging from 0.78 to 1.21 (table 6). However, values were much lower for the cover proportion models, ranging from 0.06 to 0.51 (table 7). These low chi^2/df values mean that the models overpredict cover proportion. These results occurred because most of our observations were near the zero end of the [0,1] interval; in other words, all the 0.01 (trace) and 0.05 (5 percent) cover proportions in our data caused overprediction in GLIMMIX. We explored several alternatives, but were unable to resolve the problem. However, the models presented in table 7 are still valuable because we were able to quantify cover proportion as affected by burn severity, site factors, and age. If these data are used in a predictive model such as the Forest Vegetation Simulator, it would be appropriate to quantify the distribution of cover, and then use the distribution to assign cover values to individual plots. Ferguson and Carlson (1993) used this strategy to choose the number of trees on plots as part of a regeneration model in FVS.

During development of occurrence, cover, and height models, we tested percent cover of trees on the 1/300-acre plot as an independent variable. Often the dependent variable (occurrence, cover, or height) increased with increasing tree cover, which is counterintuitive. Our explanation is that increasing tree cover is a surrogate for microsite quality. Better microsites can have both more tree cover and more shrubs. Stage and Boyd (1987), in an example from the northern Rocky Mountains, show that northerly slopes had both high tree stocking and high percent shrub cover, whereas southerly slopes had decreased tree stocking as shrub cover increased. Therefore, we did not use tree cover to predict shrub occurrence, cover, or height; we used other site quality variables (such as slope and aspect, habitat type series, and elevation). The effect of tree competition on shrub development is best explained by studies where vegetation is controlled on some plots but not controlled on other plots.

Even though shrub response to wildfire can be predicted, it should be kept in mind that these data are “noisy.” Plants can be present on a plot one year, gone the next measurement, and back the third measurement. If a plant is near the outside cylinder of the plot, it could be pushed outside the plot by snow, thus being absent one year, but may grow back into the plot another year. Disease, insects, snow breakage, and browsing can also reduce plant size from one measurement to the next. Field crews could miss recording a species on a plot, although we minimized this possibility by providing the crew with a list of species found on the plot in previous years.

Recording percent cover is subjective, even though crews were trained in ways to quantitatively estimate cover, such as dividing the plot into quadrants, measuring shrub canopy diameters and converting the measurement to percent cover, using tables that converted square feet to percent cover, having all crew members discuss their estimate and their reasoning, and making sure that crew members felt free to discuss their estimates until a consensus was reached. With these techniques, field crews usually narrowed their estimates to within 5 percent of each other.

We have observed that big game browsing can have a large effect on shrub responses. Animals can quickly reduce the size of a shrub on a plot. Browsing can confound the response of shrubs to wildfire; for example, if a species is preferred food for elk (*Cervus elaphus*) or deer (*Odocoileus* spp.) plants would not be as abundant or large in size, nor produce as many seeds. Even though the species might respond dramatically to wildfire, browsing suppression would mask the species' true response. Because browsing effects are unquantified in most studies, including ours, some species' response to wildfire may be unknown.

The models predicting average height (table 8) should not be thought of as "growth" models. They merely predict the net change in height over time. There are two reasons to be cautious. First, the plants measured at successive years may not be the same plants. This happens if a species occurs on a plot at one measurement, but the plants are not there the next measurement while other plants of the same species have become established. Second, shorter heights over time can occur even if all plants remain on the plot. Suppose a shrub species occurs on a plot with 5 percent cover and is 2 feet tall, and at the next measurement, that plant has 10 percent cover and is 2.5 feet tall. During the time interval, new plants of the same species have become established elsewhere on the plot. If the new plants have 10 percent cover and are 0.5 feet tall, average height of that species on the plot has decreased over time from 2.0 feet to 1.5 feet.

An important finding of this study is that percent cover of shrubs is generally low when the delay to plot occupancy is greater than about 2 years (fig. 4 and Appendix). For example, SPBE is a species that sprouts after being topkilled by wildfire. When SPBE was present the first year after the fire (a delay of 0 years) or the second year after the fire (a delay of 1 year), some cover values were eventually as high as 45 percent, but a delay beyond 2 years resulted in trace values with a few at 5 percent. This means that SPBE can continue to become established on plots, but will be only scattered individuals that do not become large plants.

Perhaps only species that sprout from roots or rhizomes would have decreased cover after delays of 3 or more years. However, species that reproduce after wildfire exclusively by seed (for example, CESA, CEVE, and SALX) also show a decline in percent cover with increasing years (figs. 10c, 11c, 25c in the Appendix).

Knowledge about delay to plot occupancy has management implications. An inventory 2 or 3 years after the wildfire would provide information on the percentage of plots occupied by shrub species. These are the plots that could potentially have high percent cover values over time. A high percentage of plots with a tall species at 2 to 3 years could mean a shrubfield will develop, and depending on management objectives, remedial treatments could be scheduled. Conversely, any plants of the same species that become established after a delay of 2 years are unlikely to have more than 5 percent cover.

As far as we can determine, others have not reported the effects of delay to plot occupancy. It would be useful to corroborate our finding with other studies. Perhaps there are existing studies that could be re-analyzed, or new studies could collect data to verify the effect of delay to plot occupancy.

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Appendix

The format for presentation of individual species results is as follows. First, we will review the distribution, size, reproduction, and fire effect of the species. We use the Fire Effects Information System (FEIS; http://www.feis-crs.org/feis), which is a collection of thorough online reviews of the scientific literature about fire effects on plants and animals. The authors are subject matter experts, and reviews are periodically revised to keep them current. Next, we look at occurrence in our data: percent occurrence on our 896 plots, graphs of the raw data showing percent occurrence by burn severity class and time since wildfire, and probability of occurrence models. Then, we look at cover on plots where the species occurred: graphs of raw percent cover by burn severity class and years since wildfire, the effect of delay to plot occupancy (time between the wildfire and when the species was first observed on the plot), and development of cover proportion models. Finally, information on shrub height is presented.

ACGL (*Acer glabrum*), Rocky Mountain Maple

FEIS Database

ACGL is a wide-ranging species, growing from Alaska to as far south as Arizona and New Mexico, and extending east in mountainous areas to the Great Plains (Anderson 2001a). It can typically be found growing as an understory species in a wide range of coniferous forest types. ACGL can grow as a solitary stem, 20 to 30 feet tall, though it is most often seen as multi-stemmed shrubs that are 5 to 6 feet tall. It can grow on all aspects, but percent cover is greatest on southern aspects. ACGL can germinate from seed and, when disturbed, can sprout from the root crown. After burning, ACGL can sprout prolifically and also regenerate from wind-blown seed from neighboring unburned areas. Higher severity fires tend to reduce sprouting.

Occurrence

ACGL occurred on 8.5 percent of the plots (table 4), but it rarely occurred on the BITT-BITT and MALH-FLAG fires. A graph of occurrence by burn severity and time since wildfire shows that the high burn severity class had the least occurrence (fig. 5a).

Habitat types that were excluded to develop the probability model for ACGL were the PIPO series, some high elevation ABLA habitat types, and the PICO series (table 5). The probability of ACGL occurrence decreased with increasing burn severity and elevation (table 6), and increased slightly with increasing basal area. The occurrence was highest on the ABGR/THPL/TSHE series, lower on the ABLA series, and lowest on the PSME series.

Cover

A graph of mean percent cover by burn severity class and time since wildfire shows that the high burn severity class had the lowest percent cover (fig. 5b), but this relationship was not significant in the regression analysis. Percent cover of ACGL on individual plots reached as great as 65 percent, but it was generally 25 percent or less. Cover was almost always trace amounts when the delay to plot occupancy exceeded 2 years (fig. 5c), and this figure also shows that few ACGL plants became established on plots after about 5 years.

Predicted cover of ACGL decreased with increasing basal area, elevation, and delay to plot occupancy (table 7). It increased with increasing age.

Height

Mean height for ACGL grew rapidly over the life of the study, with consistently greater height for the medium burn severity class, followed by low and then high burn severity classes (fig. 5d). For the height prediction model (table 8), height increased with increasing cover and age, whereas height decreased with increasing basal area and burn severity. Height increased with increasing slopes on southerly aspects, but decreased with increasing slopes on northerly aspects (fig. 2, pattern 2). Optimum aspect for ACGL height was 173 degrees.

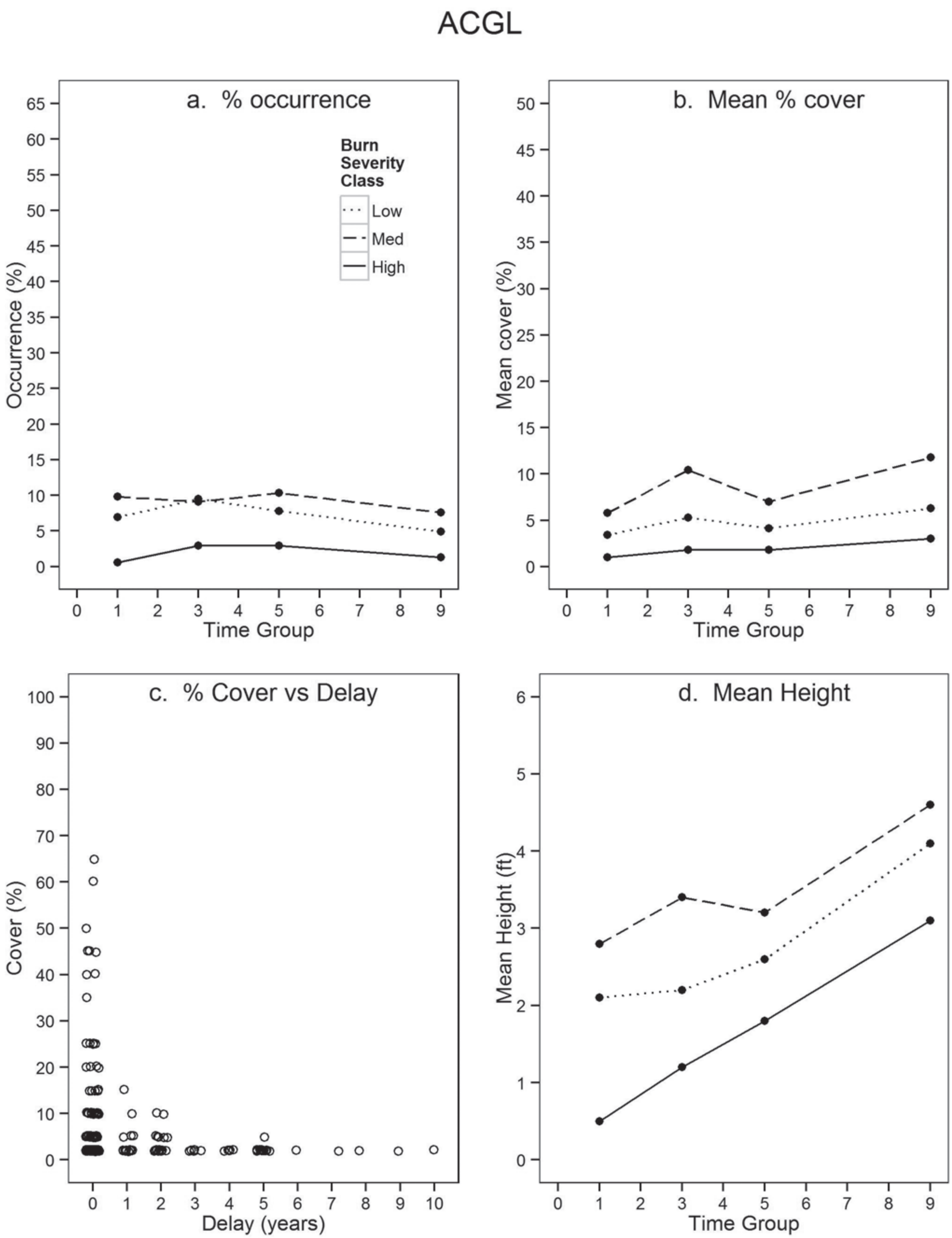

Figure 5—ACGL (*Acer glabrum*). (a). Percent occurrence by burn severity class and time since wildfire. (b). Mean percent cover by burn severity class and time since wildfire. (c). Percent cover on individual 1/300-acre plots by number of years between the wildfire and establishment of the species on the plot. (d). Mean height by burn severity class and time since wildfire.

ALVI (*Alnus viridis* ssp. *sinuata* = *A. sinuata*), Sitka Alder

FEIS Database

The range of ALVI is from Alaska south to northern California, and east to Idaho and central Montana (Uchytil 1989). It is typically a multi-stemmed shrub that grows from 10 to 15 feet tall, and on occasion grows as a single stem to 30 to 40 feet tall. It is a pioneer shrub that prefers moist cool forest sites. The primary form of regeneration is by seed, which is lightweight and easily travels from offsite plants via wind to disturbed sites. This species can also sprout from the root crown after disturbance. Only the most severe fires reduce the presence of ALVI, with low to moderate intensity fires favoring its growth.

Occurrence

ALVI occurred on 8.5 percent of the 896 plots (table 4), with none on the MALH-FLAG fire and few on the BITT-BITT fire. A graph of occurrence by burn severity and time since wildfire shows higher occurrence on the low severity class (fig. 6a).

The PIPO and PSME habitat types were excluded before developing the probability model (table 5). The probability of occurrence for ALVI decreased with increasing basal area and burn severity (table 6). It increased with time. The relationship with elevation was quadratic, with the highest probability at 3,900 feet. ALVI occurrence increased with increasing slope steepness on northerly aspects, and it decreased with increasing slope steepness on southerly aspects (fig. 2, pattern 2). The optimum aspect was 2 degrees. The ABLA/PICO series had the highest occurrence of ALVI, followed by the ABGR/THPL/TSHE series.

Cover

Mean percent cover for ALVI was considerably greater for the low burn severity class than for either the medium or high severity classes (fig. 6b). Percent cover on individual plots approached 100 percent (fig. 6c). Once the delay to plot occupancy reaches 2 years, percent cover is usually 10 percent or below.

Predicted cover decreased with increasing burn severity and delay to plot occupancy (table 7). It increased with age, and the effect of elevation is quadratic, with the highest cover at 5,100 feet. ALVI cover increased with increasing slope steepness on all aspects, especially at the optimum aspect of 258 degrees (fig. 2, pattern 1).

Height

The graph of ALVI shows mean height that increased rapidly over time, with the low burn severity class having greater mean height than the medium or high burn severity classes (fig. 6d). However, burn severity is not a significant variable in the height prediction model (table 8). ALVI height increased with increasing cover and age but decreased with increasing basal area.

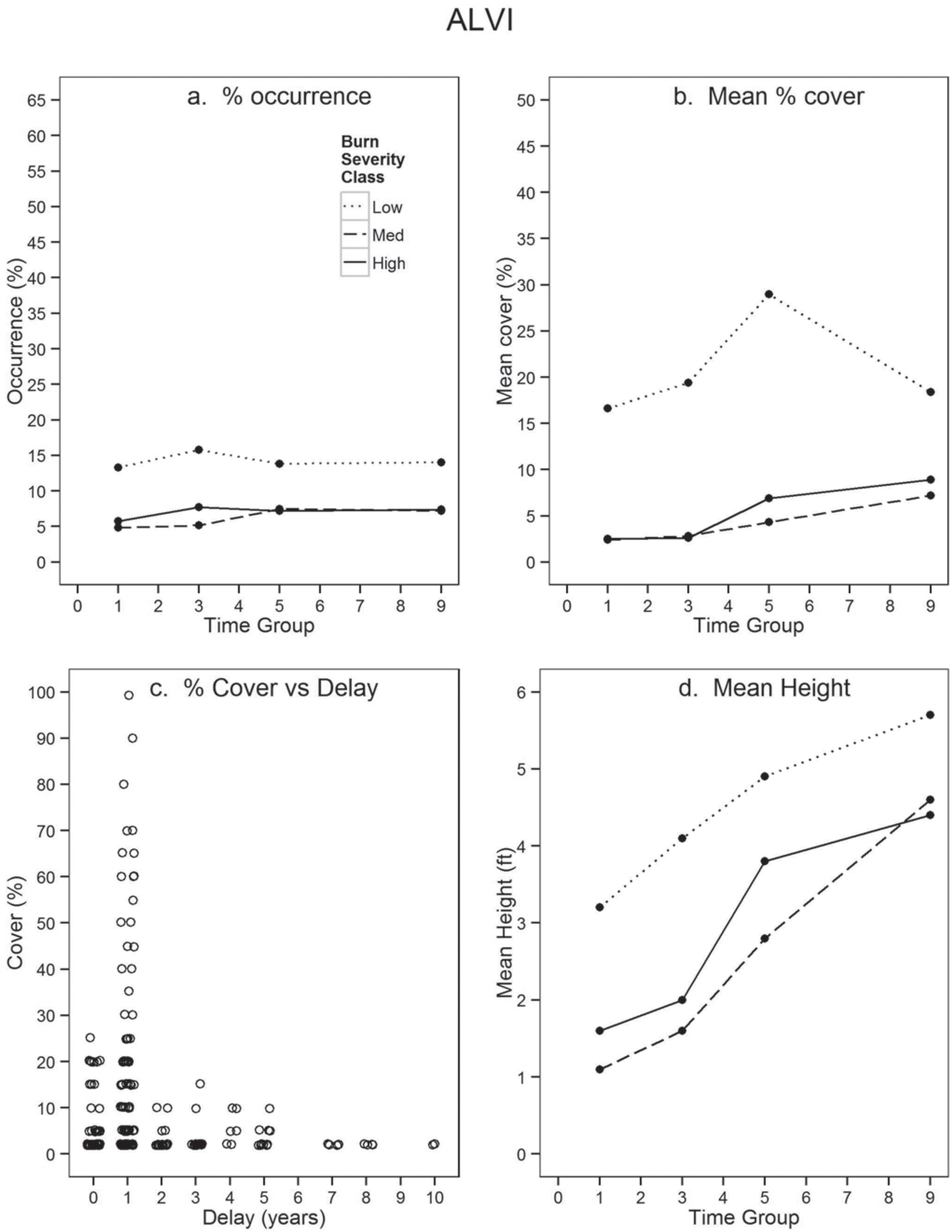

Figure 6—ALVI (*Alnus viridis* ssp. *sinuata*). (a). Percent occurrence by burn severity class and time since wildfire. (b). Mean percent cover by burn severity class and time since wildfire. (c). Percent cover on individual 1/300-acre plots by number of years between the wildfire and establishment of the species on the plot. (d). Mean height by burn severity class and time since wildfire.

AMAL (*Amelanchier alnifolia*), Saskatoon Serviceberry

FEIS Database

The distribution for AMAL is from southern Alaska to southern Oregon and east as far as the Great Plains, where it is mostly seen only in wooded draws (Fryer 1997). This species' typical habitat is in lower-elevation coniferous forests. AMAL is a deciduous shrub or small tree, reaching heights of 3 to 26 feet. It has an extensive root system, and most commonly regenerates by sprouting from the root crown or rhizomes; rarely does it regenerate from seed. It readily sprouts after wildfires, and with its deep root system, can even sprout after high intensity fires.

Occurrence

AMAL occurred on 19.6 percent of the 896 plots (table 4), although very few were found on the MALH-FLAG fire. The low burn severity class had slightly higher occurrence of AMAL than the medium or high severity classes, and occurrence increased slightly over time (fig. 7a).

Two high elevation habitat types were excluded from the data before developing the probability model (table 5). Predicted AMAL occurrence decreased with increasing burn severity and elevation (table 6). The probability increased with increasing time. Occurrence increased with increasing slope steepness on all aspects, more so at the optimum aspect of 166 degrees (fig. 2, pattern 1). Predicted occurrence was highest on the ABLA/PICO series, lower on the PIPO/PSME series, and lowest on the ABGR/THPL/TSHE series.

Cover

Mean percent cover was similar for all burn severity groups and changed little over time (fig. 7b). Coverage was always 25 percent or less, and when delay between the fire and plot occupancy was greater than 2 years, cover was minimal (fig. 7c). This figure also shows that AMAL continued to become established on plots years after the wildfire.

Predicted AMAL cover decreased with increasing burn severity, delay in occupying the plot, and elevation (table 7). Cover increased with age. It increased with increasing slope steepness on all aspects, especially at the optimum aspect of 327 degrees (fig. 2, pattern 1). The PIPO/PSME series had the most cover of AMAL, the ABLA/PICO series was intermediate, and the ABGR/THPL/TSHE series had the least.

Height

The graph of mean AMAL height by time and burn severity (fig. 7d) shows greater height for the medium severity class, followed by high severity and low severity, though burn severity was not a significant variable in the height prediction model (table 8). Predicted height increased with increasing cover and age, whereas height decreased with increasing basal area and elevation. Height increased with increasing slope steepness across all aspects, and was even greater at the optimum aspect of 114 degrees (fig. 2, pattern 1).

AMAL

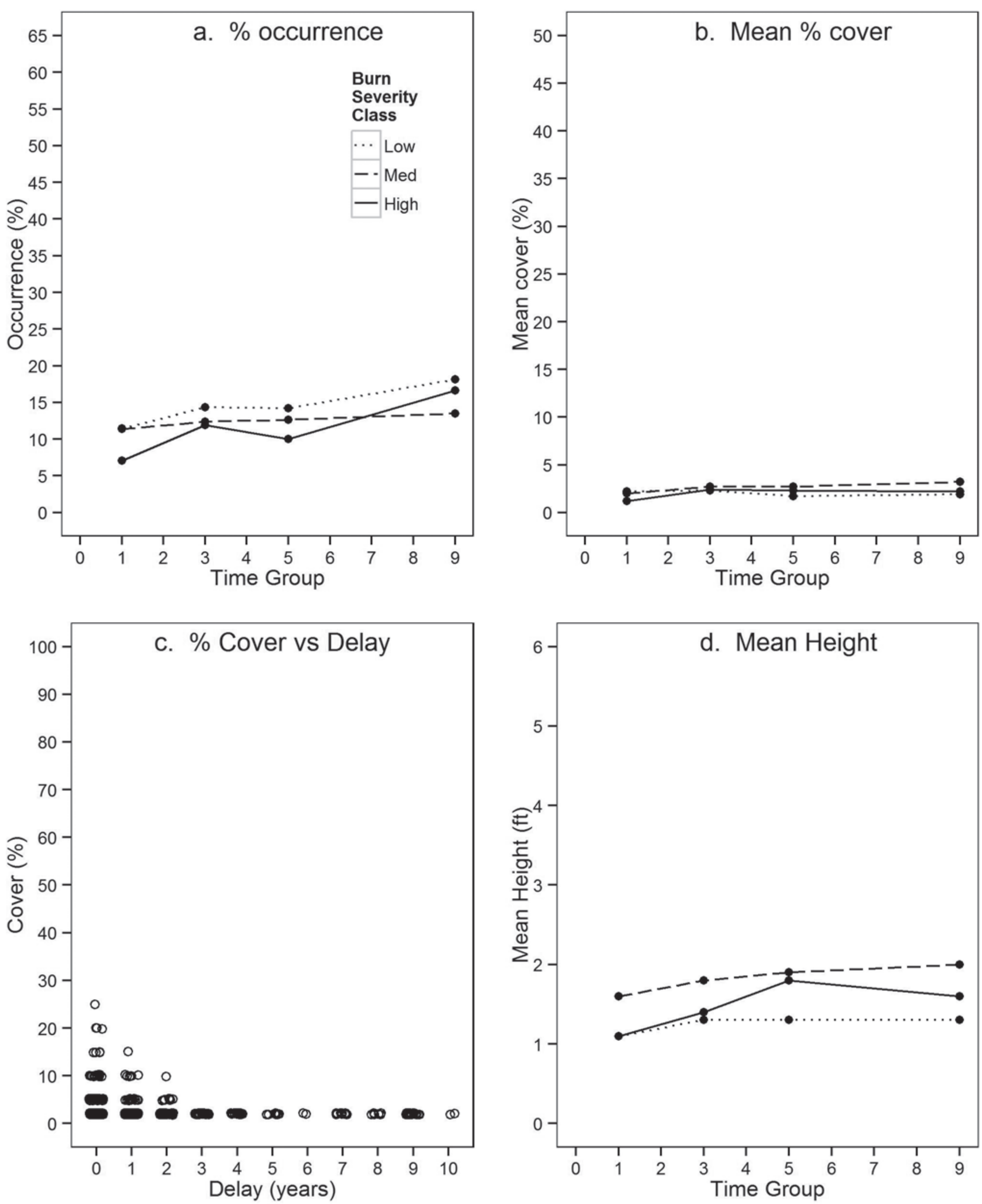

Figure 7—AMAL (*Amelanchier alnifolia*). (a). Percent occurrence by burn severity class and time since wildfire. (b). Mean percent cover by burn severity class and time since wildfire. (c). Percent cover on individual 1/300-acre plots by number of years between the wildfire and establishment of the species on the plot. (d). Mean height by burn severity class and time since wildfire.

ARUV (*Arctostaphylos uva-ursi*), Kinnikinnick

FEIS Database

ARUV has an extensive range throughout the northern United States and Canada, and extending south through the Rocky Mountains to New Mexico (Crane 1991). It is often found as an understory species in open coniferous forests, especially drier forest types. It is an evergreen shrub that grows along the ground, with many trailing stems. The primary form of regeneration is vegetatively from stems sending out roots from nodes. Because it regenerates from stems often rooted in the surface organic soil layer, intense fires that burn these organic layers will greatly hinder ARUV regeneration.

Occurrence

ARUV occurred on 9.4 percent of plots (table 4). A graph of occurrence by burn severity class and time shows the highest occurrence on the low severity class, with decreasing occurrence for medium severity, and the least for high severity (fig. 8a). There is little apparent increase in occurrence over time.

The three habitat type series excluded before developing the probability model for ARUV were the PIPO, THPL, and TSHE series (table 5). The probability of ARUV occurrence decreased with increasing burn severity (table 6). Elevation had a quadratic effect, with the highest probability at 5,000 feet. Occurrence decreased with increasing slope steepness on all aspects, slightly more so on southwesterly aspects (fig. 2, pattern 3). The optimum aspect was 48 degrees. The ABGR series had the highest occurrence, followed by the PSME series, and then the ABLA/PICO series.

Cover

Mean percent cover increased over time, with the low burn severity class having the most cover (fig. 8b). Cover on individual plots was up to 70 percent, with largest values being where delay to plot occupancy was less than 3 years (fig. 8c).

Predicted ARUV cover increased with increasing basal area and age (table 7). It decreased with increasing delay to plot occupancy. ARUV cover decreased with increasing slope steepness on westerly aspects, and increased with increasing slopes on easterly aspects (fig. 2, pattern 2). The optimum aspect for ARUV cover was 101 degrees.

Height

Both figure 8d and table 8 show that ARUV height was always 0.5 feet.

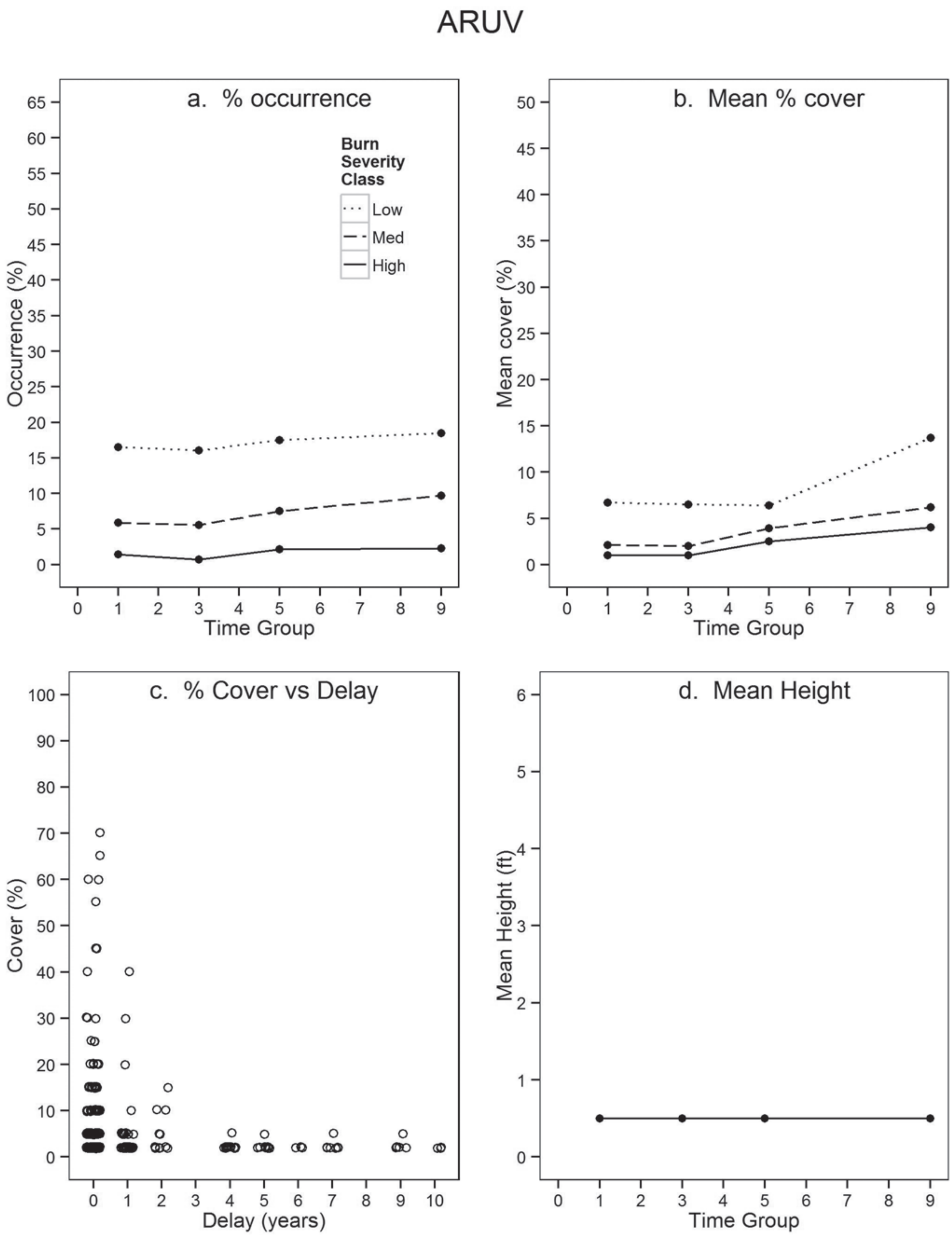

Figure 8—ARUV (*Arctostaphylos uva-ursi*). (a). Percent occurrence by burn severity class and time since wildfire. (b). Mean percent cover by burn severity class and time since wildfire. (c). Percent cover on individual 1/300-acre plots by number of years between the wildfire and establishment of the species on the plot. (d). Mean height by burn severity class and time since wildfire.

BERB (*Berberis* species), Oregon Grape

FEIS Database

Two *Berberis* species occur in the study area, *B. repens* and *B. aquifolium*; *B. repens* is much more common. Ulev (2006) provides a review of *B. repens*. The species is native to the western United States and Canada. Shrubs are evergreen, are 4 to 12 inches tall, and are found on dry to moist sites. Regeneration can be from seed, rhizome sprouting, and layering. BERB has medium resistance to fire because rhizomes can sprout after the fire, although rhizomes can be killed by severe fire. Regeneration can also occur from seed—from either seed banks or offsite seed sources.

Occurrence

BERB occurred on 32.3 percent of the 896 plots (table 4). The data plotted in figure 9a show that BERB occurrence decreased with increasing burn severity, but increased for all burn severities over time. These relationships were confirmed in the regression models.

Before fitting the probability model, higher elevation ABLA habitat types and the PICO series were excluded from the data (table 5). The probability of BERB occurrence decreased with increasing burn severity and elevation, whereas it increased with increasing time (table 6). Occurrence increased with increasing slopes on southerly aspects, and decreased with increasing slope steepness on northerly aspects (fig. 2, pattern 2). The optimum aspect was 166 degrees. Occurrence was highest on the PIPO/PSME series, a little lower on the ABGR/THPL/TSHE series, and lowest on the ABLA series.

Cover

Mean BERB cover was about 5 percent or less (fig. 9b). Maximum BERB cover on individual plots was about 20 percent (fig. 9c). Plots with the most BERB cover were those with the least delay between the fire and occurrence on plots. Although BERB continued to become established on plots 3 or more years after disturbance, cover of BERB on these plots never exceeded trace amounts.

The interaction of slope and aspect were the only significant variables for predicting BERB cover (table 7). As was the case with BERB occurrence, cover increased with increasing slope steepness on southerly aspects, and decreased with increasing slope steepness on northerly aspects (fig. 2, pattern 2). The optimum aspect for BERB cover was 197 degrees.

Height

Figure 9d shows little variation in mean BERB height over time or by burn severity class. Table 8 shows that predicted BERB height increased with increasing cover and age. BERB height decreased with increasing slope steepness on northerly aspects, and increased slightly with increasing slope steepness on southerly aspects (fig. 2, pattern 2). The optimum aspect was 164 degrees. BERB height was greatest on the ABGR/THPL/TSHE series, followed by ABLA, and then the PIPO/PSME series.

BERB

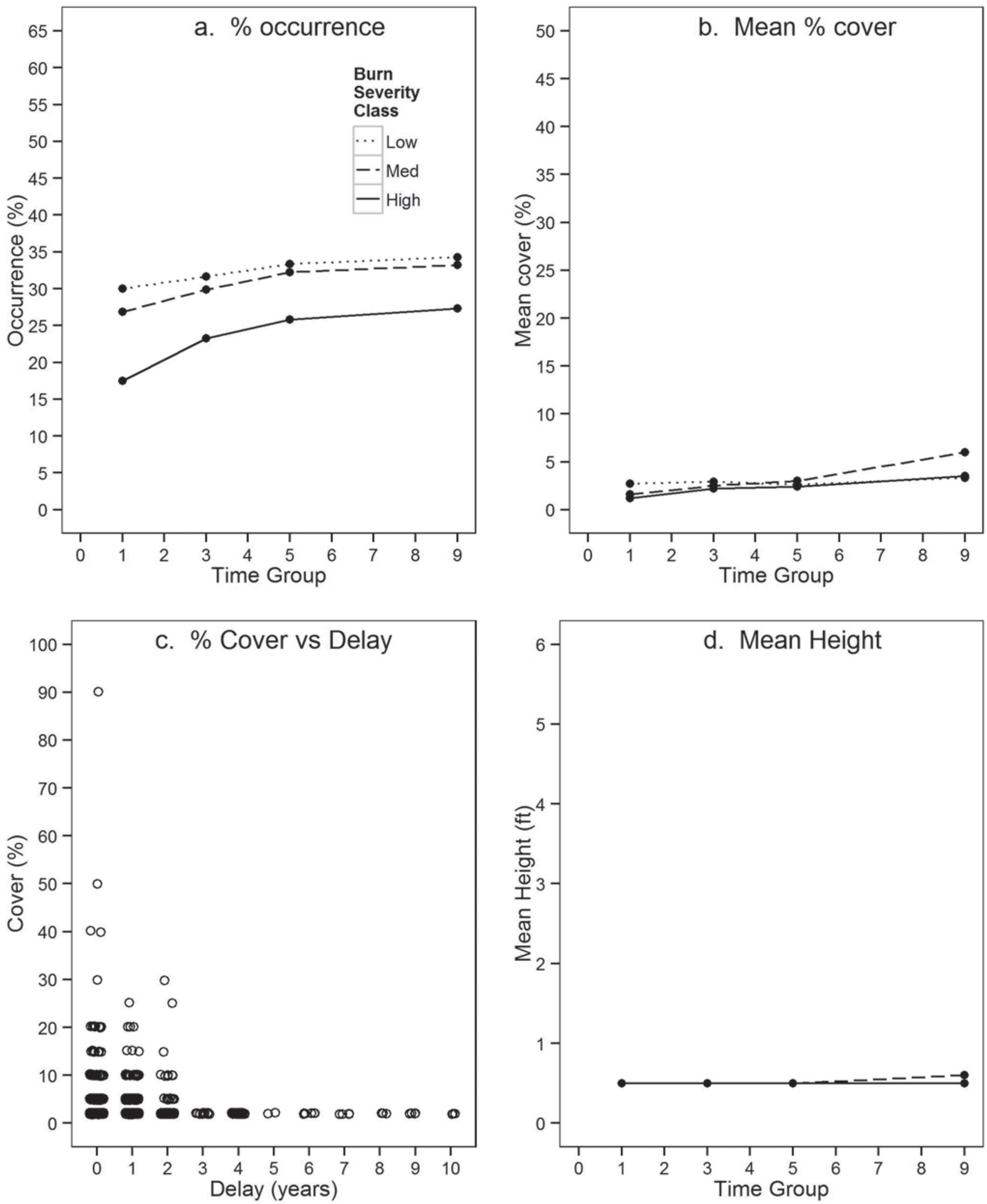

Figure 9—BERB (*Berberis* spp.). (a). Percent occurrence by burn severity class and time since wildfire. (b). Mean percent cover by burn severity class and time since wildfire. (c). Percent cover on individual 1/300-acre plots by number of years between the wildfire and establishment of the species on the plot. (d). Mean height by burn severity class and time since wildfire.

CESA (*Ceanothus sanguineus*), Redstem Ceanothus

FEIS Database

CESA grows from southern British Columbia to northern California, and as far east as Montana in moist coniferous forests (Johnson 2000). It is often a key component in seral brushfields in moist habitats. CESA is a deciduous shrub that does best on open sites, and grows from 3 to 10 feet tall. It is a prolific seed producer, and thus its primary method of reproduction is from seed stored in the soil, though it has been found to sprout from the root crown after disturbance. CESA seed is heat resistant and readily germinates in mineral soil that is heated by moderate to intense fires.

Occurrence

CESA occurred on 7.8 percent of the plots in this study (table 4). The highest concentration was on the 40 plots on the IPAN-MYRT fire. The medium burn severity class had higher occurrence of CESA (about 10 percent) than the low and high severity classes at less than 5 percent (fig. 10a).

No data were excluded to develop the probability model (table 5). The probability of CESA occurrence increased with increasing burn severity (table 6), which was the only significant independent variable.

Cover

Mean percent cover for CESA increased dramatically over time for all burn severity classes (fig. 10b). Although figure 10b shows that the high burn severity class had the lowest percent cover, the opposite was determined during regression analysis. Maximum cover on individual plots was nearly 100 percent (fig. 10c). A general trend of lower percent cover with increasing delay to plot occupancy is also evident, with only a few plots reaching more than 5 percent when delay was 2 or more years.

Predicted CESA cover decreased with increasing basal area and delay to plot occupancy, and increased with burn severity and age (table 7).

Height

Figure 10d shows that CESA heights approached 5 feet over the life of the study. The medium and low burn severity classes had greater mean height than the high burn severity class, but burn severity was not a significant variable in the height prediction model (table 8). CESA height increased with increasing cover and age, whereas height decreased with increasing basal area. Height increased with increasing slope steepness on southerly aspects, but decreased with increasing slope steepness on northerly aspects (fig. 2, pattern 2). The optimum aspect for CESA height was 175 degrees.

CESA

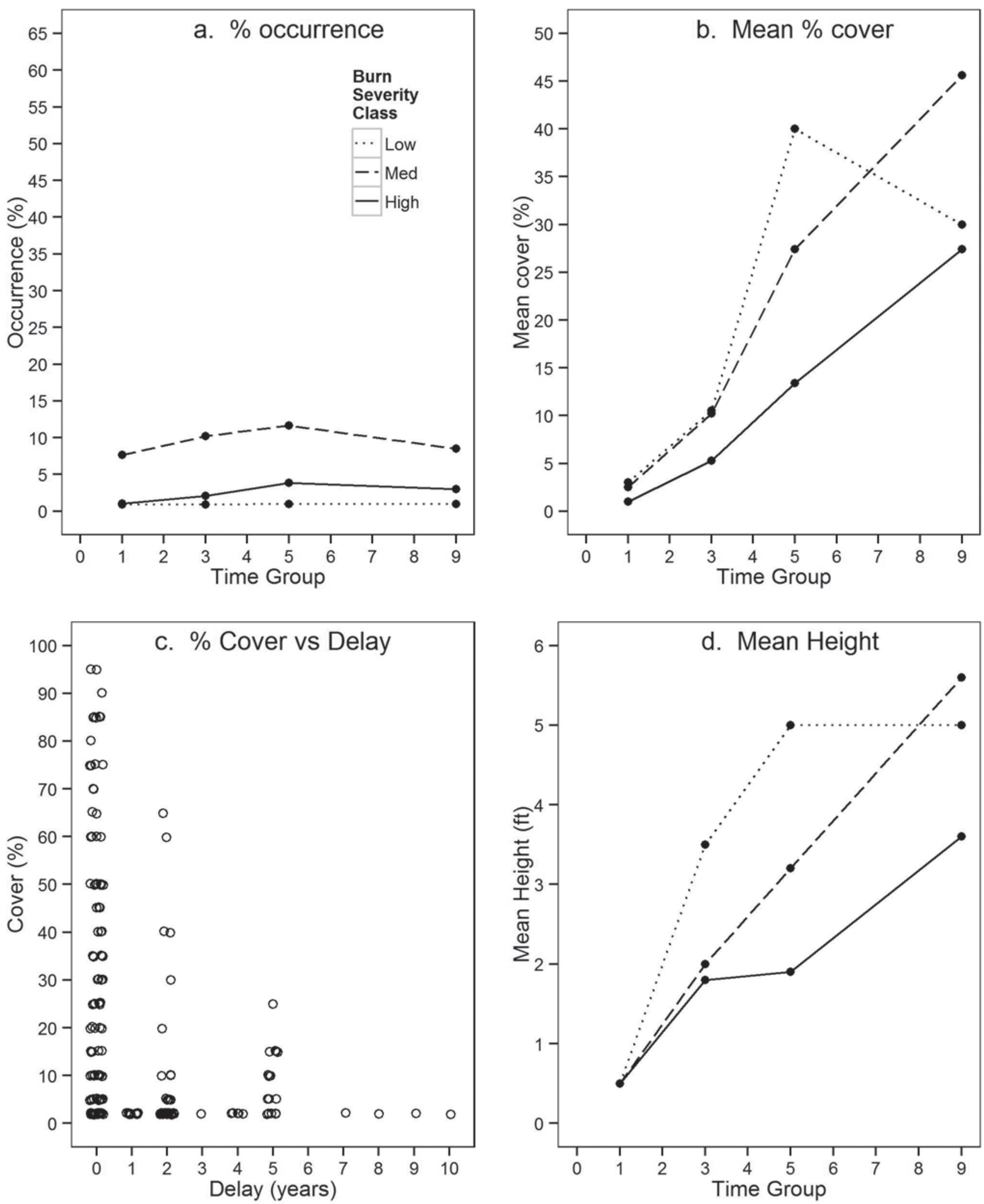

Figure 10—CESA (*Ceanothus sanguineus*). (a). Percent occurrence by burn severity class and time since wildfire. (b). Mean percent cover by burn severity class and time since wildfire. (c). Percent cover on individual 1/300-acre plots by number of years between the wildfire and establishment of the species on the plot. (d). Mean height by burn severity class and time since wildfire.

CEVE (*Ceanothus velutinus*), Snowbrush Ceanothus

FEIS Database

CEVE grows from British Columbia south to Colorado, and as far east as South Dakota (Anderson 2001b). It grows in dry to moist forest types, and can often form dense, impenetrable thickets of multiple plants. Plants are evergreen and are generally 2 to 9 feet tall, reproducing by seed, vegetative sprouting, or layering. Heating from fire stimulates the long-lived seed stored in the soil to germinate, and thus fire disturbance often results in heavy post-fire coverage of CEVE. It also sprouts prolifically after fire disturbance.

Occurrence

CEVE occurred on 27.0 percent of the 896 plots (table 4). Although CEVE was found on all wildfires in this study, occurrence was proportionally higher on the MALH-FLAG fire, where it occurred on 120 of the 180 plots. Graphing percent occurrence over time by burn severity (fig. 11a) shows a greater occurrence of CEVE on the medium burn severity class than on the low and high burn severity classes.

No data were excluded when developing the probability model (table 5). The probability of CEVE decreased with increasing basal area (table 6). Probability of occurrence increased with increasing burn severity. The effect of elevation was quadratic, with highest probability at 5,200 feet. CEVE was associated with southerly aspects. Occurrence increased with increasing slope steepness on southerly aspects, but decreased with increasing slope steepness on northerly aspects (fig. 2, pattern 2). The optimum aspect was 188 degrees. Occurrence was highest on the ABGR/THPL/TSHE series, followed by the PIPO/PSME series, and lowest on the ABLA/PICO series.

Cover

Mean percent cover rapidly increased over time, with percent cover much greater on the medium and high severity classes (fig. 11b). Cover approached 100 percent on some plots (fig. 11c). A graph of cover by years of delay between the fire and plot occupancy shows a sharp decline in cover as delay increased.

Predicted CEVE cover decreased with increasing basal area, whereas it increased with increasing burn severity and age (table 7). The effect of elevation is quadratic, with optimum cover predicted at 4,700 feet. Cover decreased with increasing slope steepness on northerly aspects, whereas it increased slightly with increasing slope steepness on southerly aspects (fig. 2, pattern 2). The optimum aspect for cover was 163 degrees. The most cover was predicted on the ABGR/THPL/TSHE series, followed closely by the PIPO/PSME series, and then the ABLA/PICO series.

Height

CEVE mean height appears greater on the medium and high burn severity classes at the end of the study (fig. 11d), though the height prediction model shows decreases in height as burn severity increased (table 8). Increasing basal area and elevation were associated with decreased CEVE height, whereas height increased with increasing cover and age. As was the case with CEVE occurrence, height increased with increasing slope steepness on southerly aspects, and decreased with increasing slope steepness on northerly aspects (fig. 2, pattern 2). The optimum aspect was 182 degrees.

CEVE

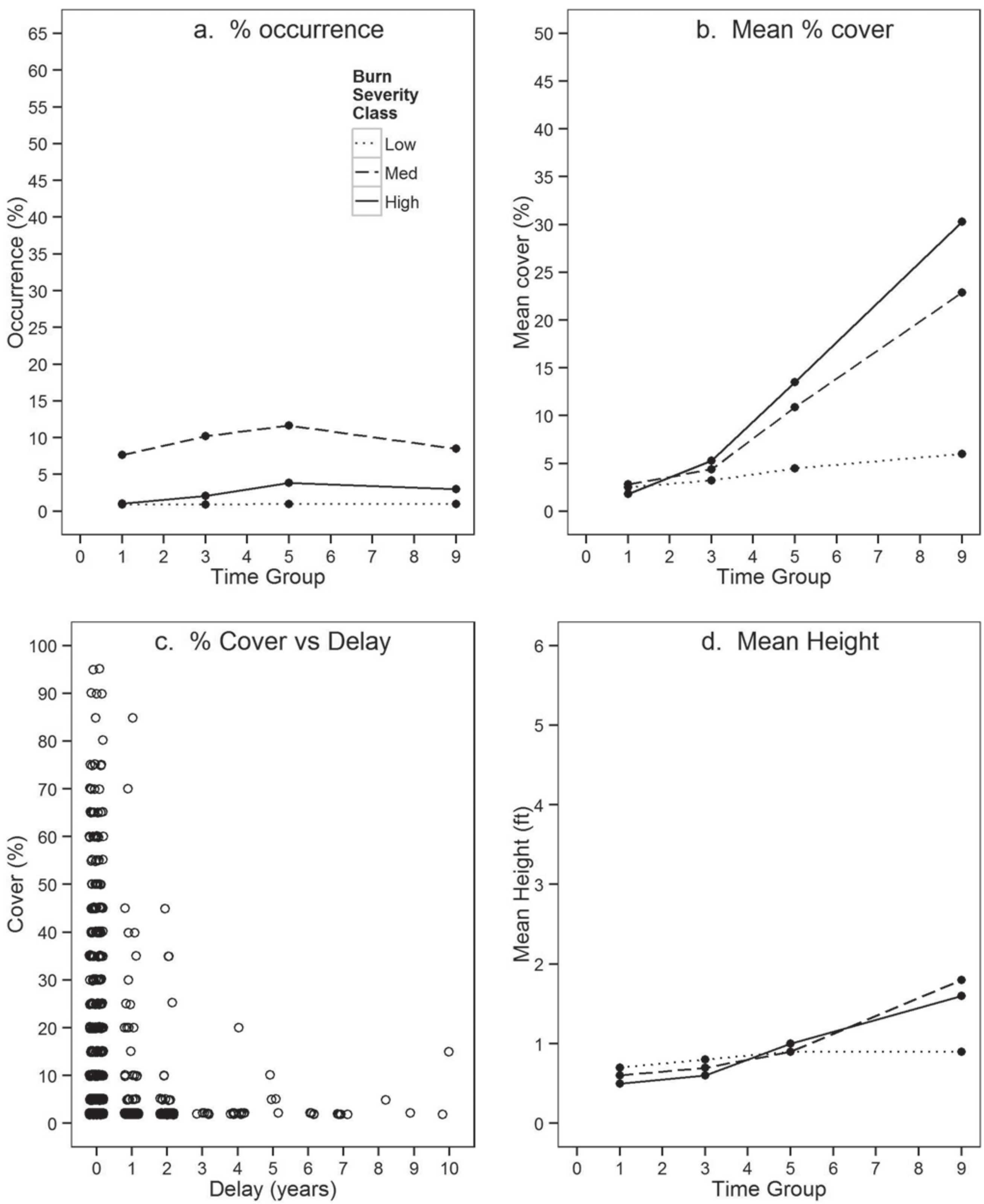

Figure 11—CEVE (*Ceanothus velutinus*). (a). Percent occurrence by burn severity class and time since wildfire. (b). Mean percent cover by burn severity class and time since wildfire. (c). Percent cover on individual 1/300-acre plots by number of years between the wildfire and establishment of the species on the plot. (d). Mean height by burn severity class and time since wildfire.

CHUM (*Chimaphila umbellata*), Pipsissewa

FEIS Database

CHUM is a widely distributed species, present throughout the northern hemisphere (Matthews 1994). It is a common understory plant within many coniferous and mixed species forests, but it rarely reaches high coverages where it occurs. CHUM is a low, evergreen shrub, with woody stems 4 to 12 inches tall. It regenerates from both seed and vegetatively from rhizomes. It is sensitive to fire—moderate to high intensity fires can kill the near-surface rhizomes, resulting in a decline after fire.

Occurrence

CHUM occurred on 14.5 percent of the 896 plots (table 4). A graph of occurrence by burn severity and time since wildfire shows that occurrence was higher on the low burn severity class than on the medium and high severity classes (fig. 12a).

No data were excluded before developing the probability model (table 5). The occurrence of CHUM increased with increasing basal area, and decreased with increasing burn severity (table 6). The effect of elevation was quadratic, with the highest probability at 5,600 feet. Occurrence increased slightly with increasing slope steepness on southeasterly aspects, but decreased with increasing slope steepness on northeasterly aspects (fig. 2, pattern 2). The optimum aspect was 119 degrees. The highest occurrence was on the ABGR/THPL/TSHE series, the lowest occurrence was on the PIPO/PSME series, and the ABLA/PICO series was intermediate.

Cover

Mean percent cover for CHUM was only slightly higher for the low burn severity class (fig. 12b). The highest percent cover on individual plots was 35 percent; most cover values were 5 percent or less (fig. 12c). Once delay to plot occupancy was more than 1 year, cover was almost always trace amounts; however, this figure also shows that CHUM continued to become established on plots long after the wildfire.

Predicted cover of CHUM decreased with increasing burn severity and with increasing delay to plot occupancy (table 7). Cover increased with increasing elevation. The large negative coefficient for slope indicates that CHUM cover decreased rapidly with increasing slope steepness.

Height

Both figure 12d and table 8 show that CHUM height was always 0.5 feet.

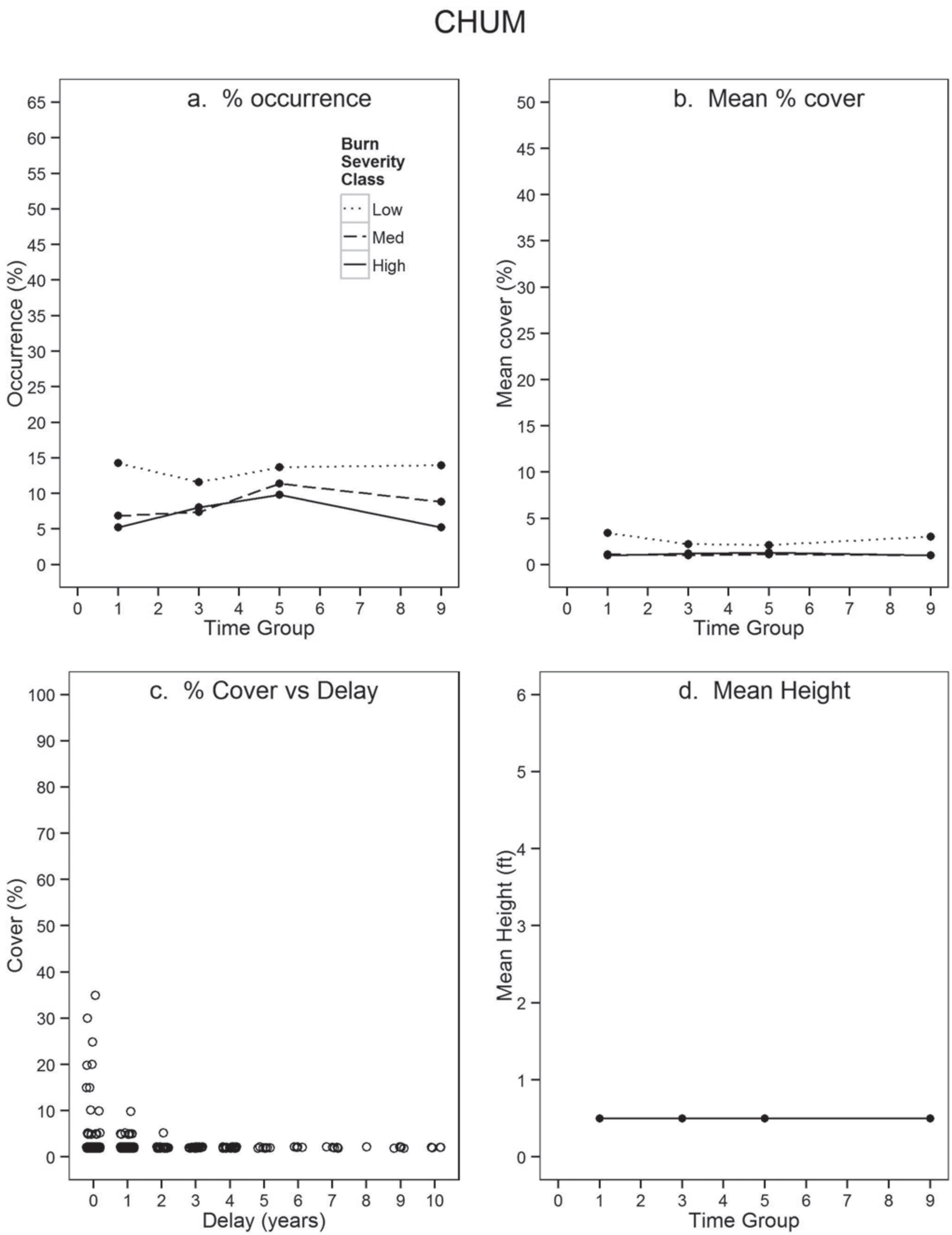

Figure 12—CHUM (*Chimaphila umbellata*). (a). Percent occurrence by burn severity class and time since wildfire. (b). Mean percent cover by burn severity class and time since wildfire. (c). Percent cover on individual 1/300-acre plots by number of years between the wildfire and establishment of the species on the plot. (d). Mean height by burn severity class and time since wildfire.

ERNA (*Ericameria nauseosa* = *Chrysothamnus nauseosus*), Rubber Rabbitbrush

FEIS Database

ERNA is a widely distributed shrub, occurring from southern Canada to northern Mexico and from the Pacific Ocean to the Great Plains (Tirmenstein 1999). It generally grows in drier environments, such as grasslands, shrublands, and drier forest types. ERNA is a rounded shrub that reaches heights of 1 to 8 feet. It readily regenerates after fire disturbance from both off-site seed and sprouts from the root crown.

Occurrence

ERNA occurred on 5.1 percent of plots (table 4), exclusively on the MALH-FLAG fire; therefore, our results apply only to the Malheur National Forest area. A graph of occurrence by time and burn severity class shows that occurrence increased over time for all sites, with the medium and high severity classes having greater occurrence than the low severity class (fig. 13a). But we found no statistical differences for burn severity during model development.

All data were excluded except for the MALH-FLAG fire to develop the probability model (table 5). The probability of ERNA occurrence increased with increasing time and slope steepness (table 6). It decreased with increasing basal area and elevation.

Cover

There was little difference in mean percent cover between burn severity classes, and only a slight increase over time (fig. 13b). Percent cover on individual plots was always equal to or less than 15 percent (fig. 13c). Plants continued to become established on plots even with a delay of up to 9 years after the wildfire.

Predicted ERNA cover increased with increasing age (table 7). ERNA cover decreased with increasing slope steepness for all aspects, especially on northerly aspects (fig. 2, pattern 3). The optimum aspect was 199 degrees.

Height

No differences in mean height were seen between burn severity classes for ERNA (fig. 13d). Predicted ERNA height increased with increasing cover, age, and elevation (table 8). Height decreased with increasing basal area. Height increased with increasing slope steepness on southwesterly aspects, but decreased with increasing slope steepness on northeasterly slopes (fig. 2, pattern 2). The optimum aspect for ERNA height was 215 degrees.

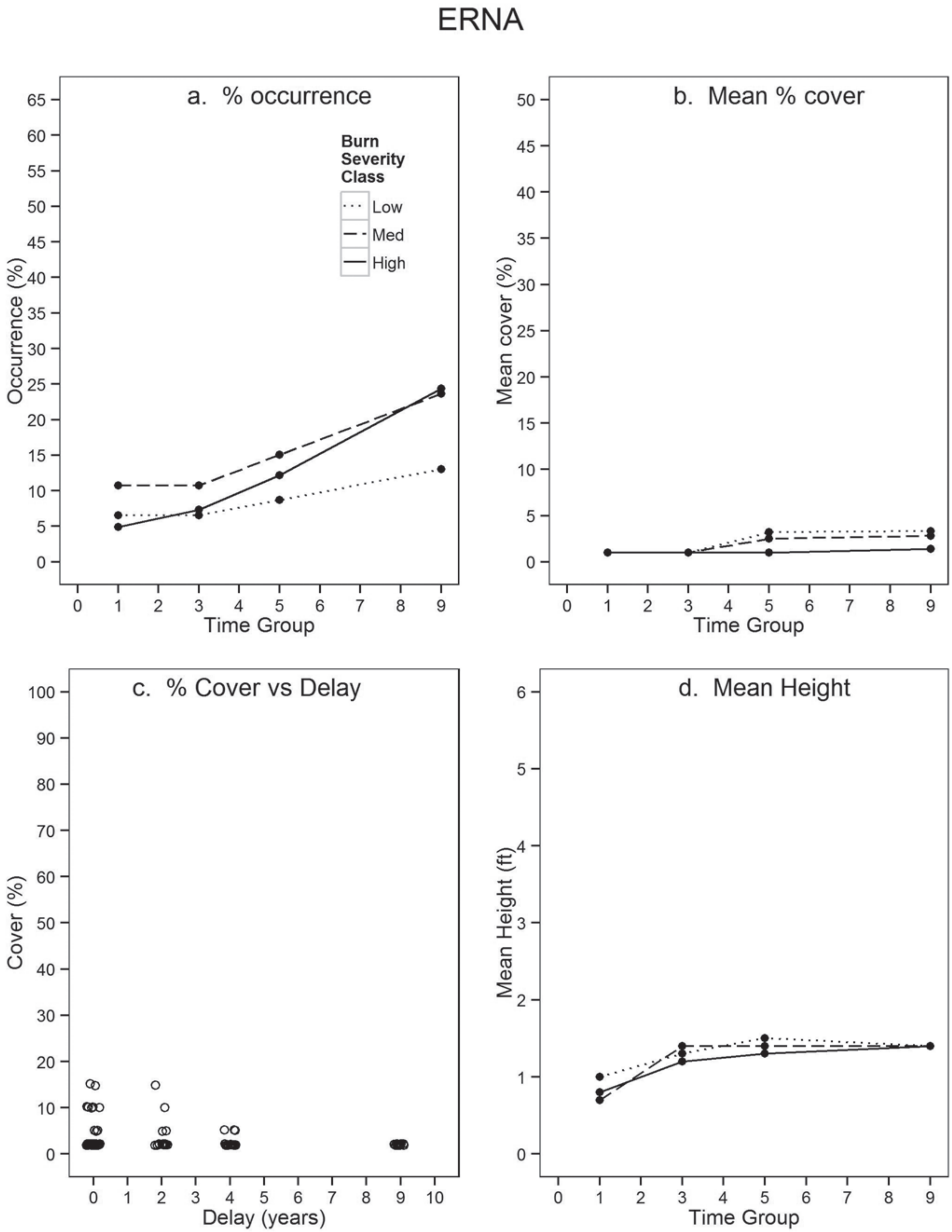

Figure 13—ERNA (*Ericameria nauseosa*). (a). Percent occurrence by burn severity class and time since wildfire. (b). Mean percent cover by burn severity class and time since wildfire. (c). Percent cover on individual 1/300-acre plots by number of years between the wildfire and establishment of the species on the plot. (d). Mean height by burn severity class and time since wildfire.

HODI (*Holodiscus discolor*), Oceanspray

FEIS Database

This species is found in the western United States and adjacent parts of Canada, from British Columbia to California and Arizona, and east to western Montana (Fryer 2010). It is common on dry, warm sites such as south-facing slopes and ridgetops. HODI can grow in a variety of mid- to low-elevation forests as well as sagebrush communities. Plants are usually 3 to 10 feet tall. Regeneration can be from seeds, layering, and sprouting from the root crown. Although seeds can persist in soil seed banks, seedling establishment is apparently uncommon. Sprouting from the root crown is the more prevalent method to colonize sites. Individual plants are topkilled by wildfires, but readily sprout from the root crown. Percent cover may be higher after severe wildfires versus low or moderate severity wildfires.

Occurrence

HODI occurred on 4.6 percent of plots (table 4), with most of those on the IPAN-MYRT fire. A graph of occurrence by burn severity and time since wildfire shows that the medium burn severity class had the highest occurrence (fig. 14a), although this relationship was found to be nonsignificant during regression analysis.

The ABLA and PICO series were eliminated before developing the probability model (table 5). Probability of occurrence of HODI increased with increasing basal area, and decreased with increasing elevation (table 6). Occurrence increased with increasing slope steepness on southerly aspects, but decreased with increasing slope steepness on northerly aspects (fig. 2, pattern 2). The optimum aspect was 181 degrees.

Cover

Mean percent cover was generally less than 5 percent (fig. 14b), with little difference among burn severity class or over time. Cover on individual plots was generally 15 percent or less (fig. 14c). Cover exceeded 5 percent only on plots where there was no delay to plot occupancy.

Only one variable was significant for predicting HODI cover. As age increased, so did HODI cover (table 7).

Height

Figure 14d shows that mean HODI height was highest on the low burn severity class, but burn severity was not significant in the regression analyses. The coefficients in table 8 indicate that predicted HODI height increased with increasing cover and age, and decreased with increasing basal area and elevation.

HODI

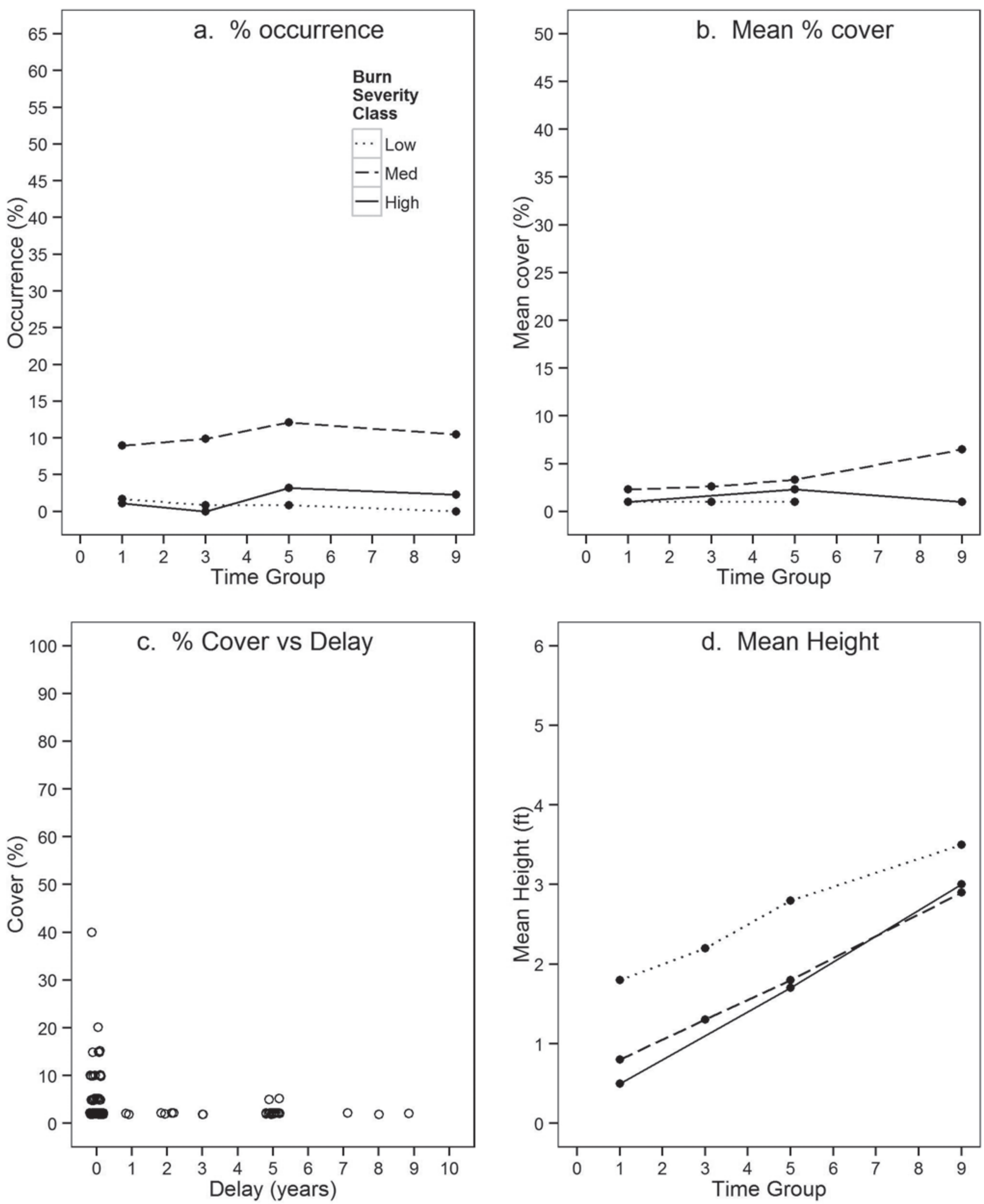

Figure 14—HODI (*Holodiscus discolor*). (a). Percent occurrence by burn severity class and time since wildfire. (b). Mean percent cover by burn severity class and time since wildfire. (c). Percent cover on individual 1/300-acre plots by number of years between the wildfire and establishment of the species on the plot. (d). Mean height by burn severity class and time since wildfire.

LIBO2 (*Linnaea borealis*), Twinflower

FEIS Database

LIBO2 is an evergreen, dwarf shrub that has a creeping or trailing growth form. Howard (1993) reports in the FEIS database that there are three subspecies of LIBO2. Our subspecies is *americana*, which is found from interior Alaska across Canada to Newfoundland, and south into Arizona, New Mexico, South Dakota, Indiana, West Virginia, and New Jersey. It grows in many coniferous forest types throughout its range. Sexual reproduction is uncommon, and the seed does not live long in soil seed banks. Vegetative reproduction is the primary method of expanding existing plants. The shallow, fibrous roots are easily killed by even low intensity wildfires; LIBO2 is classified in Howard's review as a "fire avoider" because small patches of LIBO2 that escape burning are able to expand after the wildfire.

Occurrence

LIBO2 occurred on 14.6 percent of the plots, but on only 1 of the 180 plots on the MALH-FLAG fire (table 4). A graph of occurrence by burn severity and time since wildfire (fig. 15a) shows decreasing occurrence with increasing burn severity class, but little increase over time.

Some dry habitat types, including the PIPO series, and dry PSME habitat types, were excluded from the data to develop the probability model for LIBO2 (table 5). The probability of occurrence of LIBO2 increased with increasing basal area and time (table 6). Occurrence decreased with increasing burn severity and elevation. Occurrence decreased with increasing slope steepness for all aspects, more so toward the southwest (fig. 2, pattern 3). The optimum aspect was 45 degrees. Occurrence was highest on the ABLA/PICO series, lowest on the ABGR/THPL/TSHE series, and intermediate on the PSME series.

Cover

Mean percent cover was generally less than about 5 percent, but there was a clear trend of less cover with increasing burn severity (fig. 15b). Cover on individual plots was generally less than about 30 percent (fig. 15c). Only trace amounts of LIBO2 occurred when delay to plot occupancy was 2 years or more.

Predicted LIBO2 cover decreased with increasing burn severity and delay to plot occupancy (table 7). It increased with increasing age. The effect of elevation was quadratic, with the highest cover at 4,700 feet. LIBO2 cover decreased with increasing slope steepness on southerly aspects, and it increased with increasing slopes on northerly aspects (fig. 2, pattern 2). The optimum aspect was 20 degrees.

Height

Both figure 15d and table 8 show that LIBO2 height was always 0.5 feet.

LIBO2

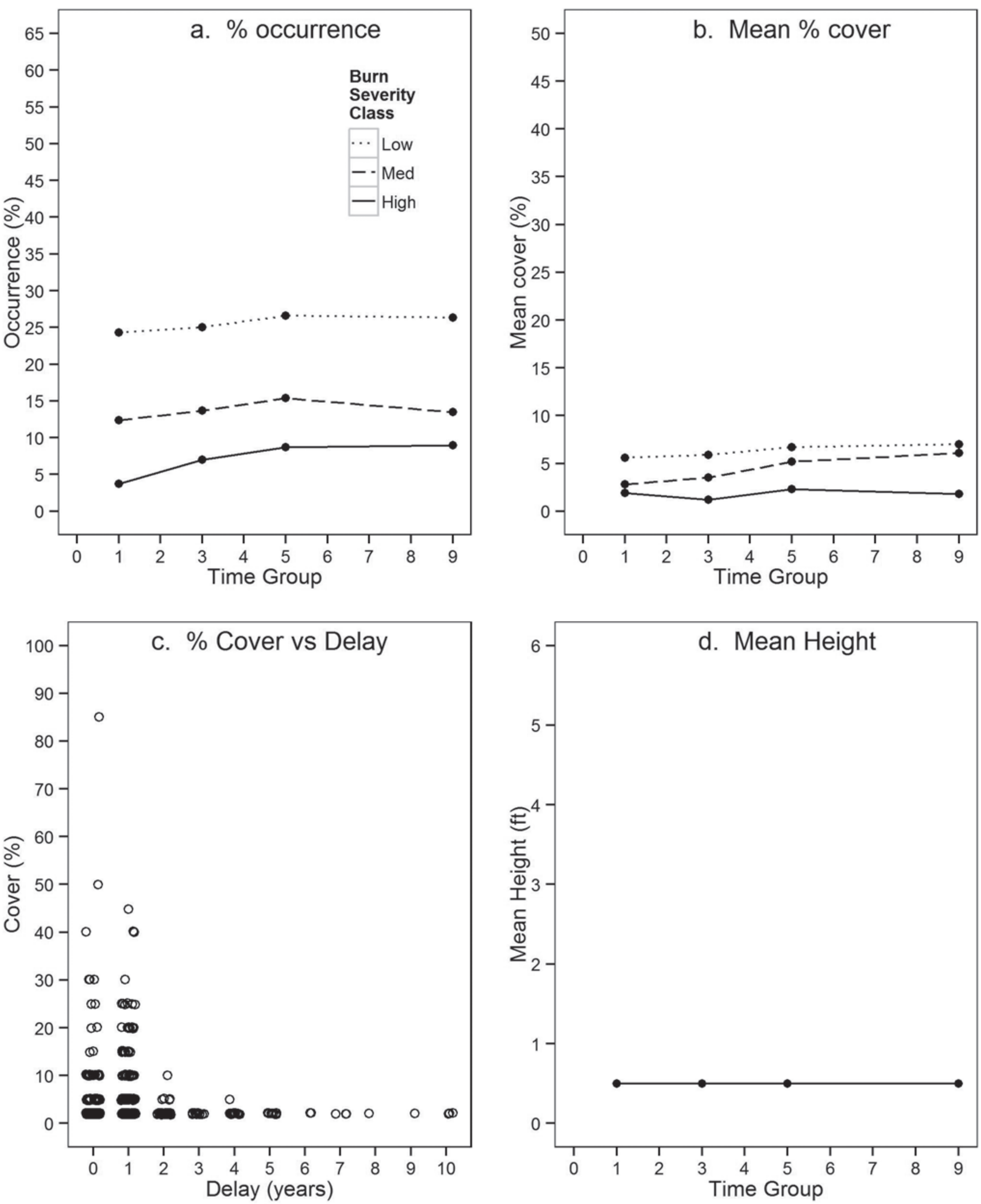

Figure 15—LIBO2 (*Linnaea borealis*). (a). Percent occurrence by burn severity class and time since wildfire. (b). Mean percent cover by burn severity class and time since wildfire. (c). Percent cover on individual 1/300-acre plots by number of years between the wildfire and establishment of the species on the plot. (d). Mean height by burn severity class and time since wildfire.

LOUT2 (*Lonicera utahensis*), Utah Honeysuckle

FEIS Database

LOUT2 is distributed from southern British Columbia and Alberta, south through the Rocky Mountains to northern California, Arizona, and New Mexico (Pavek 1993). It is found on moist, open or wooded slopes and canyons, and grows 3 to 7 feet tall. Following a wildfire, LOUT2 can sprout from the root crown, but regrowth is slow. Overall, this species decreases after wildfire.

Occurrence

LOUT2 occurred on 14.7 percent of plots (table 4). This species was found on only 3 of 180 plots on the MALH-FLAG fire. Figure 16a shows no differences in occurrence by time since wildfire and burn severity class.

The PIPO series was excluded from the data before developing the probability model (table 5). The probability of occurrence of LOUT2 decreased with increasing burn severity and elevation, and increased with increasing basal area and time (table 6). Occurrence increased with increasing slope steepness on all aspects, more so at the optimum aspect of 28 degrees (fig. 2, pattern 1). Occurrence was highest on the ABLA/PICO series, less on the ABGR/THPL/TSHE series, and least on the PSME series.

Cover

Mean percent cover on plots where LOUT2 occurred was always less than 5 percent (fig. 16b). Cover was always 20 percent or less on individual plots, with only trace coverage after a delay to plot occupancy of about 4 years (fig. 16c). Even though these were trace amounts, it shows the ability of LOUT2 to become established several years after the area has been disturbed by wildfire.

Predicted LOUT2 cover decreased with increasing elevation, whereas it increased with increasing age (table 7). Cover increased with increasing slope steepness on northerly aspects, but decreased with increasing slope steepness on southerly aspects (fig. 2, pattern 2). The optimum aspect for cover was 14 degrees.

Height

The low burn severity class had higher LOUT2 mean height early in the study, but by study end there was little difference between burn severity classes (fig. 16d). However, burn severity was a significant variable in the height prediction model, such that when burn severity increased, height decreased (table 8). Increasing elevation was associated with decreasing height. LOUT2 height increased with increasing cover, age, and slope.

LOUT2

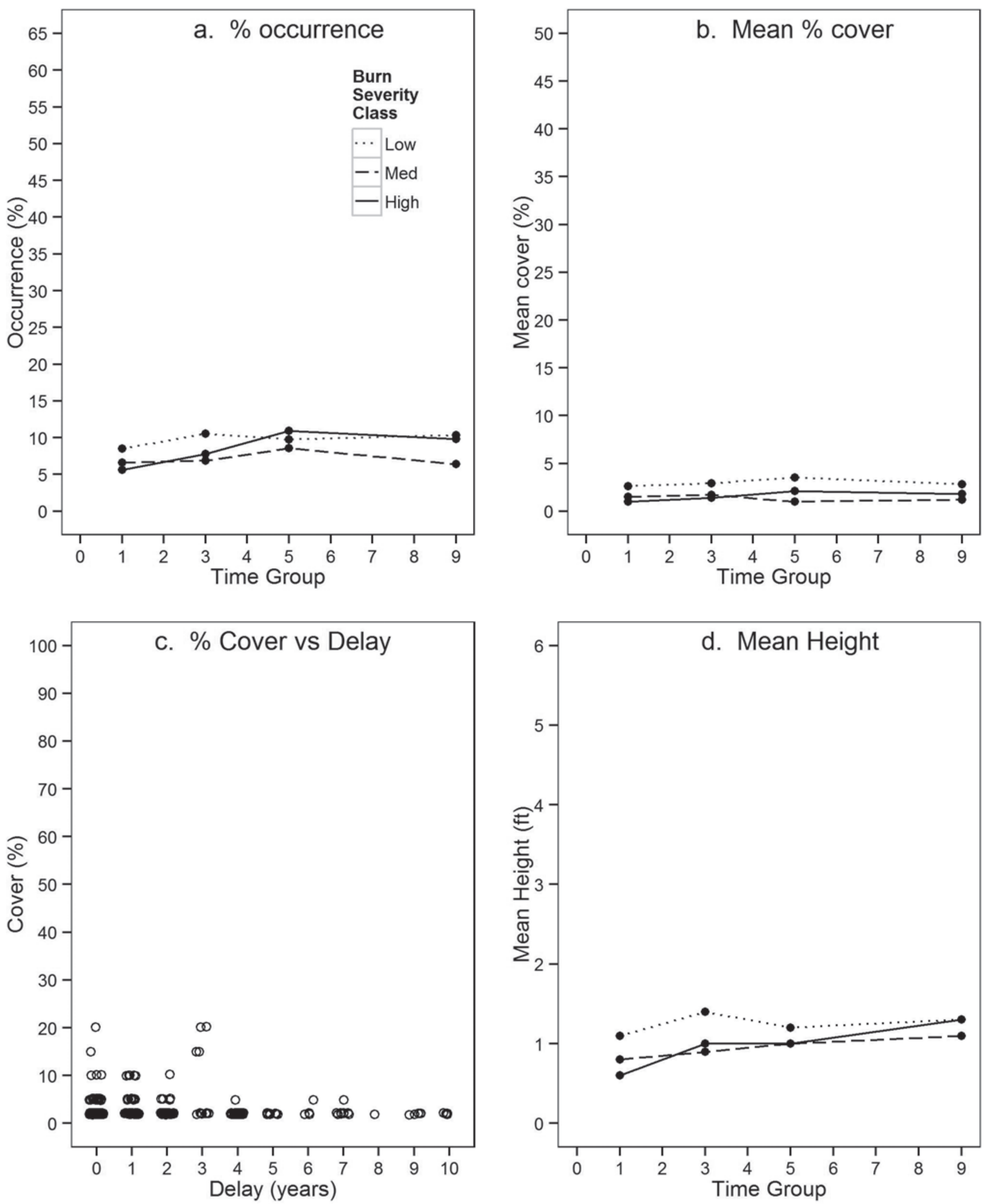

Figure 16—LOUT2 (*Lonicera utahensis*). (a). Percent occurrence by burn severity class and time since wildfire. (b). Mean percent cover by burn severity class and time since wildfire. (c). Percent cover on individual 1/300-acre plots by number of years between the wildfire and establishment of the species on the plot. (d). Mean height by burn severity class and time since wildfire.

MEFE (*Menziesia ferruginea*), Rusty Menziesia

FEIS Database

MEFE is found from Alaska to northern California, and eastward to British Columbia, Alberta, Montana, Wyoming, Idaho, Oregon, and Washington (Habeck 1992a). It is most abundant in cold, wet habitat types, especially northerly slopes. Plants grow from 3 to 7 feet tall, and height decreases with increasing elevation. MEFE reproduction can be from seeds, layering, and sprouting from root crowns. The species is very susceptible to topkill from wildfires. After topkill, it sprouts from the root crown, but development is slow.

Occurrence

MEFE occurred on 6.8 percent of the plots, with no occurrences on the MALH-FLAG fire (table 4). In our data, 82.0 percent of MEFE occurrences were on the ABLA/PICO series. A graph of occurrence of MEFE by burn severity class and time since wildfire (fig. 17a) shows decreased occurrence with increasing burn severity, but little change over time.

Before developing the probability model, the PIPO series, the PSME series, and dry ABGR habitat types were excluded from the data (table 5). MEFE occurrence decreased with increasing burn severity, and increased with increasing elevation (table 6). Occurrence increased with increasing slope steepness on northerly aspects, but decreased with increasing slope steepness on southerly aspects (fig. 2, pattern 2). The optimum aspect was 19 degrees.

Cover

Mean percent cover was highest when burn severity was the lowest (fig. 17b). Percent cover on individual plots sometimes reached 70 percent, but coverage was minimal when delay to plot occupancy was 2 years or more (fig. 17c).

Predicted cover of MEFE decreased with increasing burn severity and delay to plot occupancy (table 7). The effect of elevation was quadratic, with more cover at 6,600 feet.

Height

Mean MEFE height on the low burn severity class was always greater than for the high severity and medium severity classes (fig. 17d). Predicted MEFE height decreased with increasing burn severity and elevation (table 8). Increasing height was associated with increasing cover, basal area, and age. MEFE was the only shrub where increases in basal area resulted in greater predicted height.

MEFE

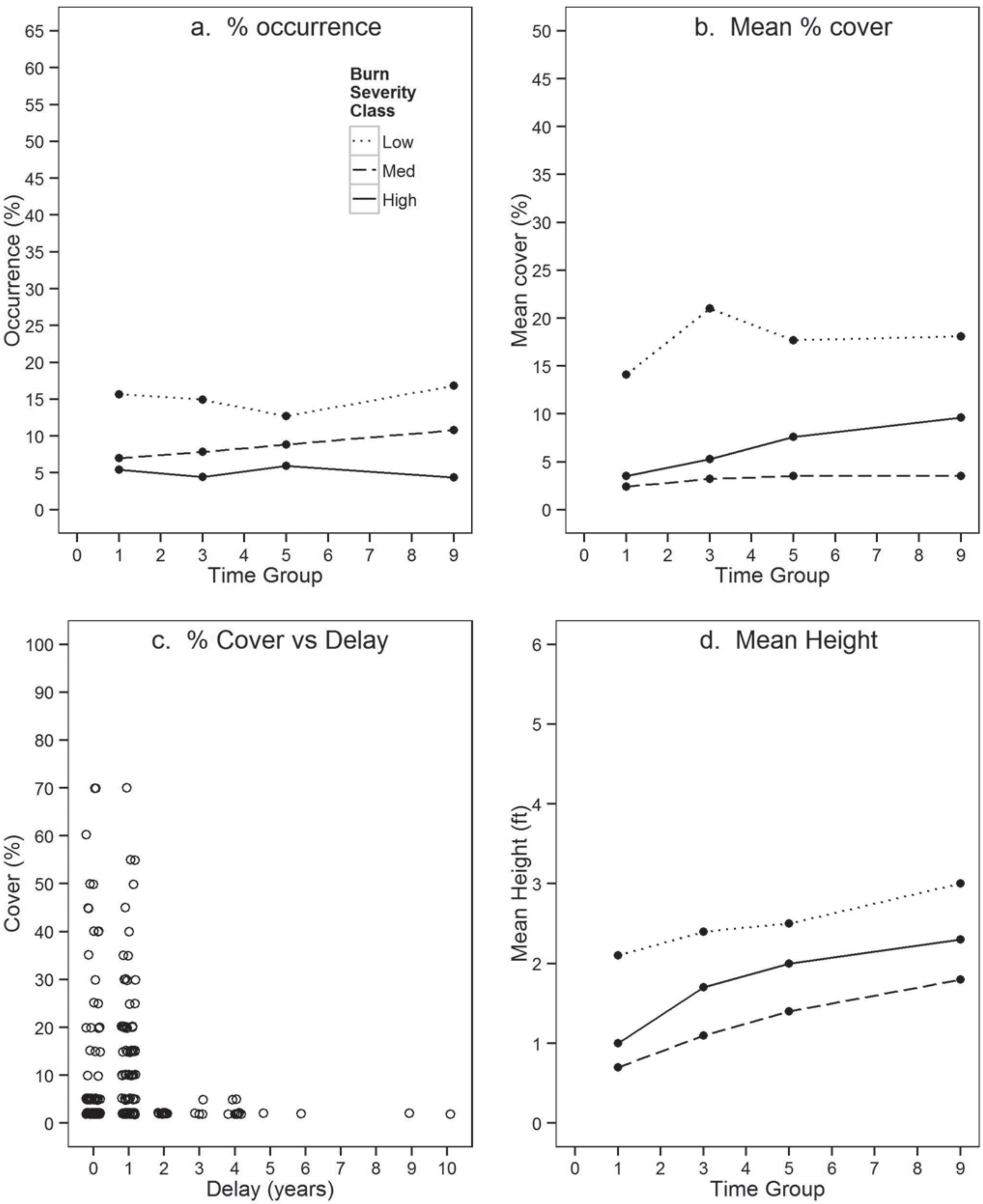

Figure 17—MEFE (*Menziesia ferruginea*). (a). Percent occurrence by burn severity class and time since wildfire. (b). Mean percent cover by burn severity class and time since wildfire. (c). Percent cover on individual 1/300-acre plots by number of years between the wildfire and establishment of the species on the plot. (d). Mean height by burn severity class and time since wildfire.

PAMY (*Paxistima myrsinites* = *Pachistima myrsinites*), Oregon Boxleaf

FEIS Database

PAMY is widely distributed from British Columbia south into California and eastward in the Rocky Mountains (Snyder 1991). Its range also extends south into Mexico. This evergreen shrub species grows from 1 to 3 feet tall, usually growing on dry to moist sites with a variety of tree and shrub species. PAMY can survive low and moderate severity wildfires, but can be killed by severe fires. It sprouts from the root crown and taproot following low to moderate severity fires. However, there is little increase or decrease in frequency of PAMY following wildfires, when compared to frequency of PAMY in unburned areas, indicating that it does not increase after wildfires.

Occurrence

PAMY occurred on 29.6 percent of the plots in this study (table 4). Very few occurrences were recorded on the BITT-BITT and MALH-FLAG fires. A graph of occurrence by time since wildfire and burn severity class (fig. 18a) shows that low burn severity had the lowest occurrence of PAMY; however, the reverse situation was found during regression analysis.

Habitat types that were excluded when developing the probability of occurrence model for PAMY were the PIPO series, dry PSME habitat types, some dry ABLA habitat types, and the PICO series (table 5). The probability of PAMY occurrence decreased with burn severity, and increased with time (table 6). The effect of elevation was quadratic, with highest probabilities at 3,800 feet. PAMY occurrence increased with increasing slope steepness on all aspects, slightly more so at the optimum aspect of 187 degrees (fig. 2, pattern 1). Predicted occurrence was highest on the ABLA series, much lower on the PSME series, and intermediate on the ABGR/THPL/TSHE series.

Cover

Mean percent cover on plots where PAMY occurred was less than 5 percent (fig. 18b), with the low burn severity class having the greatest cover. Maximum percent plot cover for PAMY was about 25 percent (fig. 18c). There is a sharp decline in cover as delay to plot occupancy increases. After a delay of 2 years, the PAMY that did become established on new plots had trace amounts of cover. Even though these were trace amounts, it shows that PAMY was still able to become established on plots several years after the wildfire.

Predicted cover decreased with increasing burn severity and delay between the fire and species occurrence on the plot (table 7). PAMY cover increased with increasing slope steepness on easterly aspects and decreased with increasing slope steepness on westerly aspects (fig. 2, pattern 2). The optimum aspect for cover was 109 degrees.

Height

By the end of the study, there was very little difference in mean PAMY height by burn severity class (fig. 18d), but the height prediction model showed that height decreased as burn severity increased (table 8). Increasing cover and age had a positive effect on PAMY height. PAMY height was highest on the ABGR/THPL/TSHE series, followed by PSME, and then the ABLA series.

PAMY

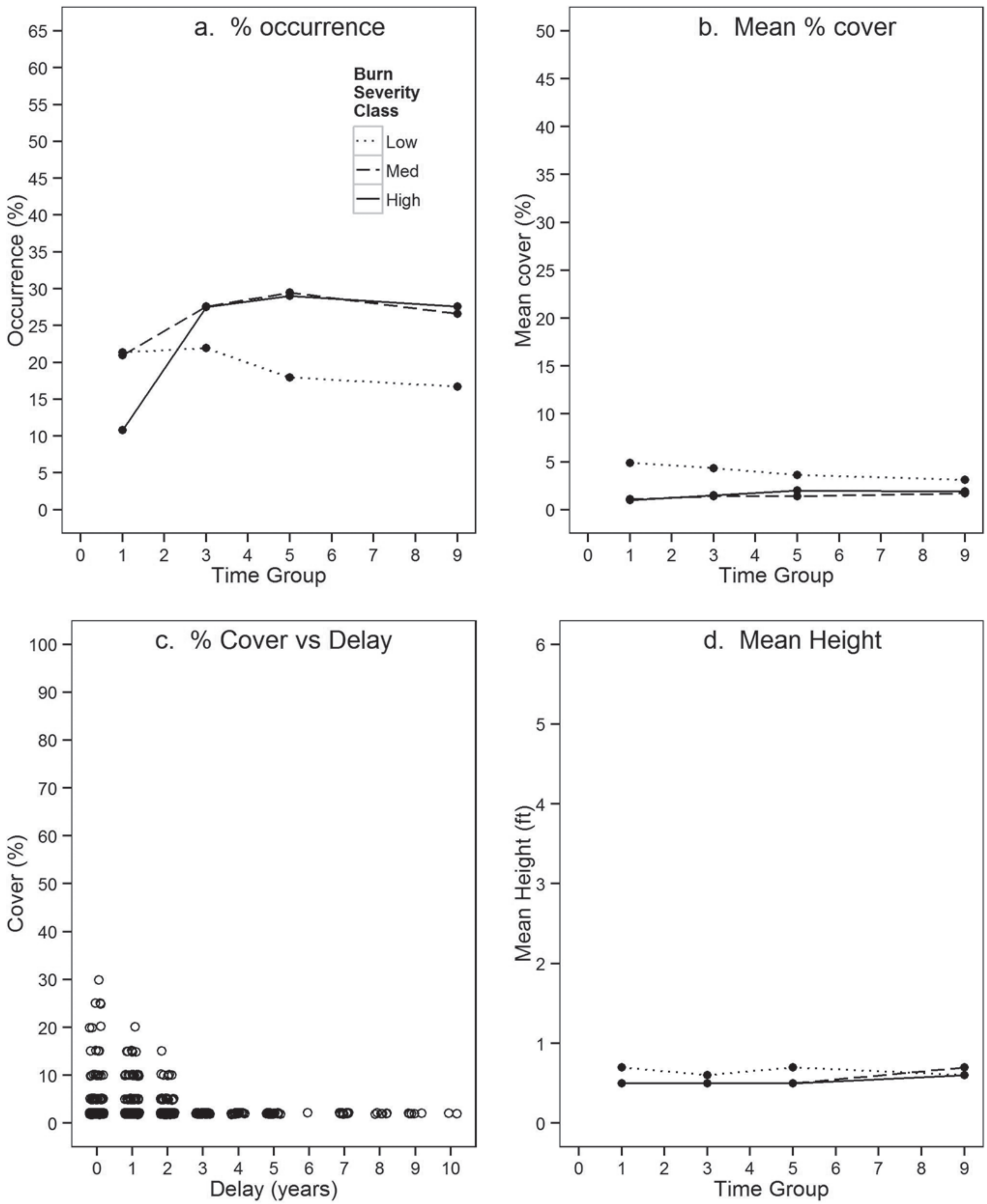

Figure 18—PAMY (*Paxistima myrsinites*). (a). Percent occurrence by burn severity class and time since wildfire. (b). Mean percent cover by burn severity class and time since wildfire. (c). Percent cover on individual 1/300-acre plots by number of years between the wildfire and establishment of the species on the plot. (d). Mean height by burn severity class and time since wildfire.

PHMA (*Physocarpus malvaceus*), Mallow Ninebark

FEIS Database

PHMA occurs in the Interior West and adjacent southern Canada, from British Columbia and Alberta south through eastern Washington, eastern Oregon, Idaho, Montana, Wyoming, Nevada, and Utah (Habeck 1992b). It is most abundant in ponderosa pine, Douglas-fir, and grand fir forests. Plants are generally 2 to 7 feet tall. Regeneration can be from seeds, which have some capacity to be stored in the soil, and rhizome sprouting. PHMA sprouts vigorously from rhizomes after wildfire, but plants can be damaged by moderate to severe wildfires. The species has a very high fire survival rating.

Occurrence

PHMA occurred on 5.7 percent of study plots (table 4), with most of those occurrences on the BITT-BITT fire. A graph of occurrence by burn severity class and time since wildfire shows higher occurrence with higher burn severity (fig. 19a).

The THPL, TSHE, ABLA, and PICO series were eliminated from the data to develop a regression model predicting the probability of occurrence for PHMA (table 5). Probability decreased with increasing basal area and elevation (table 6). Occurrence increased sharply with increasing slope steepness for all aspects, as indicated by the relatively large coefficient for slope in table 6 (fig. 2, pattern 1). Occurrence was highest at the optimum aspect of 51 degrees.

Cover

Mean percent cover on plots where PHMA occurred is graphed in figure 19b. There is a trend of higher percent cover as burn severity increased. Cover reached as high as 50 percent on individual plots, but only plots with delay to plot occupancy of less than 3 years had more than trace values (fig. 19c). This figure also shows that PHMA only occasionally became established on new plots after a delay of about 2 years.

Predicted PHMA cover decreased with increasing delay to plot occupancy (table 7). It increased with increasing burn severity and age. Cover increased with increasing slope steepness on northerly aspects, but decreased with increasing slope steepness on southerly aspects (fig. 2, pattern 2). The optimum aspect for cover was 10 degrees.

Height

Though low and high burn severity classes had greater mean height than the medium severity class (fig. 19d), burn severity was not a significant variable in the PHMA height prediction model (table 8). As with most of the other shrubs, predicted PHMA height increased with increasing cover and age, and decreased with increasing basal area. Height increased with increasing slope steepness on all aspects, especially at the optimum aspect of 116 degrees (fig. 2, pattern 1).

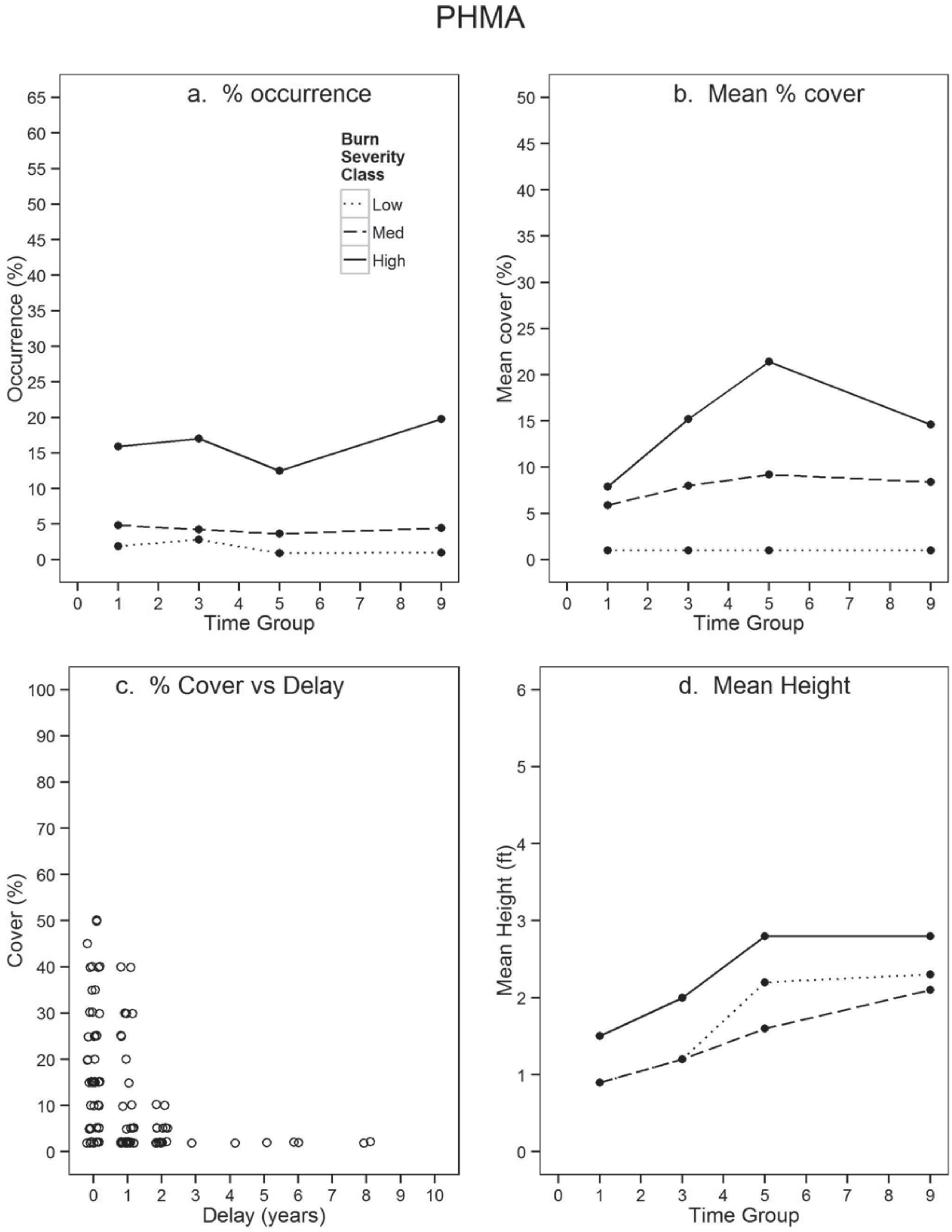

Figure 19—PHMA (*Physocarpus malvaceus*). (a). Percent occurrence by burn severity class and time since wildfire. (b). Mean percent cover by burn severity class and time since wildfire. (c). Percent cover on individual 1/300-acre plots by number of years between the wildfire and establishment of the species on the plot. (d). Mean height by burn severity class and time since wildfire.

RICE (*Ribes cereum*), Wax Currant

FEIS Database

RICE is found throughout most of the western United States and British Columbia (Marshall 1995). It is a non-rhizomatous shrub that grows up to 5 feet tall. It is found mostly on dry open forests, and reproduces mainly from seed. Seeds, which can remain dormant in the soil for many years, need scarification to germinate. Most RICE plants are killed by wildfire, but low severity fires scarify seed in the soil, thus allowing germination and establishment of new plants. Although sprouting from the root crown has been documented, it is not the major way plants become established after wildfires.

Occurrence

RICE occurred on 5.6 percent of the 896 plots (table 4), and all occurrences were on the MALH-FLAG fire. Of the 180 plots on the MALH-FLAG fire, RICE occurred on 50 of them (27.8 percent). Figure 20a shows RICE occurrence by burn severity and time for the MALH-FLAG fire. There is a trend of increasing occurrence with increasing burn severity and time.

Only data from the MALH-FLAG fire were used to develop the probability model (table 5). The probability of occurrence for RICE increased with increasing burn severity and time (table 6). Occurrence decreased with increasing elevation. It increased with increasing slope steepness for all aspects, more so at the optimum aspect of 219 degrees (fig. 2, pattern 1).

Cover

Mean RICE cover was low with slight increases over time (fig. 20b). On plots where RICE occurred, mean percent cover did not exceed about 5 percent. Although percent cover reached 45 percent on a few plots, coverage was generally 10 percent or less (fig. 20c). There is a general trend of decreasing cover as delay to plot occupancy increases.

Predicted cover of RICE increased with age and elevation, and it decreased substantially with increasing slope steepness (table 7), which indicates that RICE cover was greatest on flat topography.

Height

A graph of mean height over time for RICE shows that the medium and high burn severity classes had higher mean height than the low severity class (fig. 20d). RICE is the only shrub where increasing burn severity is associated with increased height (table 8). Cover and age also had a positive influence on RICE height, whereas increasing basal area led to decreased height.

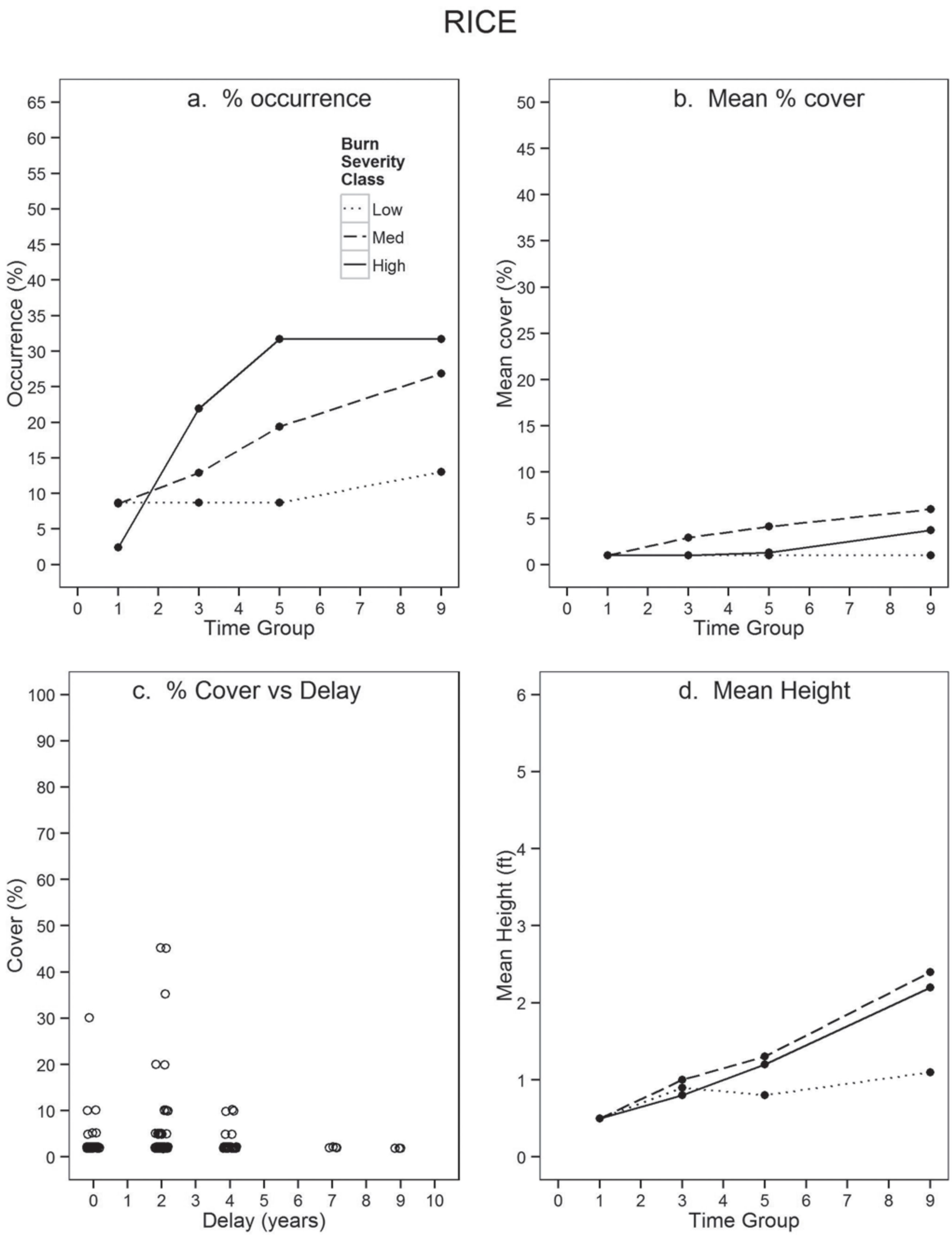

Figure 20—RICE (*Ribes cereum*). (a). Percent occurrence by burn severity class and time since wildfire. (b). Mean percent cover by burn severity class and time since wildfire. (c). Percent cover on individual 1/300-acre plots by number of years between the wildfire and establishment of the species on the plot. (d). Mean height by burn severity class and time since wildfire.

RILA (*Ribes lacustre*), Prickly Currant

FEIS Database

RILA is widely distributed in Canada and the United States (Carey 1995). It can be found throughout Canada from Newfoundland west to the Yukon, and then into Alaska. It grows south to northern California, throughout the Rocky Mountains, and into the Lake States and the Appalachian Mountains. It occurs in many forest types throughout its range, and is a common plant though not abundant. Plants grow 3 to 4 feet tall. Roots are shallow, but their lateral spread can be large. Plants have been reported to have both rhizomatous and non-rhizomatous root systems. RILA can regenerate vegetatively, but seed is apparently the more important reproduction method. Seeds can be found in soil seed banks, where they can be long-lived, or can come from offsite seed sources. This species is found more often on north and east aspects versus south and west aspects, and canopy cover increases slowly after fire.

Occurrence

RILA occurred on 11.4 percent of plots (table 4), with only one occurrence on the MALH-FLAG fire. A graph of occurrence by burn severity class and time since wildfire shows decreasing occurrence with increasing burn severity (fig. 21a).

The PIPO and PICO series were eliminated from the data in order to fit the probability model for RILA (table 5). The probability of occurrence of RILA increased with increasing basal area, and decreased with increasing burn severity and time (table 6). The effect of elevation was quadratic, with the highest probability at 5,100 feet. Occurrence decreased with increasing slope steepness on southerly aspects, but increased with increasing slope steepness on northerly aspects (fig. 2, pattern 2). The optimum aspect was 9 degrees. The ABLA series had the highest probability of occurrence, the PSME series had the lowest probability of occurrence, and the ABGR/THPL/TSHE series was intermediate.

Cover

A graph of mean cover by burn severity class and time shows minor differences (fig. 21b). Cover was always 20 percent or less on individual plots, and once plot occupancy was delayed beyond 2 years, only trace amounts were found (fig. 21c). Establishment of RILA beyond a delay of about 3 years was very limited.

Predicted RILA cover decreased with increasing burn severity (table 7). The effect of elevation was quadratic, with cover being the most at 5,300 feet. Cover decreased with increasing slope steepness on all aspects, especially southerly aspects (fig. 2, pattern 3). The optimum aspect for cover was 351 degrees.

Height

The graph of RILA mean height over time shows that height for the low burn severity class was somewhat greater than for high or medium severity classes (fig. 21d). For the height prediction model, burn severity, basal area, and slope steepness have a negative influence on height (table 8). Height increased with increasing cover and age. Taller plants were predicted on the ABGR/THPL/TSHE series, followed closely by ABLA, and then PSME.

RILA

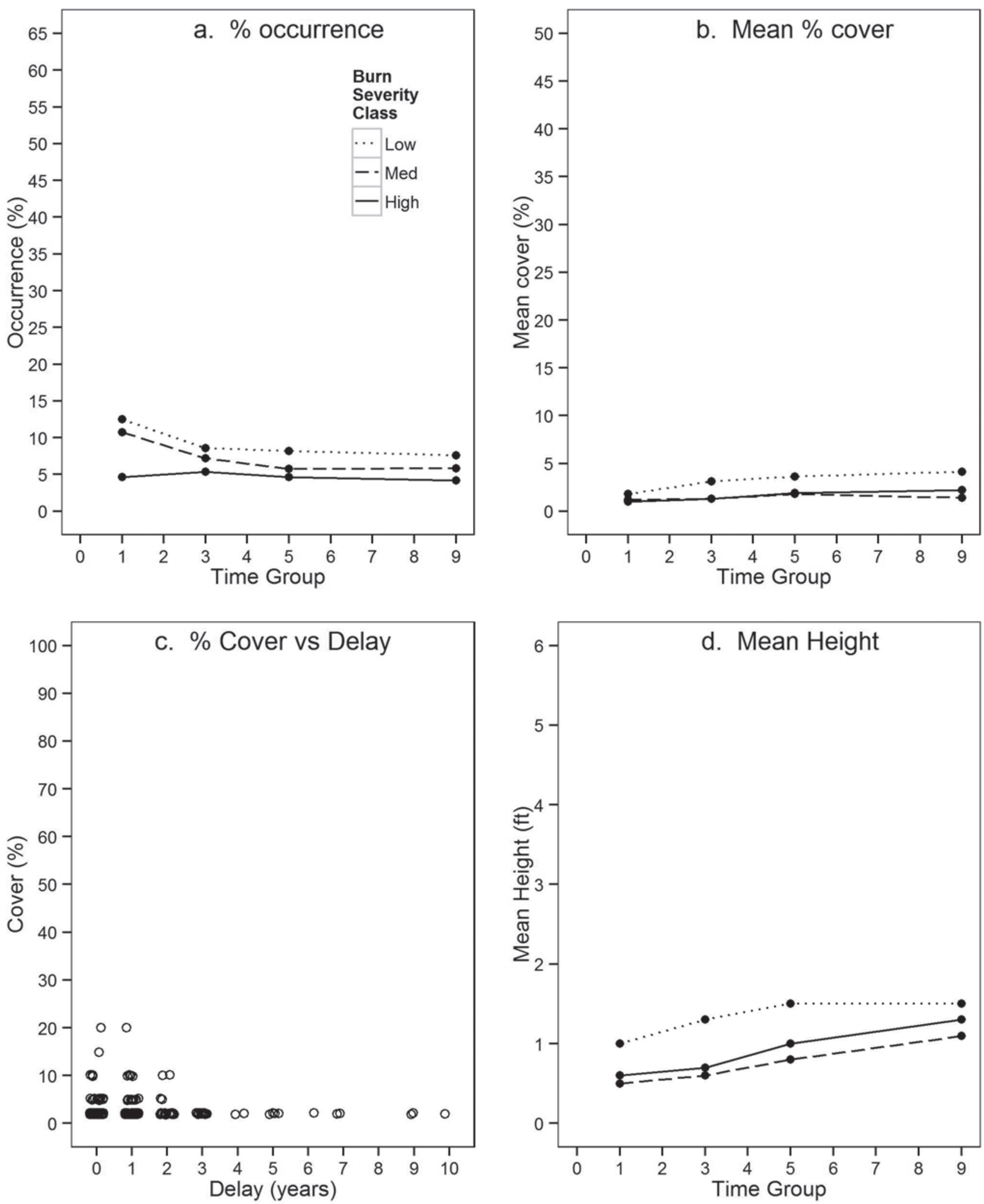

Figure 21—RILA (*Ribes lacustre*). (a). Percent occurrence by burn severity class and time since wildfire. (b). Mean percent cover by burn severity class and time since wildfire.(c). Percent cover on individual 1/300-acre plots by number of years between the wildfire and establishment of the species on the plot. (d). Mean height by burn severity class and time since wildfire.

RIVI (*Ribes viscosissimum*), Sticky Currant

Literature Review

The distribution of RIVI is from British Columbia and Alberta, south through the Rocky Mountain States as far south as Arizona (USDA Natural Resources Conservation Service 2015), but the species is not found on the west side of the Cascade Range (Hitchcock and Cronquist 2001; Johnson 1993). It can grow in a variety of coniferous forest types from the PIPO series upwards in elevation into the ABLA series, with plants being 3 to 7 feet tall (Patterson et al. 1985). Morgan and Neuenschwander (1988) report that RIVI establishment after fire is predominantly from soil seed banks, and Stickney (1986) classifies RIVI as an onsite colonizer from long-lived seeds in the soil. Kramer and Johnson (1987) quantified fairly high densities of RIVI and RILA in soil seed banks on three habitat types in central Idaho; most of the seed was in the 0 to 5 cm (0 to 2 inch) soil depth versus the 5 to 10 cm (2 to 4 inch) depth.

Occurrence

RIVI occurred on 14.8 percent of the plots (table 4), but very few plants were found on the MALH-FLAG fire. A graph of occurrence by burn severity and time since wildfire shows that higher burn severities usually had higher occurrences versus the low burn severity class (fig. 22a), but burn severity was not significant in the probability model.

The PICO series was eliminated from the data before developing the probability model for RIVI (table 5). The probability of RIVI increased with increasing basal area, time, and elevation (table 6). RIVI occurrence increased with increasing slope steepness for all aspects, and was slightly higher at the optimum aspect of 319 degrees (fig. 2, pattern 1). Occurrence was highest on the ABLA series, lowest on the PIPO/PSME series, and intermediate on the ABGR/THPL/TSHE series.

Cover

Mean percent cover was very low and nearly identical for all burn severity classes (fig. 22b). The highest percent cover (15 percent) was found on only plot, and only a few plots exceeded trace amounts of RIVI unless the delay to plot occupancy was less than 3 years (fig. 22c). This figure also provides evidence that RIVI can continue to become established many years after the wildfire.

Only basal area and elevation were significant predictors of RIVI cover (table 7). Cover increased with increasing basal area. Elevation had a quadratic effect, with the most cover expected at 5,400 feet.

Height

Figure 22d shows very little variation in RIVI height among burn severity classes. Increased height was associated with increasing cover and age, whereas height decreased with increasing basal area (table 8). Elevation had a quadratic effect on height, with the greatest height at 4,900 feet. Height increased with increasing slope steepness on southerly aspects, but decreased with increasing slope steepness on northerly aspects (fig. 2, pattern 2). The optimum aspect for height was 190 degrees.

RIVI

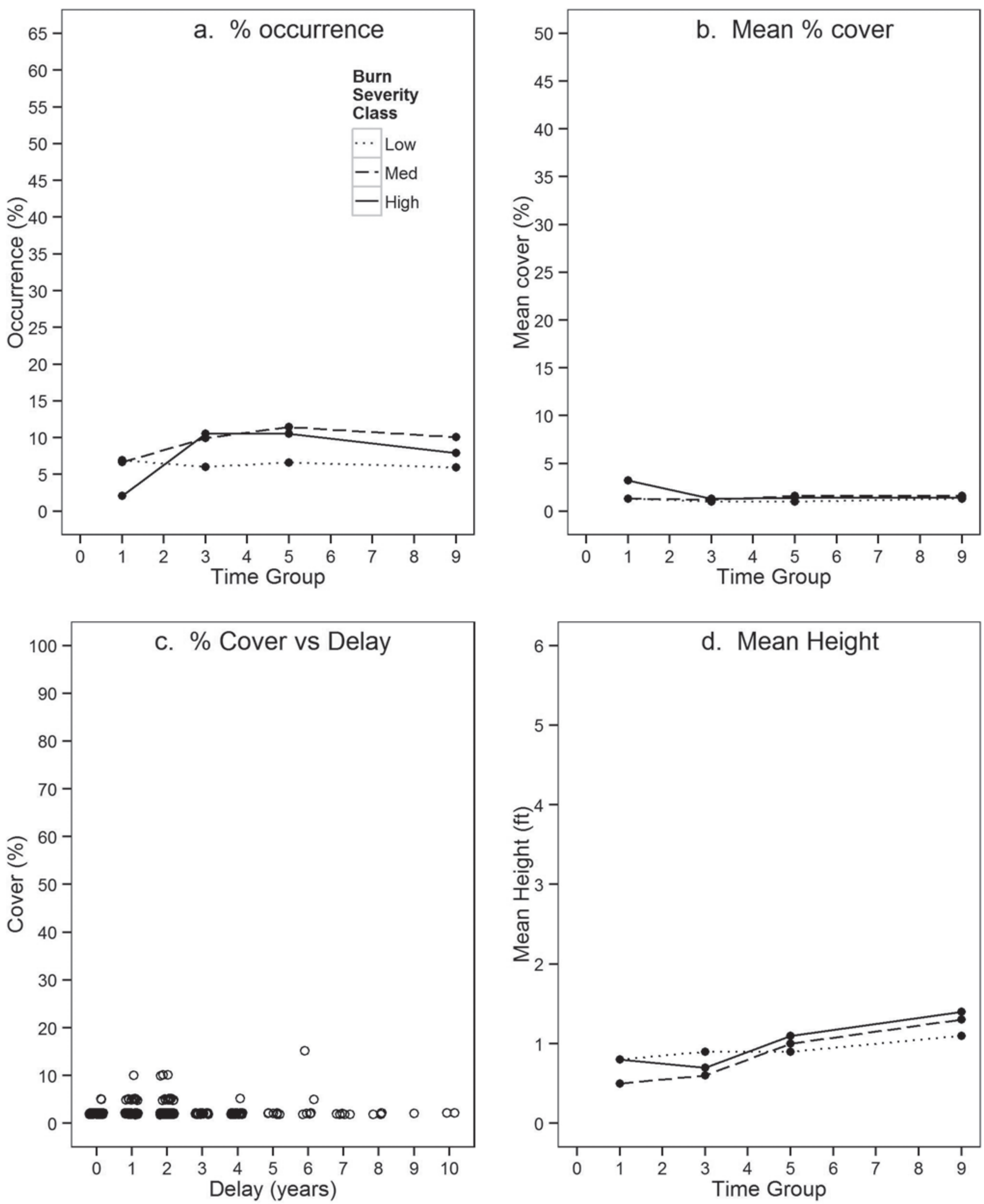

Figure 22—RIVI (*Ribes viscosissimum*). (a). Percent occurrence by burn severity class and time since wildfire. (b). Mean percent cover by burn severity class and time since wildfire. (c). Percent cover on individual 1/300-acre plots by number of years between the wildfire and establishment of the species on the plot. (d). Mean height by burn severity class and time since wildfire.

ROSA (*Rosa* species), Rose

FEIS Database

Three species are included in the ROSA grouping: *Rosa gymnocarpa* (baldhip rose), *Rosa woodsii* (Woods' rose), and *Rosa nutkana* (Nootka rose), in descending order of occurrence in our area. *Rosa gymnocarpa* ranges from southern British Columbia south into the Sierra Nevada Mountains in California, and east to Idaho and Montana (Reed 1993a). *Rosa woodsii* var. *woodsii* has a wide distribution from British Columbia to California, east to Saskatchewan, and south to New Mexico (Hauser 2006). *Rosa nutkana* is distributed from Alaska south to California and eastward throughout the Rocky Mountains into western Montana and New Mexico (Reed 1993b). All three species can be topkilled by low to moderate severity wildfires, but readily sprout from rhizomes and the root crown. Reproduction from seed is rarely seen in burned areas, even though seed can survive several years in the soil. Various researchers have found increases, decreases, and no change in ROSA abundance following wildfires.

Occurrence

ROSA occurred on 29.7 percent of the plots (table 4). Only a few plants were found on plots in the MALH-FLAG fire. As shown in figure 23a, percent occurrence decreased with increasing burn severity, and occurrence changed little over time. Both of these findings were confirmed in regression analysis.

All data were used to fit probability models for ROSA. The probability of occurrence for ROSA decreased with increasing burn severity, basal area, and elevation (table 6). Occurrence increased with increasing slope steepness on all aspects, especially at the optimum aspect of 150 degrees (fig. 2, pattern 1). The PIPO/PSME series had the highest probability of occurrence, followed by the ABGR/THPL/TSHE series, and then the ABLA/PICO series.

Cover

Mean percent cover on plots where ROSA occurred was less than 5 percent and did not appear to change with age (fig. 23b); however, age was significant in the regression analysis. Percent cover of ROSA on individual plots was always low, with no plots greater than 20 percent (fig. 23c). Beyond a delay to plot occupancy of 2 years, percent cover of ROSA rarely exceeded trace amounts (fig. 23c). The figure also shows that ROSA became established on only a few plots beyond about 4 years after the wildfire.

Predicted cover increased with age, and decreased with elevation (table 7). Cover increased with increasing slope steepness on all aspects, with greater increases at the optimum aspect of 269 degrees (fig. 2, pattern 1). The PIPO/PSME series had the most cover, followed by the ABGR/THPL/TSHE series, and then the ABLA/PICO series.

Height

ROSA height is slightly greater on the medium burn severity class than on the low or high burn severity classes (fig. 23d), though burn severity was not a significant factor in the height prediction model (table 8). Predicted ROSA height increased with increasing cover, age, and slope steepness. Decreases in height were associated with increasing basal area and elevation. ROSA height was greatest with the PIPO/PSME series, followed by the ABGR/THPL/TSHE series and ABLA/PICO series.

ROSA

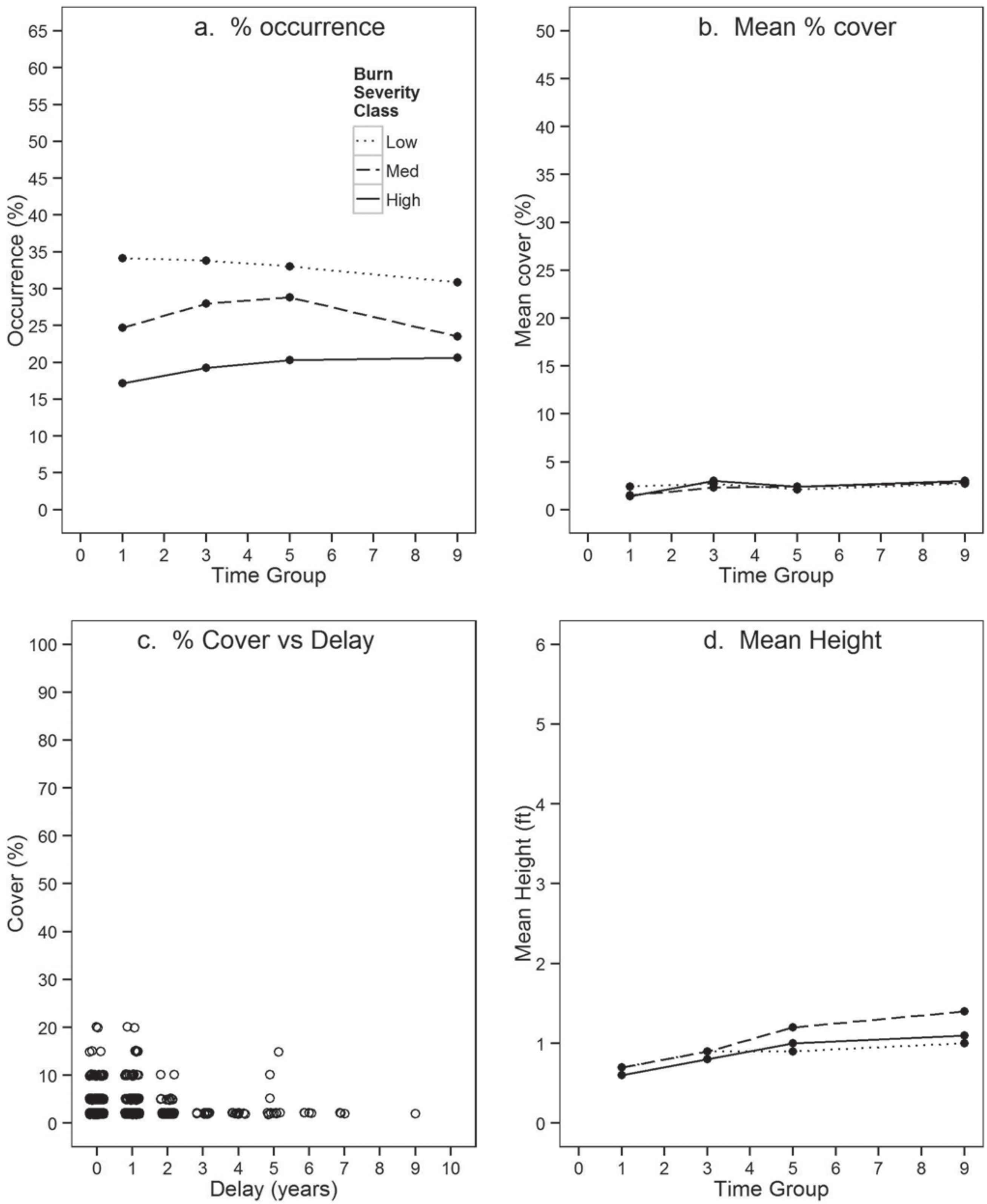

Figure 23—ROSA (*Rosa* spp.). (a). Percent occurrence by burn severity class and time since wildfire. (b). Mean percent cover by burn severity class and time since wildfire. (c). Percent cover on individual 1/300-acre plots by number of years between the wildfire and establishment of the species on the plot. (d). Mean height by burn severity class and time since wildfire.

RUPA (*Rubus parviflora*), Thimbleberry

FEIS Database

RUPA is found throughout the western United States, south into Mexico, and north into British Columbia and Alberta, including southeast Alaska. It is also found eastward in South Dakota and into the Lake States region (Gucker 2012). RUPA is found on cool, moist sites in forests and riparian areas, and reaches heights of up to 10 feet tall. This species can reproduce from seed, rhizomes, and rhizome fragments. Seeds most likely survive many years in the soil; however, they may be killed by fires where the heat penetrates the soil. Most fires only topkill RUPA, which then sprouts from rhizomes. Reestablishment of RUPA plants is rapid after wildfire, but may be delayed after severe fires.

Occurrence

RUPA occurred on 22.0 percent of the plots (table 4), with no plants recorded on the MALH-FLAG fire. Figure 24a shows no differences in occurrence by time and burn severity class.

The following habitat types were excluded before developing the probability model for RUPA: the PIPO series, the PSME series, some ABLA habitat types, and the PICO series (table 5). The probability of occurrence of RUPA decreased with increasing burn severity and elevation (table 6).

Cover

Mean percent RUPA cover was less than 10 percent (fig. 24b). On a few plots, cover did reach 60 percent, but most cover values were 30 percent or less. Plots where cover exceeded trace amounts occurred only where delay was less than 2 years (fig. 24c).

Predicted RUPA cover decreased with increasing delay between the fire and first occurrence on the plot, whereas cover increased with increasing age (table 7). The most coverage was found on the ABLA series and the least on the ABGR/THPL/TSHE series.

Height

Mean RUPA height for low and medium burn severity classes was greater than for the high burn severity class (fig. 24d). The height model shows that increased burn severity had a negative effect on RUPA height (table 8). Increases in height were associated with increased cover and age. Height increased with increasing slopes on southerly aspects, and decreased with increasing slopes on northerly aspects (fig. 2, pattern 2). Optimum aspect for height is 167 degrees.

RUPA

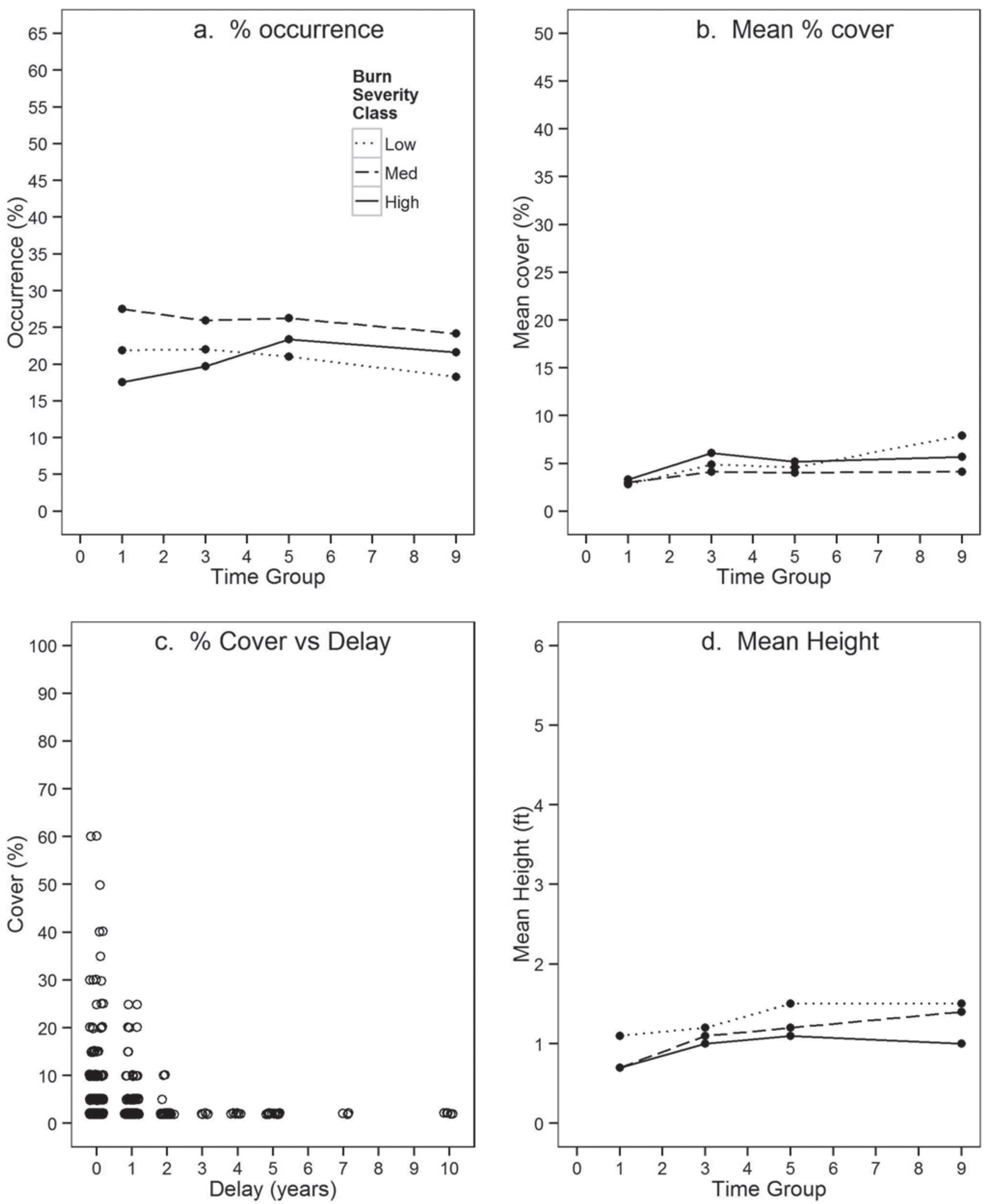

Figure 24—RUPA (*Rubus parviflorus*). (a). Percent occurrence by burn severity class and time since wildfire. (b). Mean percent cover by burn severity class and time since wildfire. (c). Percent cover on individual 1/300-acre plots by number of years between the wildfire and establishment of the species on the plot. (d). Mean height by burn severity class and time since wildfire.

SALX (*Salix* species), Willow

FEIS Database

Most of the willow encountered in this study was *Salix scouleriana*; therefore, our results and discussion pertain mainly to this species. The species has a wide distribution, including Alaska, Canada, the western United States, and into Mexico (Anderson 2001c). Its lifeform is a shrub, but can occasionally be a tree. SALX is non-rhizomatous; however, plants have deep root systems that can sprout after disturbances. In addition, disturbed sites are colonized by offsite seed dispersed by wind and water. The seeds, which have cottony hairs, can travel several miles on the wind. Seeds germinate within 12 to 24 hours after dispersal, but mineral soil and adequate sunlight are needed for seedling establishment. Increases in SALX volume can occur rapidly after wildfires.

Occurrence

SALX ranked third in abundance, with this species occurring on 51.6 percent of the plots (table 4). Figure 25a shows occurrence by burn severity and time since wildfire. Occurrence was higher for medium and high burn severity versus low burn severity, a difference that was statistically significant when regression models were developed.

All data were used to predict the probability of occurrence for SALX. Probability of occurrence increased with increasing burn severity and with time since wildfire (table 6). Occurrence decreased with elevation. It increased with increasing slope steepness on northerly aspects, but decreased with increasing slope steepness on southerly aspects (fig. 2, pattern 2). The optimum aspect was 41 degrees. Occurrence was highest on the ABGR/THPL/TSHE series, lowest on the PIPO/PSME series, and intermediate on the ABLA/PICO series.

Cover

Mean percent cover on plots where SALX occurred increased with age, but did not exceed 10 percent (fig. 25b). A graph of percent cover by delay shows a decline in coverage as delay increases (fig. 25c). Maximum SALX plot coverage was about 40 percent, and this species was able to exceed trace coverages when the delay to plot occupancy was over 2 years. Figure 25c also shows that SALX was able to colonize sites long after the wildfire.

Predicted SALX cover increased with age and elevation, but burn severity was not significant (table 7). Cover decreased with increasing basal area, and with increasing delay to plot occupancy. The ABLA/PICO series had the least coverage, ABGR/THPL/TSHE had the most, and the PIPO/PSME series was intermediate.

Height

The low burn severity class had greater height early in the study, but by study end, height on medium and high severity classes was greater (fig. 25d). Cover, age, and slope had a positive effect on SALX height. Height decreased with increasing basal area, burn severity, and elevation (table 8). Height was greatest on ABLA/PICO series, followed by the PIPO/PSME series, and the ABGR/THPL/TSHE series.

SALX

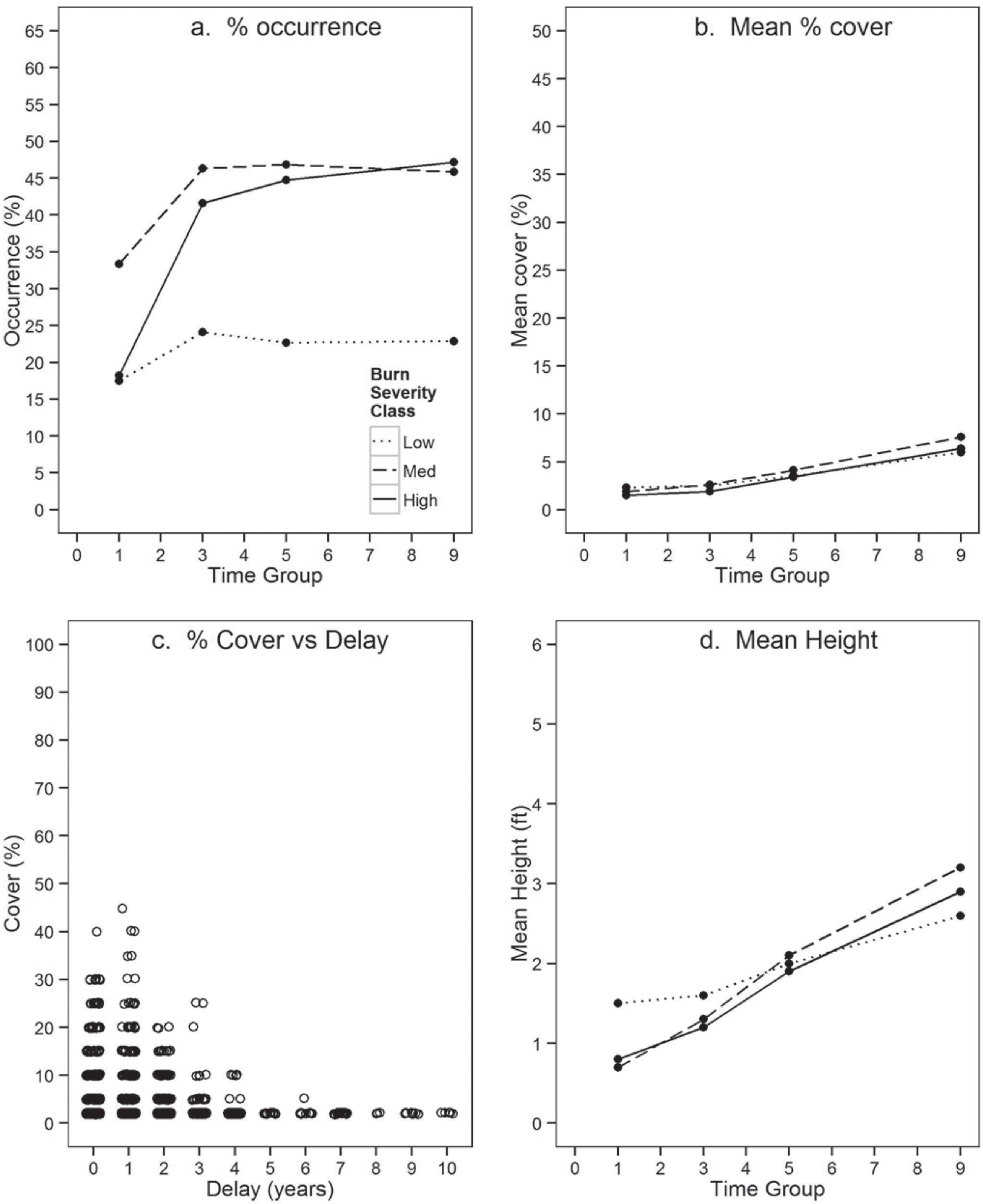

Figure 25—SALX (*Salix* spp.). (a). Percent occurrence by burn severity class and time since wildfire. (b). Mean percent cover by burn severity class and time since wildfire. (c). Percent cover on individual 1/300-acre plots by number of years between the wildfire and establishment of the species on the plot. (d). Mean height by burn severity class and time since wildfire.

SARA (*Sambucus racemosa*), Red Elderberry

FEIS Database

SARA is native to North America and Eurasia. In North America, it is found from Alaska to California, throughout the western United States, and even east as far as Maine and North Carolina (Fryer 2008). It is found in a variety of forest communities throughout its range as well as in riparian areas. Shrubs are 7 to 20 feet tall, and tree forms are occasionally found. Regeneration can be from off-site seed, seed banks, rhizome and root crown sprouting, and layering. The species is not always rhizomatous, so root crown sprouting after wildfire is more common than sprouting from rhizomes. Seed dormancy can be broken by wildfire, which cracks the seed coat; however, prolonged heat can kill the seed. Even though there are several ways for SARA to reproduce, it usually remains a minor component of the vegetation following wildfire.

Occurrence

SARA was the least abundant of the shrubs reported in this study, with 2.8 percent occurrence on 896 plots (table 4). Figure 26a shows occurrence by burn severity class and time since wildfire. No appreciable differences are evident.

The PIPO and PSME series were eliminated before fitting the probability model for SARA (table 5). The probability of SARA occurrence increased with increasing elevation (table 6). Occurrence increased with increasing slope steepness on northerly aspects, but decreased sharply with increasing slope steepness on southerly aspects (fig. 2, pattern 2). The optimum aspect was 336 degrees.

Cover

Mean percent cover did not exceed 5 percent (fig. 26b). Only three plots reached 5 percent cover; the rest had trace values (fig. 26c). After a delay of about 2 years, SARA became established on only a few plots. No variables were significant in predicting SARA cover (table 7). This is not surprising given that all but three plots had trace values for SARA cover.

Height

By the end of the study, mean SARA height on the low and high burn severity classes were the same and were greater than on the medium severity class (fig. 26d). Predicted height decreased with increasing burn severity and elevation (table 8).

SARA

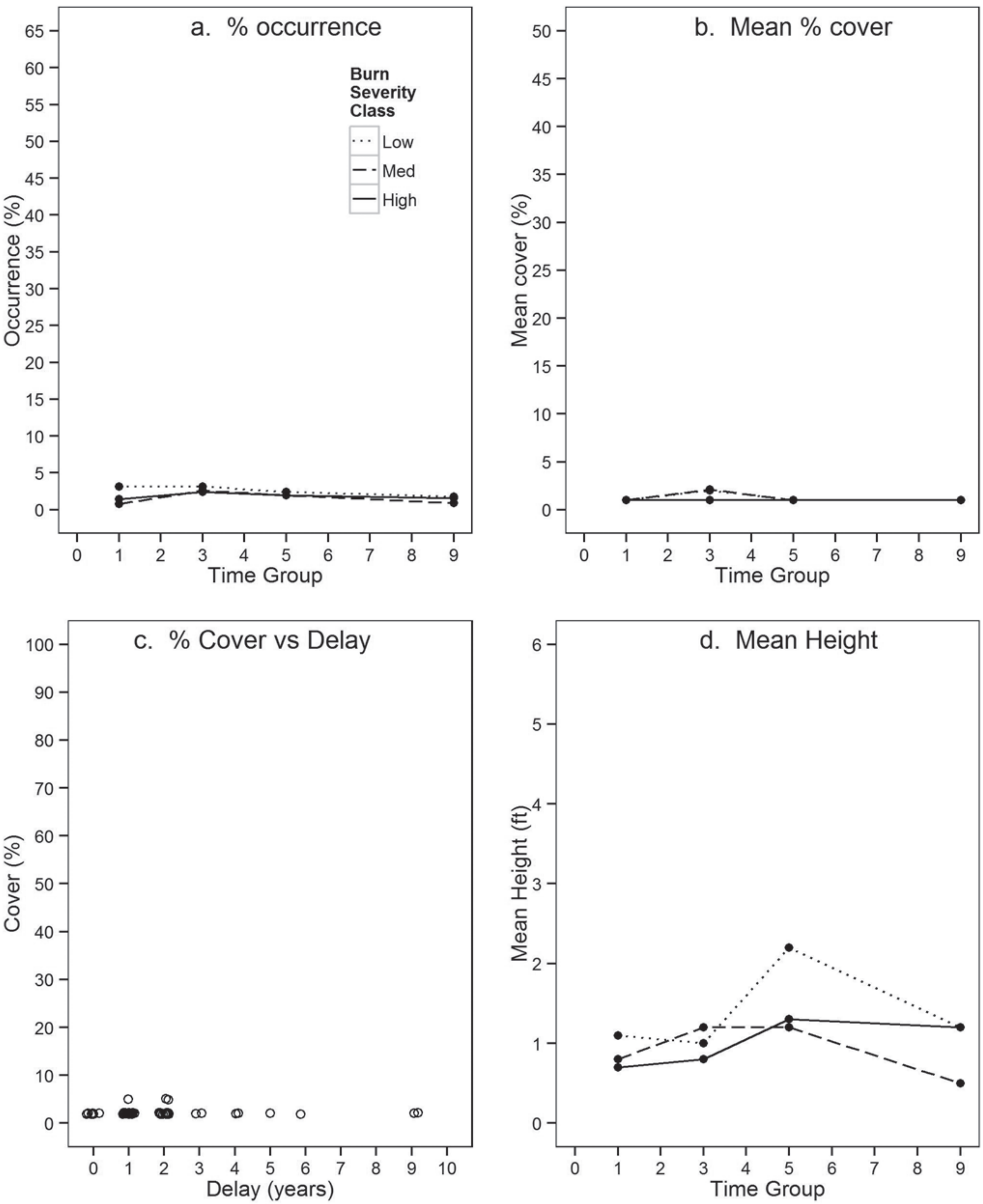

Figure 26—SARA (*Sambucus racemosa*). (a). Percent occurrence by burn severity class and time since wildfire. (b). Mean percent cover by burn severity class and time since wildfire. (c). Percent cover on individual 1/300-acre plots by number of years between the wildfire and establishment of the species on the plot. (d). Mean height by burn severity class and time since wildfire.

SHCA (*Shepherdia canadensis*), Russet Buffaloberry

FEIS Database

SHCA occurs throughout Canada and Alaska, and in the Rocky Mountains as far south as Arizona (Walkup 1991). It is a deciduous shrub that reaches heights of 3 to 13 feet and can grow on sites ranging from dry to moist. This species can regenerate from either seed or sprouting from the root crown after disturbance, but with either method, it is not an aggressive colonizer. Low intensity fires will maintain SHCA on a site, but regrowth is slow. It can be eliminated from sites by high intensity fires.

Occurrence

SHCA occurred on 3.3 percent of the plots (table 4), with no occurrences on the MALH-FLAG fire. There was very little variation in occurrence among burn severity classes, and occurrence did not increase over time (fig. 27a).

No data were excluded to develop the probability model for SHCA (table 5). Predicted occurrence (table 6) increased with increasing slope steepness on northeasterly aspects, but decreased with increasing slope steepness on southeasterly aspects (fig. 2, pattern 2). The optimum aspect was 67 degrees. Predicted occurrence was highest on the ABGR/THPL/TSHE series, intermediate on the ABLA/PICO series, and lowest on the PIPO/PSME series (table 6).

Cover

Mean percent cover was higher for the low burn severity class than for the medium or high severity classes, though mean cover for SHCA never exceeded 10 percent (fig. 27b). Cover was as high as 20 percent on a few plots, and this species continued to become established on plots well after the wildfire (fig. 27c).

Predicted SHCA cover decreased with increasing burn severity, and increased with increasing age (table 7).

Height

Mean height for SHCA was greater on the low burn severity class until the last measurement, when the low and high severity classes were similar and were greater than mean height for the medium severity class (fig. 27d). Predicted SHCA height decreased with increasing burn severity and elevation, whereas increasing cover and age were associated with higher predicted height (table 8). Height increased with increasing slope steepness on southerly aspects, but decreased with increasing slope steepness on northerly aspects (fig. 2, pattern 2). The optimum aspect was 180 degrees.

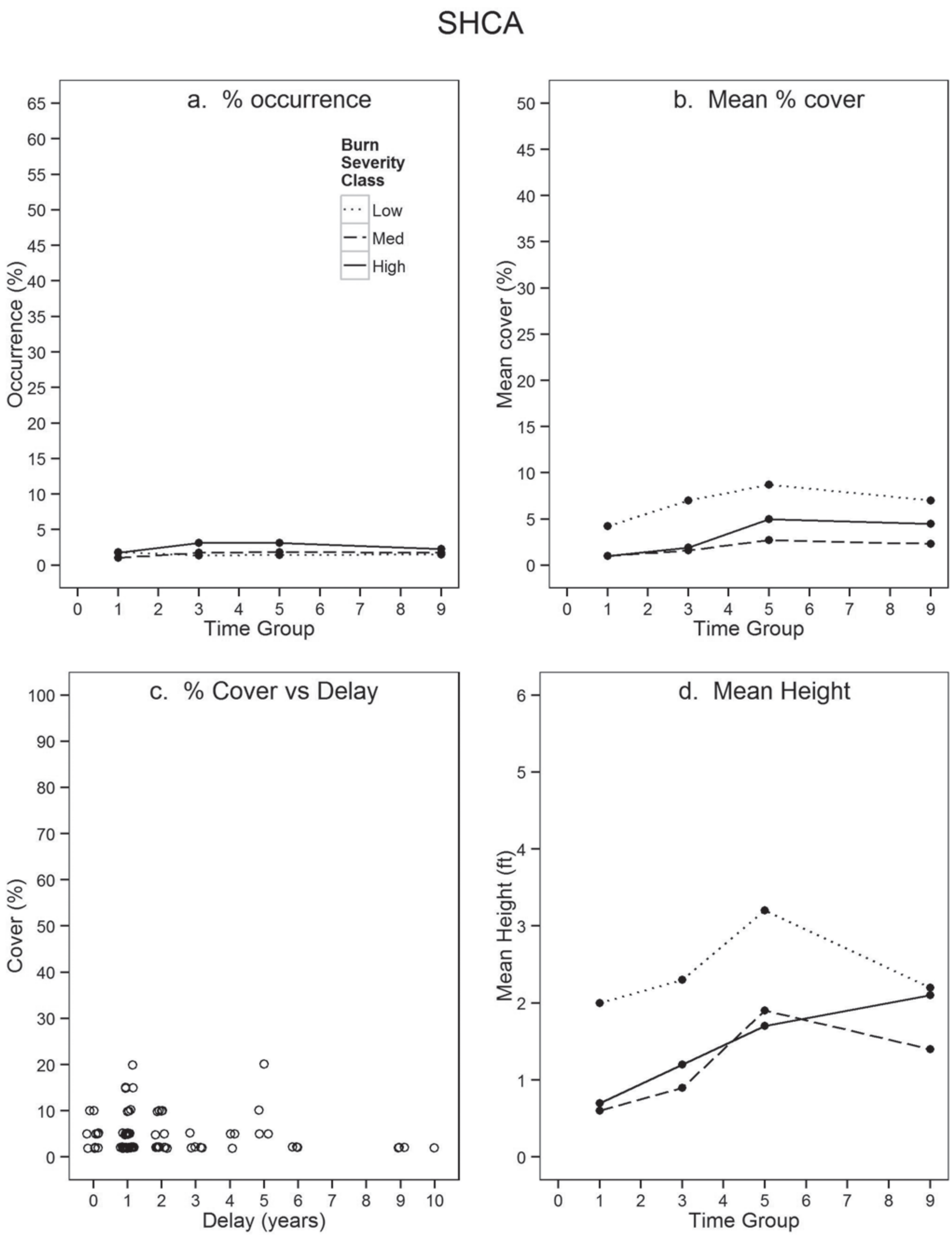

Figure 27—SHCA (*Shepherdia canadensis*). (a). Percent occurrence by burn severity class and time since wildfire. (b). Mean percent cover by burn severity class and time since wildfire. (c). Percent cover on individual 1/300-acre plots by number of years between the wildfire and establishment of the species on the plot. (d). Mean height by burn severity class and time since wildfire.

SOSC2 (*Sorbus scopulina*), Greene's Mountain Ash

Literature Review

SOSC2 occurs in mostly moist, montane to subalpine sites, from Alaska south to Wyoming and Colorado, and east to the Dakotas (USDA Natural Resources Conservation Service 2015). It is a deciduous shrub, generally 3 to 15 feet tall, often growing in a cluster of stems (Patterson et al. 1985). This species grows in a variety of coniferous forest types from the PSME series upwards in elevation through the ABLA series (Patterson et al. 1985). It propagates from seed. Stickney (1986) classified SOSC2 as a wildfire survivor because it is adapted to sprouting from the root crown.

Occurrence

SOSC2 occurred on 4.4 percent of the 896 plots (table 4), with no occurrences on the MALH-FLAG fire. Occurrence was always 5 percent or less and there were no apparent differences in SOSC2 occurrence between the burn severity classes (fig. 28a).

Plots in the PIPO and PICO habitat type series were excluded when fitting the probability of occurrence model for SOSC2 (table 5). The probability of SOSC2 decreased with increasing burn severity and elevation (table 6). Occurrence increased with increasing slope steepness across all aspects, especially at the optimum aspect of 342 degrees (fig. 2, pattern 1). Predicted occurrence was highest on the ABLA series, lower on the ABGR/THPL/TSHE series, and lowest on the PSME series.

Cover

Mean percent cover was always less than 5 percent (fig. 28b). SOSC2 cover on individual plots never exceeded 5 percent, with most occurrences only trace amounts (fig. 28c). SOSC2 continued to become established on plots for several years after the wildfire.

Increasing cover of SOSC2 was associated with increasing burn severity, whereas cover decreased with increasing delay to plot occupancy (table 7). Cover increased with increasing slope steepness on northerly aspects, but decreased with increasing slope steepness on southerly aspects (fig. 2, pattern 2). The optimum aspect for cover was 12 degrees.

Height

SOSC2 mean height differed by burn severity class through the early years of the study but by study end, there was little difference in SOSC2 mean height (fig. 28d). Predicted height increased with increasing cover and age (table 8).

SOSC2

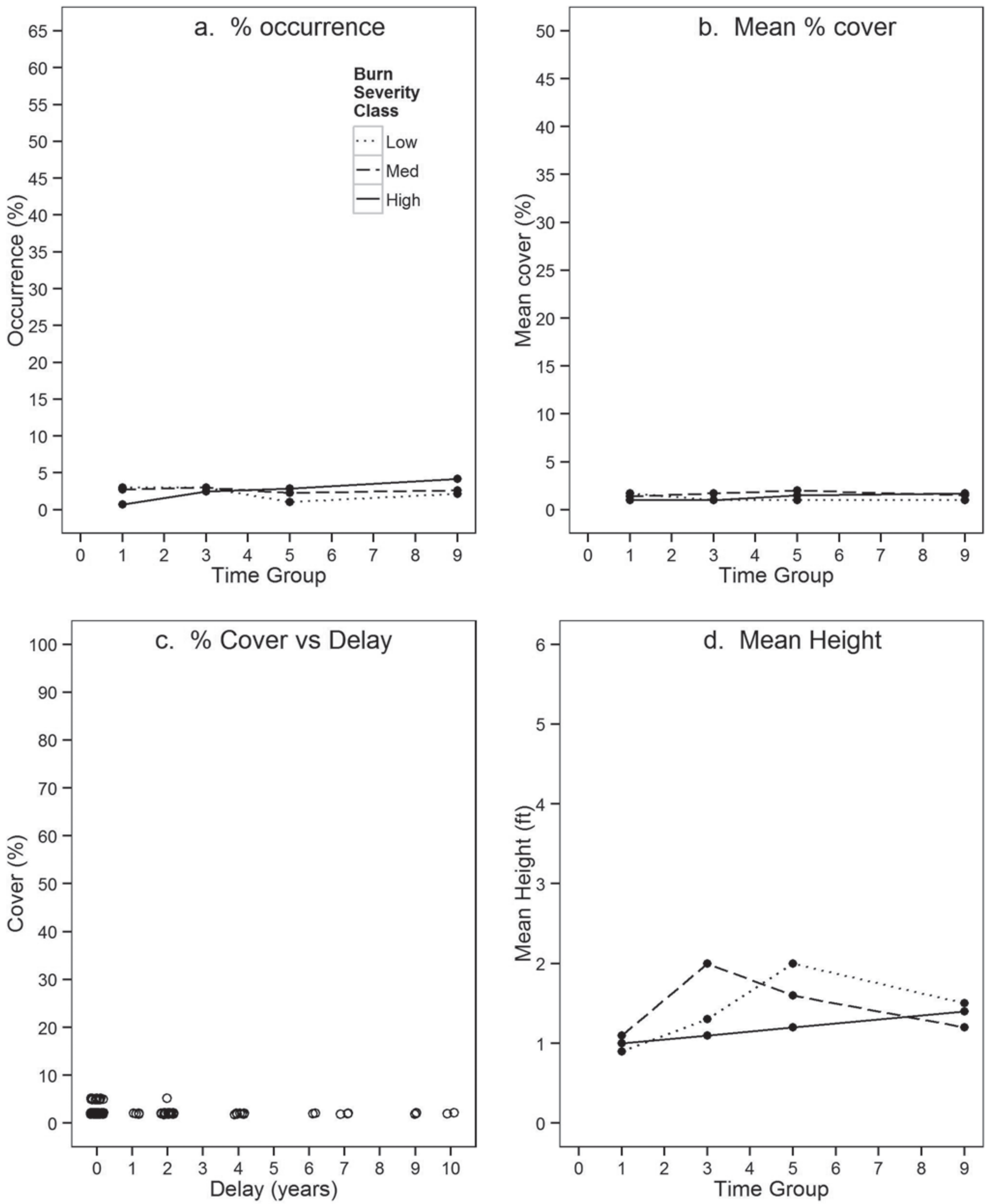

Figure 28—SOSC2 (*Sorbus scopulina*). (a). Percent occurrence by burn severity class and time since wildfire. (b). Mean percent cover by burn severity class and time since wildfire. (c). Percent cover on individual 1/300-acre plots by number of years between the wildfire and establishment of the species on the plot. (d). Mean height by burn severity class and time since wildfire.

SPBE (*Spiraea betulifolia*), White Spirea

FEIS Database

SPBE is found throughout the Interior West from southern Idaho north through western Oregon and Washington and western Montana, and east into Wyoming and the Black Hills of South Dakota. It is also found in southern British Columbia and east into Saskatchewan and Alberta (Habeck 1991). It grows in sagebrush communities upward in elevation in many forest and subalpine communities. It reaches heights of 1 to 3 feet. SPBE is rated as a dependable fire-survivor species because the roots and rhizomes are highly resistant to being consumed by wildfire. Although plants are almost always topkilled by moderate to high intensity wildfires, the rhizomes still survive. Seed dispersal is evidently not a major regeneration mechanism because seed numbers are low in soil seed banks and SPBE seedlings are rarely found.

Occurrence

SPBE had the highest occurrence of all species in this study with 57.7 percent on the 896 sample plots (table 4). SPBE was rarely found on plots in the MALH-FLAG fire (only 3 of the 180 plots). Occurrence by burn severity class and time since wildfire is shown in figure 29a. Although the graph shows occurrence was greatest on the high burn severity class, this result was opposite in the regression analysis, as noted below.

No data were excluded when the regression model for the probability of occurrence for SPBE was developed (table 5). The probability of SPBE decreased with increasing burn severity, and with increasing elevation (table 6). SPBE occurrence increased slightly with increasing basal area. Occurrence decreased with increasing slope steepness on northerly aspects, but there was little difference between slopes on southerly aspects (fig. 2, pattern 3). The optimum aspect was 187 degrees. The ABLA/PICO series had the highest probability of SPBE occurrence, followed by the PIPO/PSME series, and then the ABGR/THPL/TSHE series.

Cover

Figure 29b shows mean percent cover of SPBE on plots where it occurred. Means were low with little differences among burn severity classes. Percent cover on individual plots was generally 30 percent or below (fig. 29c). This figure also shows that cover of SPBE was nearly always trace values when delay to plot occupancy reached 2 years.

Predicted SPBE cover decreased with increasing delay to plot occupancy and elevation (table 7). Cover increased with age. It increased with increasing slopes on all aspects, but the increase was greatest at the optimum aspect for cover of 266 degrees (fig. 2, pattern 1). The most coverage was found on the ABLA/PICO series, followed by the PIPO/PSME series, and least on the ABGR/THPL/TSHE series.

Height

The graph of mean height by time shows little to no difference between burn severity classes (fig. 29d). Predicted SPBE height increased with increasing SPBE cover on the plot, age, and slope steepness, whereas it decreased with increasing basal area and elevation (table 8). Greatest height was on the ABGR/THPL/TSHE series, followed by the ABLA/PICO series, and then the PIPO/PSME series.

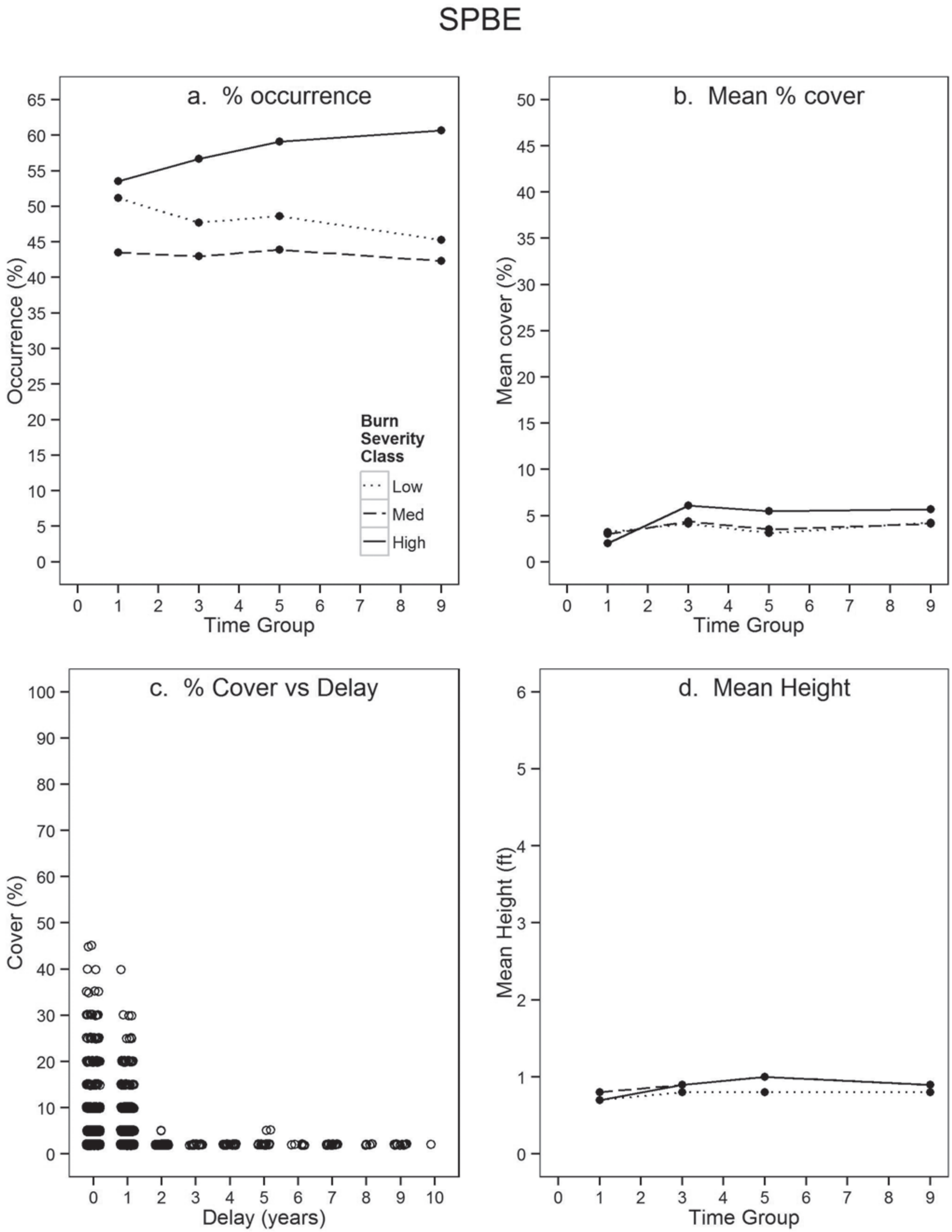

Figure 29—SPBE (*Spiraea betulifolia*). (a). Percent occurrence by burn severity class and time since wildfire. (b). Mean percent cover by burn severity class and time since wildfire. (c). Percent cover on individual 1/300-acre plots by number of years between the wildfire and establishment of the species on the plot. (d). Mean height by burn severity class and time since wildfire.

SYAL (*Symphoricarpos albus*), Common Snowberry

FEIS Database

The Pacific variety of SYAL (var. *laevigatus*) is found from southern portions of Alaska south to California and eastward into the Rocky Mountains (McWilliams 2000). In the northern Rocky Mountains, it grows in forests that support ponderosa pine, Douglas-fir, grand fir, cedar, hemlock, and subalpine fir. Heights of plants are typically 3 to 4.5 feet. SYAL is one of the first species to recolonize a burned site. Plants are often topkilled by fire, but belowground parts are very resistant to fire. New plants arise via sprouts from rhizomes and roots. Although the main method of reproduction is from rhizomes, regeneration from buried seed can occur following low severity fires that remove little of the soil organic material.

Occurrence

SYAL occurred on 26.1 percent of the plots (table 4). Figure 30a shows a decrease in occurrence of SYAL as burn severity increased as well as an increase for all burn severity classes over time. This relationship was verified during regression analysis.

Habitat types that were excluded when developing the probability model for SYAL were some upper elevation ABLA habitat types and the PICO series (table 5). The probability of occurrence of SYAL decreased with increasing burn severity and basal area, whereas it increased with time (table 6). Occurrence increased with increasing slope steepness on all aspects, especially at the optimum aspect of 203 degrees (fig. 2, pattern 1). The PIPO/PSME series had the highest occurrence, followed by the ABLA series, and then the ABGR/THPL/TSHE series.

Cover

Mean percent cover on plots where SYAL occurred was slightly higher for the low burn severity class (fig. 30b), and there were slight increases over time. Maximum cover of SYAL on individual plots was 90 percent, but was typically below 50 percent (fig. 30c). Highest cover percentages were on plots where the species became established quickly. Once the delay between disturbance and plot occupancy reached 3 years, very few of these plots had SYAL cover greater than trace amounts.

Predicted SYAL cover decreased with increasing basal area, delay to plot occupancy, and slope steepness, whereas it increased with age (table 7). The least coverage occurred on the ABGR/THPL/TSHE series—it was more on the PIPO/PSME series, and most on the ABLA series.

Height

The medium burn severity class had slightly greater mean SYAL height than the low or high severity classes (fig. 30d), though burn severity was not a significant variable in the height prediction model (table 8). SYAL height increased with increasing cover, age, and slope steepness. Increasing basal area and elevation were associated with decreased height. SYAL height was highest on the PIPO/PSME series, followed by the ABGR/THPL/TSHE series, and then the ABLA series.

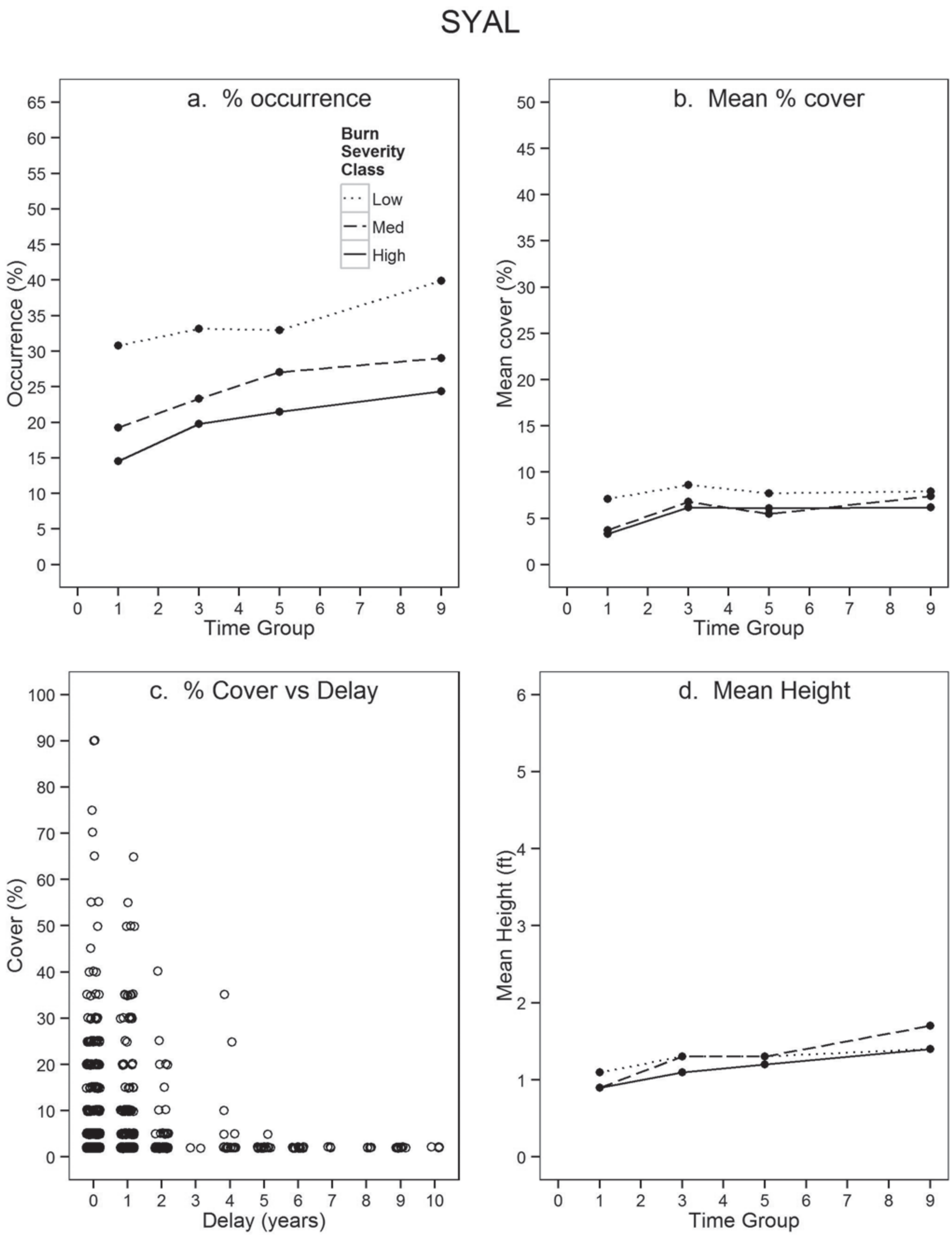

Figure 30—SYAL (*Symphoricarpos albus*). (a). Percent occurrence by burn severity class and time since wildfire. (b). Mean percent cover by burn severity class and time since wildfire. (c). Percent cover on individual 1/300-acre plots by number of years between the wildfire and establishment of the species on the plot. (d). Mean height by burn severity class and time since wildfire.

VAME (*Vaccinium membranaceum* = *V. globulare*), Thinleaf Huckleberry

FEIS Database

VAME is found from Alaska to California and eastward in Ontario, Wyoming, Idaho, Montana, Utah, Colorado, South Dakota, and Minnesota (Simonin 2000). It is found in most forest types in the Interior West, and is found in greater abundance on northern aspects. Reproduction can be through seed and expansion via rhizomes, although VAME seeds are a minor component of soil seed banks and reproduction via seed is rare. Plants can survive low intensity wildfires, but are topkilled by higher intensity wildfires. Plants topkilled by wildfires resprout from rhizomes and root crowns. In general, VAME is slow to recover from moderate to severe wildfires.

Occurrence

VAME had the second highest overall occurrence with 53.0 percent (table 4). This species was found on only 5 of the 180 plots on the MALH-FLAG fire. A graph of occurrence by burn severity and time since wildfire (fig. 31a) shows higher occurrence for the higher burn severity class, but the opposite was found during regression analysis.

Habitat types excluded from the data for development of the probability model for VAME were the PIPO series, dry PSME habitat types, and the ABLA-PIAL/VASC habitat type (table 5). Probability of occurrence decreased with increasing burn severity, but increased with increasing time (table 6). The effect of elevation was quadratic, with highest occurrence at 6,800 feet. Occurrence increased with increasing slope steepness, especially at the optimum aspect of 328 degrees (fig. 2, pattern 1). The ABLA/PICO series had the highest occurrence of VAME, followed by the ABGR/THPL/TSHE series, and then the PSME series.

Cover

A graph of mean cover of VAME showed decreased cover in the high burn severity class, and an increase with time (fig. 31b). Most cover on individual plots was less than about 50 percent (fig. 31c). This figure also shows a drop in percent cover when the delay between the wildfire and plot occupancy exceeded 2 years. VAME continued to become established years after the wildfire occurred, but coverage rarely exceeded trace amounts.

Predicted VAME cover decreased with increasing burn severity and number of years of delay (table 7). Percent cover increased with increasing age. The effect of elevation was quadratic, with an optimum of 5,900 feet. Cover increased with increasing slope steepness on southerly aspects, but there was little difference on northerly slopes (fig. 2, pattern 1). The optimum aspect for VAME cover was 199 degrees. Cover was most on the ABGR/THPL/TSHE series, followed by the ABLA/PICO series, and then the PSME series.

Height

Although mean height for the low burn severity class was slightly greater than for the medium or high burn severity classes through most of the study, by the end of the study there were no differences among the burn severity classes (fig. 31d). Predicted VAME height increased with increasing cover and age (table 8). Height decreased with increasing burn severity and slope steepness. Elevation had a quadratic effect on height, with the optimum height at 5,600 feet. Height was greatest on the ABGR/THPL/TSHE series, followed by ABLA/PICO, and then the PSME series.

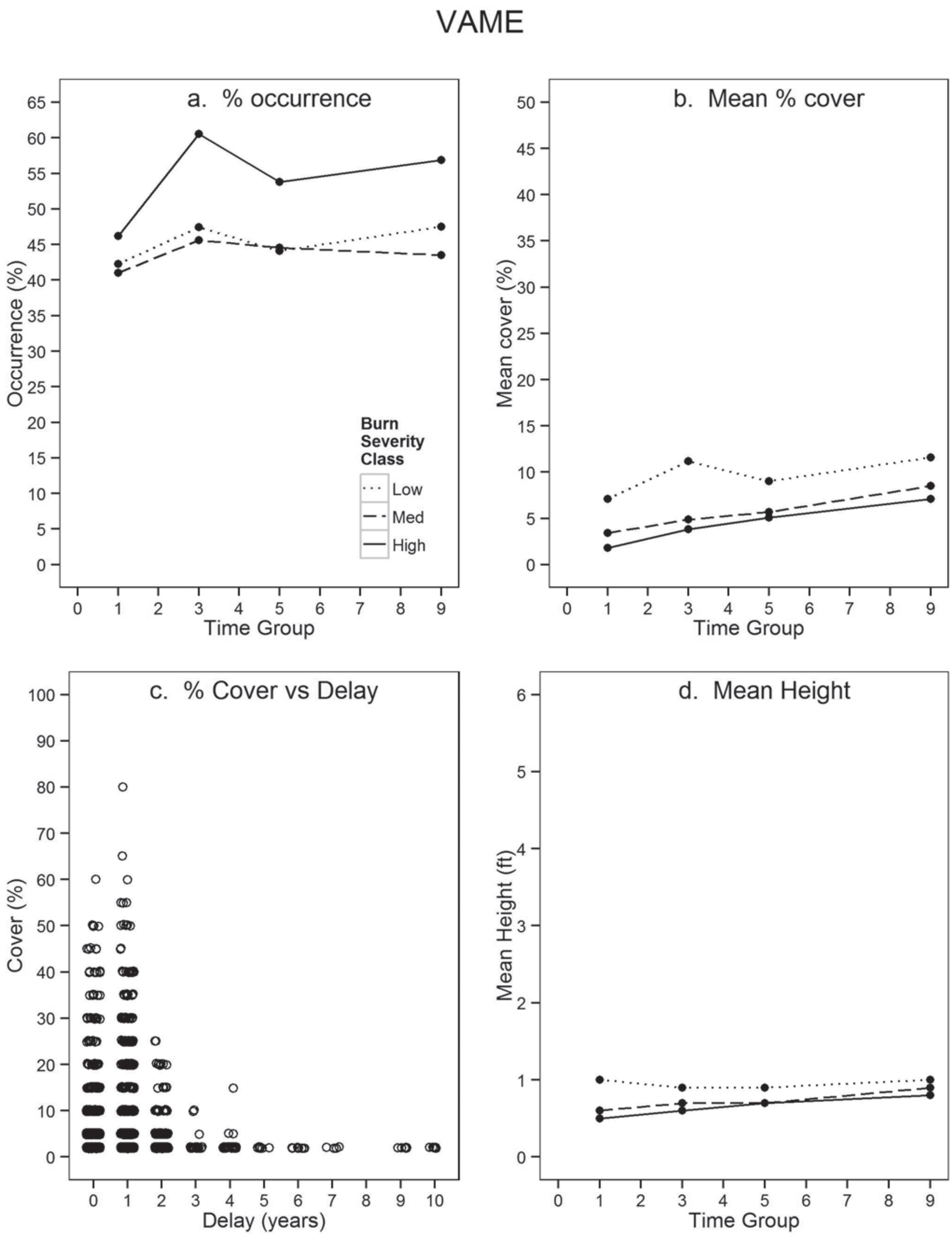

Figure 31—VAME (*Vaccinium membranaceum*). (a). Percent occurrence by burn severity class and time since wildfire. (b). Mean percent cover by burn severity class and time since wildfire. (c). Percent cover on individual 1/300-acre plots by number of years between the wildfire and establishment of the species on the plot. (d). Mean height by burn severity class and time since wildfire.

VASC (*Vaccinium scoparium*), Grouse Whortleberry

FEIS Database

VASC is found in subalpine forests throughout the Rocky Mountains in Canada and the United States, with scattered occurrence below elevations that support subalpine forests (Johnson 2001). It has a low growth form with heights from 4 to 20 inches. The species has shallow rhizomes, which can readily sprout following disturbances, but seedlings have been rarely found in the field. VASC is moderately resistant to wildfire. After low or moderate severity fires that do not kill the shallow rhizomes, VASC sprouts are common. Severe wildfires can kill the plants.

Occurrence

VASC had the fourth highest occurrence of shrub species in our sample with 33.6 percent (table 4). Figure 32a shows occurrence by burn severity class and time since wildfire. Occurrence was highest on the low burn severity class, which was verified in the regression analyses.

Habitat types that were excluded before developing the probability of occurrence model for VASC were the PIPO series, dry PSME habitat types, and the THPL series (table 5). The probability of occurrence of VASC decreased with increasing burn severity, but increased with increasing basal area, time, and elevation (table 6). Occurrence decreased with increasing slope steepness, especially away from the optimum aspect of 56 degrees (fig. 2, pattern 3). The ABLA/PICO series had the highest occurrence, followed by the ABGR/TSHE series, and the PSME series was lowest.

Cover

Figure 32b shows that plots with medium and high burn severity had lower percent cover, but mean percent cover did not exceed about 15 percent. Percent cover of VASC on individual plots did not exceed 70 percent (fig. 32c). Higher cover percentages occurred only when VASC became established without a delay or with a delay of only 1 year. VASC was able to become established on additional plots as time increased, but beyond a delay to plot occupancy of about 3 years, coverage did not exceed trace amounts.

Predicted VASC cover decreased with increasing burn severity and the number of years of delay (table 7), whereas it increased with increasing age. The effect of elevation was quadratic, with cover the highest at 7,400 feet. Cover decreased with increasing slope steepness on easterly aspects, with little difference among westerly slopes (fig. 2, pattern 3). The optimum aspect was 266 degrees. Cover was least on the PSME series, intermediate on the ABGR/TSHE series, and highest on the ABLA/PICO series.

Height

VASC has a small stature, so with height measured to the nearest 0.5 feet, no changes appeared through time or by burn severity class (fig. 32d). However, predicted VASC height increased slightly with increasing cover (table 8).

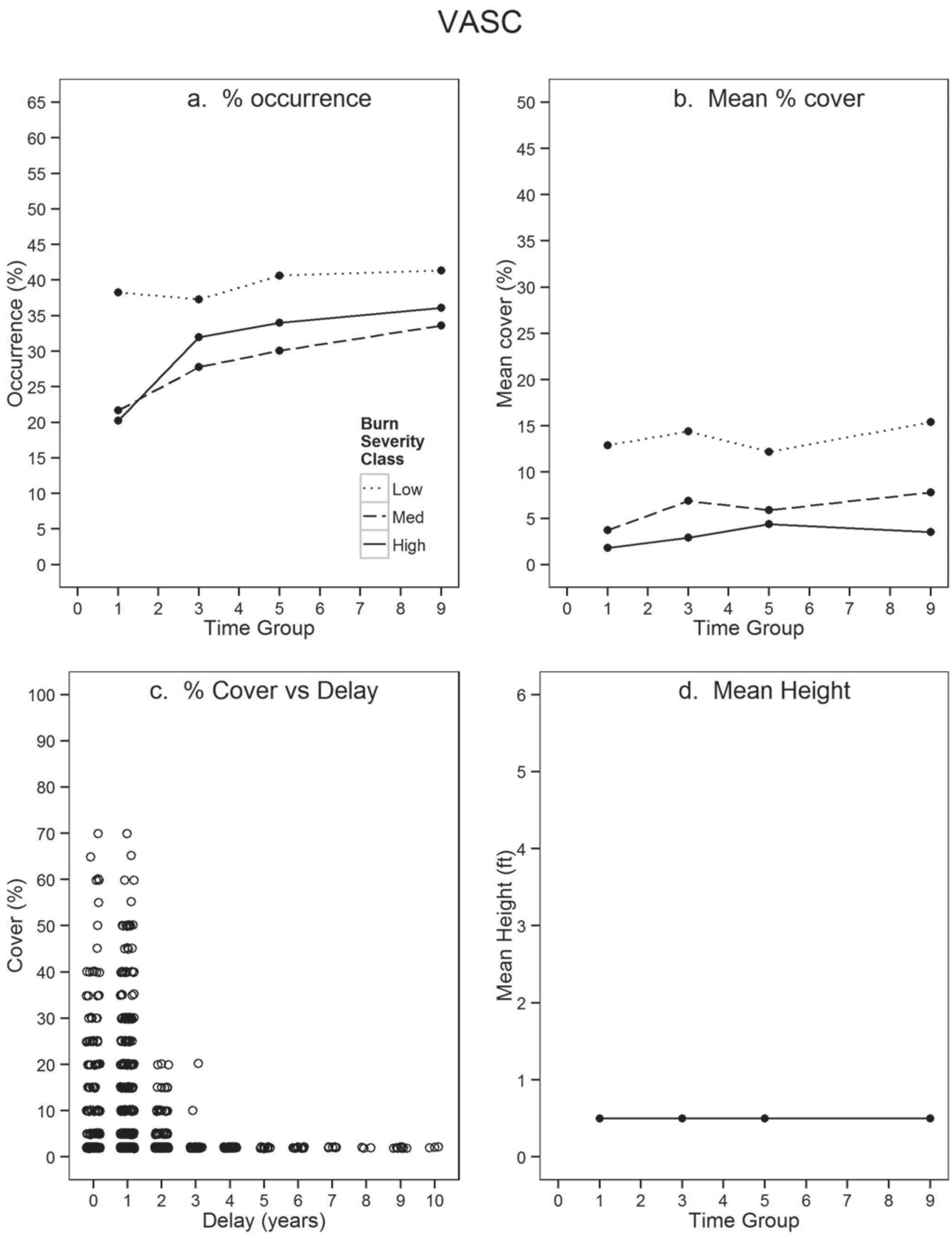

Figure 32—VASC (*Vaccinium scoparium*). (a). Percent occurrence by burn severity class and time since wildfire. (b). Mean percent cover by burn severity class and time since wildfire. (c). Percent cover on individual 1/300-acre plots by number of years between the wildfire and establishment of the species on the plot. (d). Mean height by burn severity class and time since wildfire.

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