

Characteristics of Pinyon-Juniper Woodlands in Grand Staircase-Escalante National Monument: Changes Since Monument Establishment and Prospects for Future Monitoring

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ABSTRACT

Recent data from the USDA Forest Service Forest Inventory and Analysis (FIA) program have documented spatial and temporal patterns of drought-related mortality across woodlands of the Southwest (Shaw et al. 2005). In the early 1990s, FIA collected data on forested land now included in Grand Staircase-Escalante National Monument (GSENM or the Monument) as part of a comprehensive periodic inventory of Utah (O'Brien 1999). In 2000, FIA implemented an annual inventory system in Utah, measuring 10 percent of the full plot complement each year. These data provide a baseline of conditions just prior to establishment of the Monument and, following establishment, annual measurements spanning the years that vegetation was most affected by drought. Pinyon-juniper woodlands within the Monument have experienced comparable rates of mortality and changes in composition and structure to similar woodlands in the Southwest. The FIA program will continue to collect inventory data in GSENM and provide a framework for monitoring forest vegetation.

Keywords: drought, mortality, stand density, species composition

Introduction

The Forest Inventory and Analysis (FIA) program of the Forest Service, U.S. Department of Agriculture, is responsible for assessing the status and trends of all forested lands in the U.S. (Gillespie 1997), including those within the boundaries of Grand Staircase – Escalante National Monument (GSENM). In the mid 1990s, prior to Monument establishment, the Interior West FIA program (IW-FIA) established permanent inventory plots within the current Monument boundary as part of a statewide periodic inventory of Utah. In 2000, IW-FIA began the process

of re-visiting the plots as part of a new annual inventory protocol. In recent years, pinyon-juniper woodlands across the Southwest have experienced elevated rates of mortality due to a complex of drought, insects, and disease (Breshears et al. 2005; Shaw et al. 1995; Shaw 2006b). Because pinyon-juniper woodlands are the dominant forest type on GSENM, we expected that some mortality occurred on the Monument as well. Fortunately, the timing of the two FIA inventory cycles in Utah permits us to assess drought-related changes to pinyon-juniper woodlands, starting shortly after establishment of the Monument.

In this paper we describe the FIA plot history in GSENM, what FIA data reveal with respect to vegetation change, and how changes in GSENM compare to changes observed in the pinyon-juniper forest type as a whole. We also discuss how the FIA inventory protocol may be used to monitor forests in the Monument in the future.

Methods

The national FIA program conducts inventory on all forested lands of the U.S. using a nationally standardized plot design (Figure 1) at an intensity of approximately one field plot per 2,388 hectares (6,000 acres). IW-FIA is responsible for FIA plots in Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, Utah, and Wyoming. These states encompass over 85 percent of forests in the pinyon-juniper group in the western U.S.

Surveys conducted by IW-FIA prior to 2000 were generally statewide periodic inventories, but in some cases National Forests or tribal lands were inventoried as separate units. Under the periodic system, the entire plot grid in the area of interest was visited over a period of one to several years. As a result, the number of plots visited in any given year varied in number and geographic extent. In

2000, IW-FIA implemented a continuous annual inventory system (Gillespie 1997). Under annual inventory, approximately 10 percent of plots from the full sample set are measured each year. Plots belonging to an annual panel are distributed across each state so as to be free of geographic bias. States have been gradually phased into the annual system (Utah, 2000; Arizona, 2001; Colorado, 2002; Idaho, 2003; Montana, 2003), increasing geographic coverage of the Interior West over the past five years. A pilot inventory of Nevada employed the annual plot system in 2004 and 2005.

About the same time that IW-FIA was implementing the new annual survey, much of the western United States began to enter a period of drought. As the drought continued, managers noted an increase in mortality within pinyon-juniper woodland types. Mortality peaked in 2003, when drought facilitated an explosion of the pinyon ips (*Ips confusus* Laconte) population in many areas (Shaw et al. 2005). The most severely affected areas were located in northern Arizona, northwestern New Mexico, and southwestern Colorado. Analysis of FIA data spanning the peak of mortality – 2000 to 2005 in Utah, 2001 to 2005 in Arizona, and 2002 to 2005 in Colorado – suggested that annual measurements could reveal changes of a relatively small magnitude (Shaw 2006a). The episode of drought-related mortality provided an

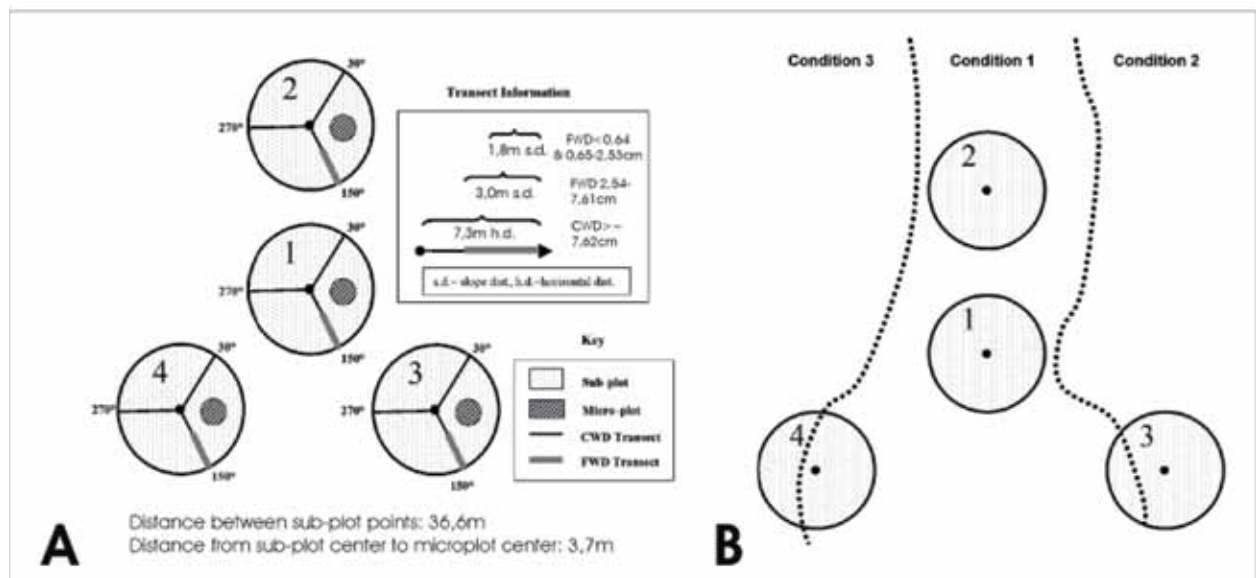


Figure 1. National standard FIA plot design (A). Plots are established systematically, using a pre-determined coordinate for the center of subplot 1. Plots that span multiple conditions – e.g., changes in age, density, or composition – are mapped (B). Tally trees and site variables are assigned to conditions.

opportunity to assess the effectiveness of annual inventory in detecting and tracking these types of disturbance events. It also provided an opportunity to explore ways of using periodic data and the new annual data in concert. Because the periodic inventory data were obtained under pre-drought conditions, it could be used to estimate “typical” rates of mortality and pre-drought composition and structure.

In the eight states covered by the IW-FIA program, pinyon or juniper species were found on 14,929 plots, measured between 1981 and 2005. Of the total number of plots, 10,807 were unique plot locations, with the remainder being repeat visits to plots in different inventory cycles. Of the 298,324 trees measured on all plots, 212,142 were pinyon or juniper species. On GSENM, pinyon or juniper species were found on 143 plots. Of these, 50 were part of the Utah periodic inventory and were established and measured in 1994 and 1995, while 93 plots were measured under the annual inventory system. Approximately 218 plots are expected to be visited on the Monument during a 10-year inventory cycle. However, many of these will be classified as non-forest so the final number of field points in the cycle will be less than 218. Because most drought-related mortality occurred in 2003, our analysis of pre- and post-drought conditions necessitates grouping periodic and annual plots to represent pre-drought conditions (95 plots visited between 1994 and 2002). Post-drought conditions are represented entirely by annual inventory plots (48 plots visited from 2003 to 2005).

Up to 140 tree and plot variables are collected on FIA plots. Data on stand and site characteristics can be correlated with mortality rates. FIA sampling protocol includes measurement of live and dead trees. Dead trees are classified as either old dead (snags) or recent mortality and are assigned a mortality code (MORTCD). “Recent” mortality is defined by IW-FIA as trees judged to have died < five years prior to the plot visit. The FIA criteria used to make this distinction, e.g., presence or absence of dead foliage, sloughing bark, or fine twigs, are consistent with the characteristics found to be correlated with stages of deterioration in a pinyon snag longevity study (Kearns et al. 2005).

When a tree is designated as recent mortality, a causal agent code is assigned (AGENTCD). The exact cause of drought-related mortality can be difficult to assess, because trees may be pre-disposed to insect attack by drought, disease, or a combination of factors (Shaw et al. 2005). We will not attempt to tease apart the relative effects of contributing agents here; rather, we filter out the effects of factors that are not part of the complex (primarily fire) and analyze the remainder.

Shaw (2006b) reported results based on analysis of data spanning the geographic range of the pinyon-juniper type. We examined the data from plots located within GSENM and performed the same analyses as were used on the complete data set. Analysis of forest composition data was done using percent of basal area (BA) by species (one inch or greater diameter at root collar) on a plot. Dead and mortality components were computed as per Shaw (2006b):

$$\text{percent mortality} = \text{mortality BA} / (\text{live BA} + \text{Mortality BA})$$

$$\text{percent dead} = \text{dead BA} / (\text{live BA} + \text{mortality BA} + \text{dead BA})$$

Because of variations in survey type and location over time, it was not practical to scale up to population-level estimates on an annual or multi-year basis. Rather, this study analyzes characteristics and trends found in the sample. Comparability among years is achieved by normalizing the data into proportions of live, dead, and mortality trees.

Results and Discussion

The pinyon mortality event was widespread and detectable, but not as profound as some local reports would suggest. Local reports of near-complete mortality of pinyon appear to be isolated and not reflective of conditions throughout the west. Pre-drought data (1980 to 2002 range-wide and 1994 to 2002 on GSENM) on pinyon trees showed mortality occurring in 0.6 percent of all plots where pinyon was found and on 5.0 percent of the plots containing pinyon in GSENM (Figure 2A). In comparison, post drought data (2003-2005 in all

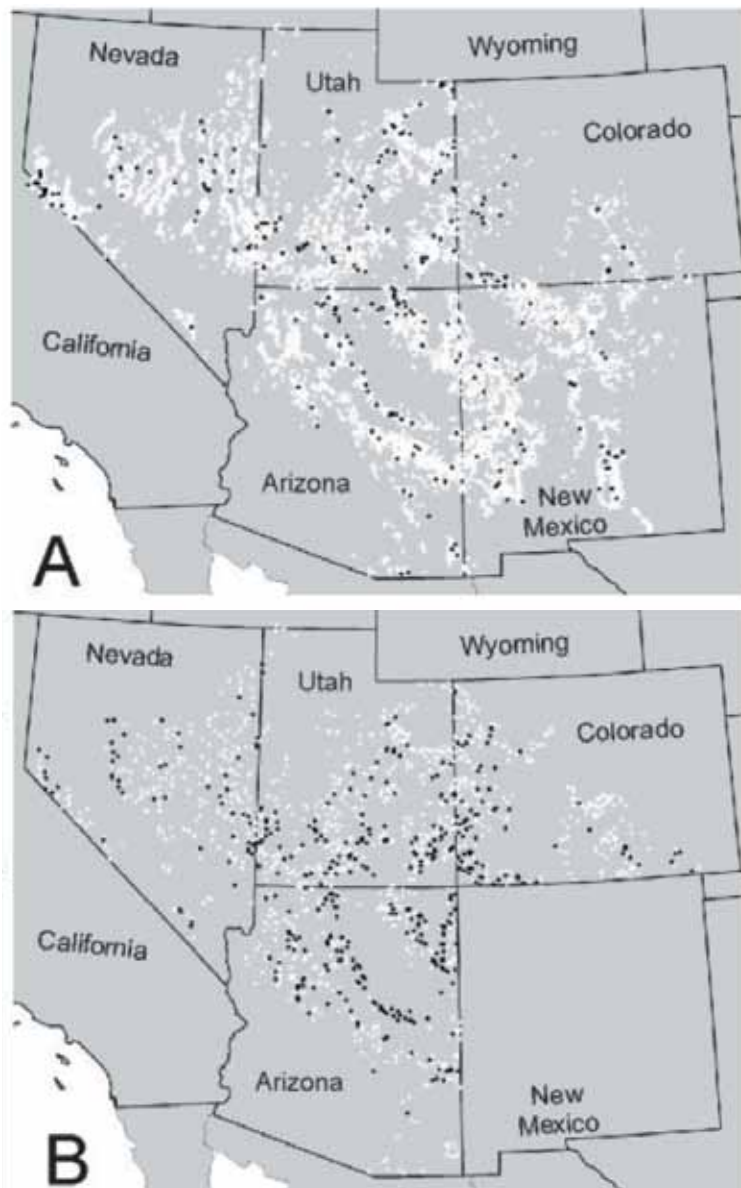


Figure 2. GSENM and surrounding areas, showing plots with mortality during the pre-drought (A) and post-drought (B) periods. Black symbols show plots with no mortality at the time of measurement, and open circles show plots with at least 1 mortality tree present.

areas) indicate mortality increased to 7.8 percent range-wide and 30 percent in GSENM (Figure 2B). In the Monument, pre-drought mortality affected 0.8 percent of pinyon trees and post-drought mortality was approximately 7.1 percent. This is much lower than the 90-100 percent mortality reported in some stands in the southwest. Given that the data show higher mortality rates in stands where pinyon contributes a large proportion of the basal area (see discussion below), it is likely that these reports refer to areas of high pinyon basal area. Further analysis of plot data in or near these sites could address this idea.

Across their range, pinyons account for a minority of stocking (<50 percent of basal area) of most stands in which they occur. The mean proportion of pinyon basal area to total stand basal area is 37 percent, with relatively fewer plots as pinyon percentage increases (Figure 3A). The notable exception is pure stands of pinyon which tend to be more common than stands with >90 percent and <100 percent pinyon. This distribution pattern of composition is common in many other species. Within the boundaries of GSENM, pinyons appear to account for a relatively lower proportion of stocking, with 30 percent of total

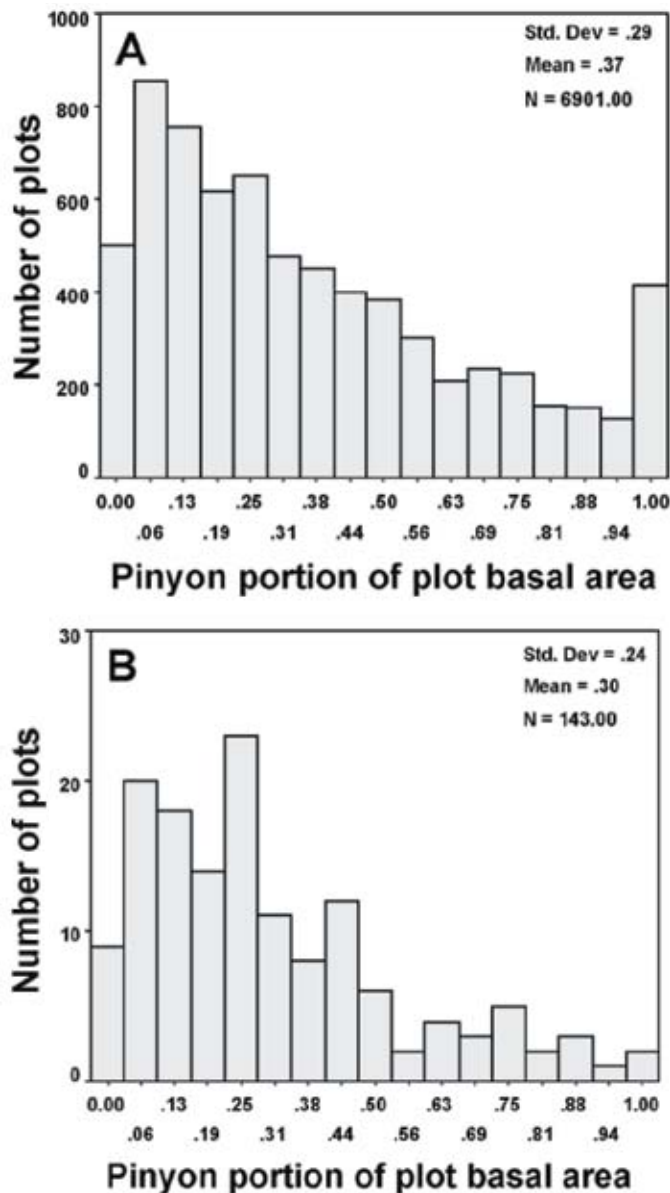


Figure 3. Pinyon species as a component of FIA plots: A) all plots in the IW-FIA states (see text) that include the species *Pinus edulis* Engelm., *P. cembroides* Zucc., or *P. discolor* Bailey & Hawksworth; B) plots that occur on GSENM (all *P. edulis*).

basal area on average (Figure 3B). Although it is difficult to compare the composition distribution from GSENM with the general population, primarily because of the relatively small number of plots measured on the Monument to date, there appear to be relatively fewer pure stands on the Monument than in the larger population. In general, however, the composition pattern of pinyon stands on GSENM is comparable to the composition of pinyon stands throughout the range of the species.

The data suggest that drought-related mortality altered the composition of pinyon-juniper plots (defined here as any plot having pinyon and/or

juniper found on it) on GSENM. The composition pattern of plots measured prior to the recent drought (Figure 4A) is similar to the pattern found for pinyon-juniper plots in general (Figure 3A). However, there appear to be relatively fewer plots on which pinyon makes up a small percentage of stocking (<20 percent of basal area) and pure pinyon stands are absent from post-drought plots on the monument (Figure 4B). The resulting effect of “trimming” both ends of the range of composition is that mean composition remained the same, but with less variability in composition. While some reduction in pinyon basal area was detected in most stands, pure or near-pure stands of pinyon

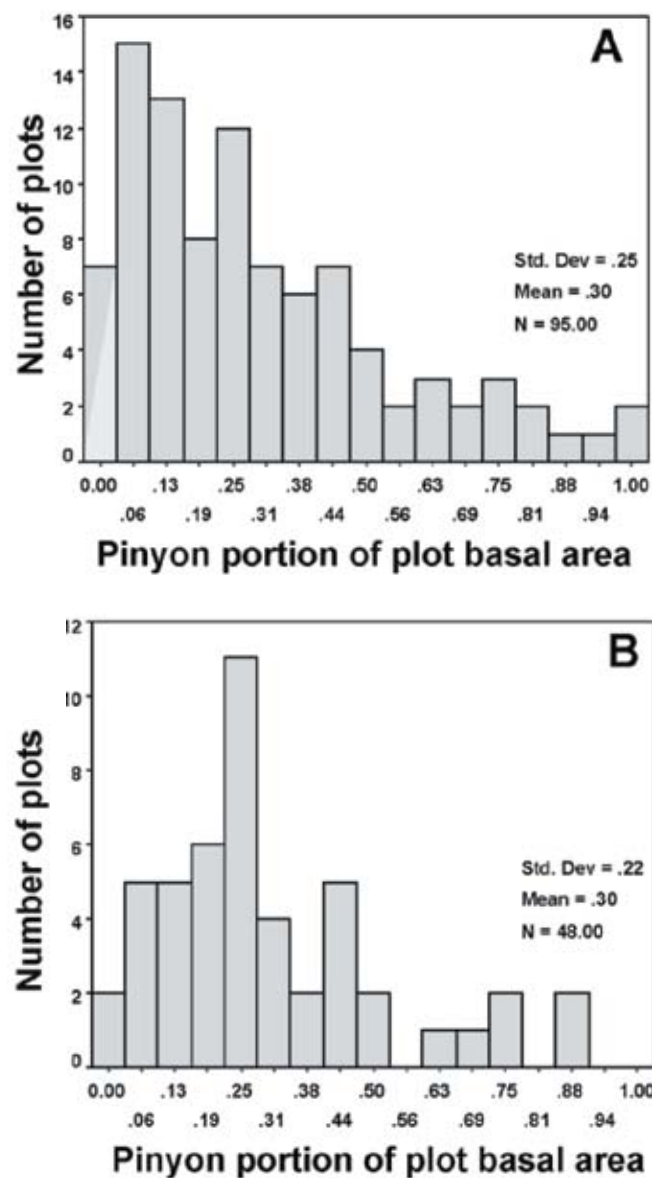


Figure 4. Compositional change in pinyon stands before (A; 1994 – 2002) and after (B; 2003 – 2005) drought on GSENM.

appear to have suffered complete mortality of the pinyon component within the Monument. We consider this a preliminary result that may be verified after reconciliation of plots that are common to both the periodic and annual inventories.

The contribution of pinyon to stand basal area in GSENM closely reflects what is occurring range-wide with the species and forest types in question. The recent drought appears to have eliminated pure pinyon stands from FIA plots in GSENM. It is not known how much pure or near-pure pinyon stands remain within the monument's boundaries, but the data suggest they were rare even before the drought. FIA data shows that prior

to the recent drought, six percent of GSENM plots had more than 80 percent of their basal area from pinyon species. This number drops to four percent after the onset of the drought, with stands having greater than 88 percent basal area from pinyon completely removed from the sample. There was also a detectable change in stand composition on plots where pinyon contributed relatively little to total basal area, both range-wide and within the GSENM. However, this change was much smaller than in pinyon dominated stands. A possible explanation for this may be the relative ease in which the pinyon ips can spread when trees are densely stocked compared to stands where pinyon trees are rare and/or spread out.

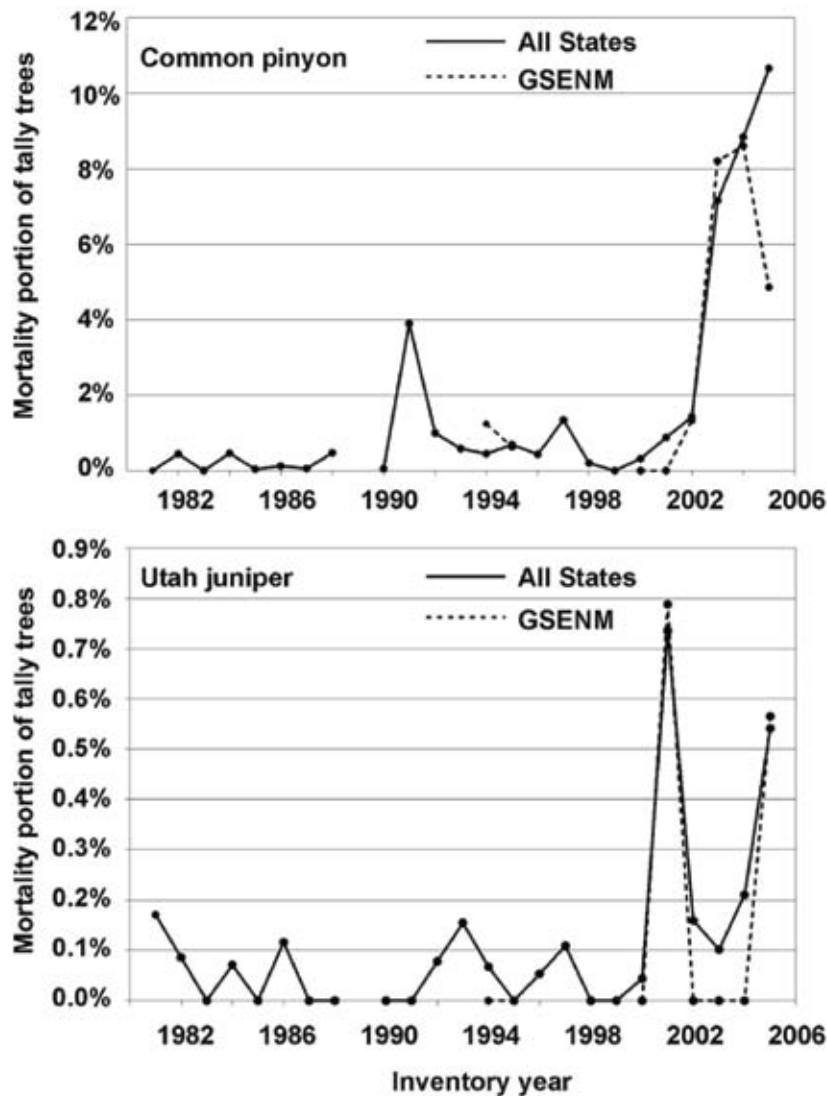


Figure 5. Temporal trends in mortality of common pinyon and Utah juniper, expressed as the proportion of tally trees that were counted as “mortality trees” (see text). Note difference between graphs in the scale of the y-axis.

Tree data from GSENM plots detected changes between pre- and post-drought mortality rates in both pinyon and juniper species. In general, the timing and magnitude of mortality on GSENM was comparable to mortality in the pinyon-juniper type as a whole (Figure 5). Common pinyon experienced a small increase in mortality in 2002, followed by a substantial increase in 2003. In the general population, mortality continued to increase through 2005, but at a decreasing rate. The apparent drop in mortality on GSENM in 2005 is likely to be a sampling artifact. Shaw (2006b) confirmed field observations that indicated juniper species had experienced little mortality during the period when the most severe pinyon die-off occurred. Pre-drought data show that in “normal” years,

juniper mortality is near zero. For example, the five-year mortality rate for Utah juniper is commonly < 0.1 percent. During the drought years, juniper mortality increased dramatically over the background rate, but, at < 1 percent, remains well below the background rates found in other species. As a result, even though the relative magnitude of change was similar between species the absolute change in mortality rate was much higher in pinyon than in juniper species.

Juniper and pinyon species reacted differently to recent drought. Although juniper trees showed an increase in mortality range-wide, the average mortality was still less than 1 percent. Pinyon mortality rose by an order of magnitude, averaging

almost eight percent across its range. This reaction has been documented before by Mueller et al. (2005), who found similar differences in pinyon and juniper mortality rates in Arizona. Once established, juniper appears to be quite resistant to drought related stress. Conversely, pinyon seems to be more susceptible to disease and/or insect infestation after prolonged periods of drought. Based on this, one would not expect to see noticeable range contraction of this forest type during stressful periods, but rather a change in stand composition moving toward juniper dominance, as noted in Allen and Breshears (1998).

Conclusions

Drought-related response of pinyon and juniper species was detected across the range of each species as well as on a small subset of FIA survey plots in southern Utah. Both species have seen mortality rates increase by an order of magnitude, with pinyon species incurring a much higher absolute mortality rate. Stands that had a very high proportion of pinyon were impacted more than those stands where pinyon was a lesser component. The data from GSENM closely reflected some of the trends shown in the range-wide dataset, suggesting that this area can be used as a case study for all pinyon-juniper woodlands. However, the percentage of plots having recently dead trees tallied is higher in the Monument than on range-wide plots. This is the case for both pre- and post-drought records. That GSENM has a higher baseline mortality rate should be considered when designing experiments using the monument as a case study for all lands containing pinyon species.

The GSENM appears to be of sufficient size to allow for salient analysis using FIA annual data. Over 300 points occur within the borders of the monument and although less than half are forested, the potential exists to use the grid to cohabitate other resource sampling efforts on these plots, thereby allowing FIA data to be used in conjunction with these other efforts.

Data from both old and current FIA protocols were used to show changes in mortality rates due to stress brought on by drought. This illustrates that some variables that are shared between the

two methodologies can be used for temporal and spatial analyses. These analyses should be stronger than those using one dataset or the other. However, care must be taken when choosing variables from both datasets. For example, woodland species such as pinyon and juniper had different thresholds for when they would be measured on a plot. During periodic inventories, a woodland tree species had to meet certain growth form requirements such as a minimum height or diameter. These thresholds are not present in annual inventory. Therefore, some plots that show lower stocking in the periodic data and higher in annual data could be an instance of more trees measured during periodic, not necessarily more trees present on the plot since the last visit.

One of the main goals of the annual inventory system is to provide data on a more timely schedule than was possible under the periodic inventory system. Annual, incremental updates to FIA data make it possible to assess changes in forest health, productivity, composition, and status over time and space. As the body of annual data increases, so should the ability to glean meaningful insights from it. This analysis illustrates the potential to detect changes using only the six years of annual data collected so far. Though trend analysis is strengthened as more years are added, the current data can be useful for predicting future rates of change and identifying future research potential once a more robust dataset exists.

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