View metadata, citation and similar papers at core.ac.uk

brought to you by CORE

provided by OpenKnowledge@NAU

United States Department of Agriculture

Forest Service

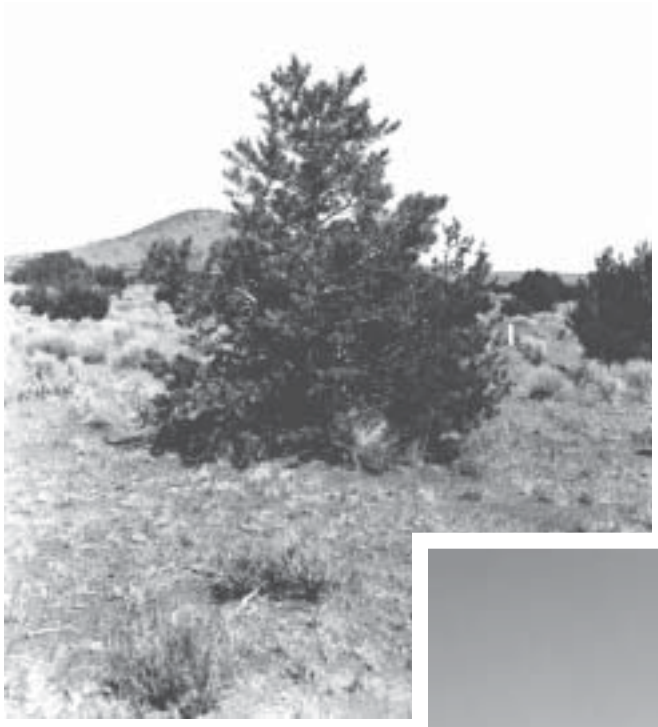
Rocky Mountain Research Station

Research Paper RMRS-RP-35

February 2002

Dynamics of a Pinyon-Juniper Stand in Northern Arizona: A Half-Century History

Peter F. Ffolliott
Gerald J. Gottfried



Abstract

Ffolliott, Peter F.; Gottfried, Gerald J. 2002. **Dynamics of a pinyon-juniper stand in northern Arizona: a half-century history**. Res. Pap. RMRS-RP-35. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 10 p.

This paper adds to the limited knowledge of stand dynamics in pinyon-juniper woodlands by reporting on the changes in species composition, numbers of trees, arrangements of trees, and total height and volume in a stand from late 1938 to early 1991. This information should be helpful in managing pinyon-juniper woodlands to sustain their productivity and maintain their multiple-use values. The annual increase of 1.2 trees per acre does not reflect the massive invasion of trees suspected by many people.

Keywords: Pinyon, *Pinus edulis,* juniper, *Juniperus monosperma*, woodlands, stand dynamics, total height growth, volume growth, long-term changes, Arizona, southwestern United States

The Authors

Peter F. Ffolliott is a Professor in the School of Renewable Natural Resources, University of Arizona, Tucson, Arizona.

Gerald J. Gottfried is a Research Forester for the Rocky Mountain Research Station, USDA Forest Service, Phoenix, Arizona.

You may order additional copies of this publication by sending your mailing information in label form through one of the following media. Please specify the publication title and Research Paper number.

Fort Collins Service Center

Telephone	(970) 498-1392
FAX	(970) 498-1396
E-mail	rschneider@fs.fed.us
Web site	http://www.fs.fed.us/rm
Mailing Address	Publications Distribution Rocky Mountain Research Station 240 West Prospect Road Fort Collins, CO 80526

Rocky Mountain Research Station
324 25th Street
Ogden, UT 84401

Dynamics of a Pinyon-Juniper Stand in Northern Arizona: A Half-Century History

Peter F. Ffolliott
Gerald J. Gottfried

Introduction

Pinyon-juniper woodlands of the southwestern United States provide wood products, livestock forage, wildlife habitats, and watershed protection (Aldon and Shaw 1993; Everett 1987; Gottfried and Pieper 2000; Monsen and Stevens 1999; Shaw and others 1995). Knowledge of how these woodland stands change in composition and structure promotes understanding of ecological processes, ensures sustainability of products and amenities, and helps to plan and evaluate land management activities. Ecologists and land managers also use long-term study results to outline the development of stands and depict tree and stand responses to climatic variability and interspecific competition.

Earlier Studies

Results of only a few long-term studies of the stand dynamics in the pinyon-juniper woodlands of the southwestern United States are available. Herman (1953) and Myers (1962), respectively, reported on 10 and 20 years of growth and mortality in a stand comprised mostly of Utah juniper (*Juniperus osteosperma*) trees near Sedona, Arizona. Jameson (1965) described 20 years of total height growth in a stand north of Flagstaff, Arizona, that was dominated by one-seed juniper trees *J. monosperma* (see below). Little (1987) outlined the growth patterns of individual pinyon trees for a 47-year period in two stands near Santa Fe, New Mexico. Conner and others (1990) presented volume, growth, and mortality estimates of all woodland types in Arizona from the results of the continuing forest survey in the State. Gottfried and Ffolliott (1995) described the dynamics of a 24-year growth period for two stands dominated by alligator juniper (*J. deppeana*) trees on the Beaver Creek watershed in north-central Arizona.

This paper adds to the existing knowledge of stand dynamics in the pinyon-juniper woodlands of the southwestern United States by reporting on changes in a stand of pinyon and one-seed juniper trees located on Deadman Flat about 20 miles north of Flagstaff, Arizona, from late 1938 to early 1991. This is the same stand upon which Jameson (1965) reported earlier.

Land-Use History of Deadman Flat

Little is known about the land-use history of the Deadman Flat area before the early 1850s. Jameson (1965), in citing Woodhouse (1853), deduced from reports of the Sitgreaves Expedition to northern Arizona that Deadman Flat was a savanna or open woodland that was "covered with fine grama grasses and cedars" at this time. Navajo people herded sheep in the area from the 1850s until the 1980s. Ranching by Euro-Americans began in the late 1870s and large herds of cattle were introduced onto the area in the early 1880s (Wyllys 1960). The heaviest livestock grazing likely occurred between the 1890s and 1920s (Trimble 1982, as cited by Cinnamon 1988). Cinnamon (1988) suggested that the cool and moist climatic conditions between the 1890s and 1920s period were probably "ideal" for the germination of juniper seeds throughout the region. The earlier heavy livestock grazing had reduced the cover of competing herbaceous plants, providing suitable regeneration niches for juniper. Reduced frequencies of naturally occurring fire largely because of the fire suppression policies of the land management agencies also contributed to successful establishment and subsequent survival of juniper seedlings at the same time. Jameson (1965) observed that most of the trees on the Deadman Flat area were "young" in 1958. It is possible that many of the trees on Deadman Flat originated from a similar sequence of climatological and biological events that resulted in an "abundance" of ponderosa pine regeneration in the adjacent, higher-elevation montane forests in 1919 (Pearson 1950; Schubert 1974). This being the case, the "young" trees observed by Jameson

(1965) could have been about 40 years old in the late 1950s.

Deadman Flat is part of a USDA Forest Service grazing allotment on the Coconino National Forest. This allotment was grazed heavily for short periods in the summer months by bands of 500 to 800 sheep until 1984. At that time, the rancher holding the allotment permit converted to a cattle operation, although his permit allowed both cattle and sheep to graze. However, no sheep have grazed on the area since the early 1990s. The ranch adjacent to the allotment was bought by the Navajo Nation in 1986. The general Deadman Flat area has not been used heavily by livestock since. There is also little evidence of recent harvesting of pinyon and juniper trees in area.

Stand Studied

The stand studied is located on an alluvial fan extending outward from the north side of the San Francisco Peaks, near Flagstaff, Arizona. Soils on the site are derived from alluvial or dacite/andesite (Miller and others 1995) and the underlying bedrock is basalt that came from volcanic eruptions 20,000 to 200,000 years ago. At the present time, the soil surface components are 50 percent rock fragments, 35 percent bare soil, 10 percent litter, and 5 percent vegetation. The soils are classified as Typic Argiustolls, loamy skeletal, mixed, mesic and, in general, are more than 40 inches deep. The elevation of the site is approximately 6,500 feet, slope is about 2 percent, and the aspect is northeast.

The site is classified in the *Juniperus monosperma*/*Bouteloua gracilis* habitat type (plant association) by the USDA Forest Service (1997). This habitat type is found throughout the southwestern United States where annual precipitation averages 14 to 16 inches and winters are relatively cool and dry. An "undisturbed plant community" on these sites is generally open, with individual species canopy covers of 15 percent juniper, 10 percent pinyon, 20 percent blue grama, and less than 5 percent other species (Miller and others 1995).

Methods

A 2-acre plot was established in the stand in September 1938. All of the trees on the plot were numbered and tagged. Observations and measurements made of each tree included species, total height, and crown diameter. These observations and measurements were repeated at the end of the 1948 and 1958 growing seasons and at the beginning of the 1991 growing season. Tally trees that were missing and presumed dead (mortality) and regeneration (in-growth) were recorded in 1948, 1958, and 1991. Arrangements of the tally trees with respect to surrounding trees were noted at the time of some (but not all) of the observation and measurement periods. A limited number of repeated stem diameter measurements were obtained on a small sub-sample of trees. The gender of a subsample of the dioecious one-seed juniper trees was noted in 1991; these trees were considered female if berries were present and male if berries were absent.

The limited stem diameter measurements precluded the use of this variable as a basis to estimate individual tree volumes from a standard volume table, which is the common procedure in tree inventories (Avery and Burkhart 1994; Husch and others 1982). It was necessary, therefore, to derive estimates of individual tree volumes from the succession of total height measurements taken in 1938, 1948, 1958, and 1991. A volume table constructed by Howell (1940) for pinyon and juniper trees in northern Arizona and northern New Mexico, and reprinted by Barger and Ffolliott (1972), presents average cubic-foot volumes of individual trees in terms of their total height in feet. All pinyon and juniper species were grouped together into their respective genera in this volume table. Cubic-foot volume and total height values from the volume table were regressed against each other to derive an equation to estimate individual tree volumes as a function of the total heights of the tallied trees. A standard error or other measures of accuracy for this equation is meaningless because the source data that Howell used in constructing the original volume table are not available.

Results and Discussion

Species Composition, Numbers of Trees, Arrangements of Trees

Pinyon trees comprised 25 percent of the woodland overstory on the 2-acre plot in 1938, 25 percent again in 1948, 28 percent in 1958, and 36 percent in 1991, with one-seed juniper trees representing the reciprocal proportions. A greater proportion of pinyon trees were found in the younger age classes in 1991 than in the earlier observation and measurement periods, suggesting periods of episodic establishment. There was little evidence of recent reproduction of one-seed juniper trees in 1991, and the juniper trees present appeared to be aging. A greater success of pinyon establishment relative to juniper trees has been observed throughout the pinyon-juniper woodlands of the southwestern United States (Barger and Ffolliott 1972). Juniper species are often more common in the larger size classes of trees. Juniper trees usually become established first but are often followed and replaced by pinyon (Gottfried 1992). While birds disperse seeds of both species, pinyon germination is

greater (about 85 to 95 percent) than most juniper species; one-seed juniper germination ranges from 20 to 75 percent. However, Gottfried and Ffolliott (1995) found that there was no significant increase in the density of pinyon trees in the 24-year growth period studied, although these authors reported average annual increases of 2.2 alligator juniper and 0.5 Utah juniper trees per acre.

The total numbers of trees on the plot increased steadily (if slightly) from 597 trees in 1938 to 639 trees in 1948, to 678 trees in 1958, to 717 trees in 1991. These increases translate into an average annual increase of 1.2 trees per acre over the 50 years. In terms of species, there were 148 pinyon and 449 one-seed juniper trees on the plot in 1938. The numbers were 160 and 479 pinyon and one-seed juniper trees in 1948. There were 188 pinyon and 490 one-seed juniper trees on the plot in 1958 and 258 pinyon and 459 one-seed juniper trees in 1991. Average annual increases of 1.1 pinyon and 0.1 one-seed juniper trees per acre are reflected by these changes.

Arrangements of trees on the plot in 1991 were largely the same as the general distribution patterns described by Jameson (1965). The arrangements included isolated trees at a distance of 1 tree-height or more from other trees; small groups of essentially the same-sized trees with their crowns often intermingling; and smaller trees becoming established and growing under larger trees. These arrangements have probably persisted throughout the half-century even though trees present through the 50 years increased in their crown volumes, total heights, and diameter. The evolution of these arrangements through time is illustrated by the series of photographs presented in figures 1, 2, 3, and 4.

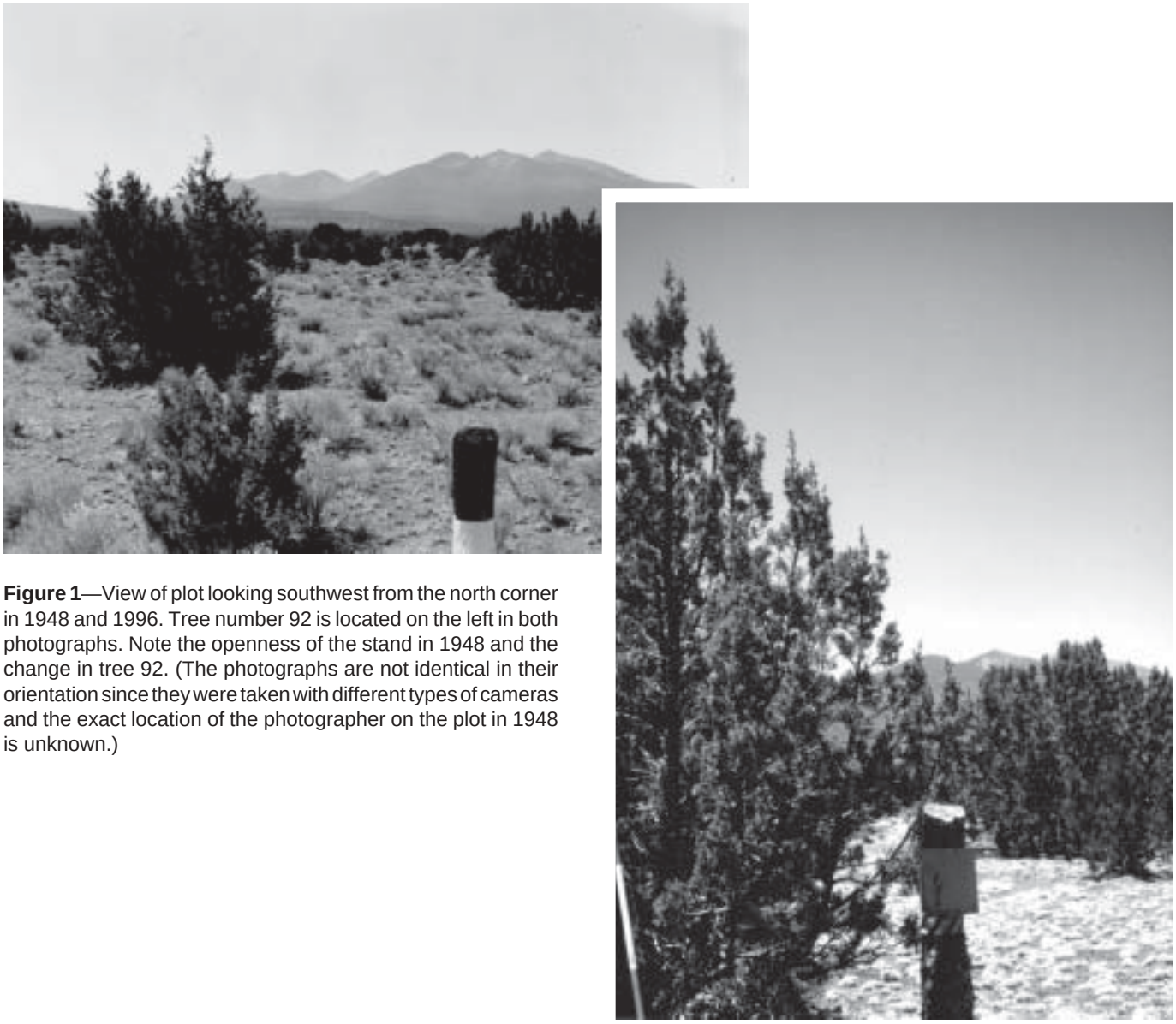


Figure 1—View of plot looking southwest from the north corner in 1948 and 1996. Tree number 92 is located on the left in both photographs. Note the openness of the stand in 1948 and the change in tree 92. (The photographs are not identical in their orientation since they were taken with different types of cameras and the exact location of the photographer on the plot in 1948 is unknown.)

Figure 2—View of the plot looking south from the north corner in 1948 and 1996 showing changes in individual trees and stand characteristics.

Figure 3—View of the plot from the east corner in 1948 and 1996. One-seed juniper tree number 10 is located in the center foreground of both photographs.

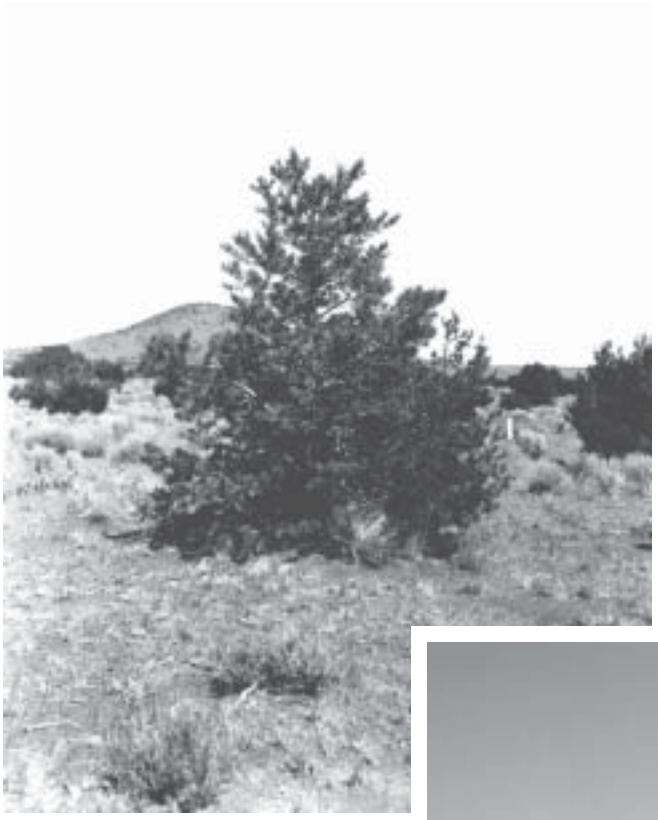


Figure 4—Pinyon tree 299, which became established beneath one-seed juniper tree 297 and dominated it in 1948. The same pinyon tree is located in the right foreground of the 1996 photograph.

Total Height Growth

Total heights of the pinyon and one-seed juniper trees on the plot increased steadily throughout the 50 years (table 1). The average annual total height growth was 0.07 foot and 0.08 foot for pinyon and one-seed juniper trees, respectively, for the half-century. Little (1987) measured about 0.09 foot of average annual total height growth of pinyon trees in his 47-year study period. The trees sampled by Little were taller at the start of his study than the pinyon trees on Deadman Flat in 1938, however. Little did not measure juniper trees since there only were a few Rocky Mountain juniper (*J. scopulorum*) trees on the plot.

Growth in total height of the pinyon and juniper trees on Deadman Flat is also reflected by the frequency distributions of numbers of trees by total height classes for the series of measurements in 1938, 1948, 1958, and 1991. As might be expected, the mode(s) for these frequency distributions continuously shift to the right, indicating the increasing total height growth of the trees (fig. 5 and 6). It also appears that these frequency distributions are evolving from a skewed to more "normal" distributions through time.

Volume Growth

The estimated volume of pinyon trees on the plot was 6.9 cubic feet in 1938, 11.1 cubic feet in 1948, 14.3 cubic feet in 1958, and 32.0 cubic feet in 1991. The estimated volume of one-seed juniper trees was greater for each of the measurements, totaling 43.5 cubic feet in 1938, 72.2 cubic feet in 1948, 110 cubic feet in 1958, and 288 cubic feet in 1991. Average annual volume growth of the pinyon trees was 0.25 cubic foot per acre for the 50 years, while the corresponding average annual volume growth of the one-seed juniper trees was 2.45 cubic feet per acre. Total growth was, therefore, 2.70 cubic feet per acre, which is less than that of "commercial woodlands" in the region.

The estimated average annual volume growth of the trees on Deadman Flat plot was similar to that reported by Herman (1953) and Myers (1962), who found (respectively) that the average annual volume growth of a stand of mostly Utah juniper for 10- and 20-year growth periods remained unchanged at 2.9 cubic feet per acre for both periods of measurement. The average annual volume growth rates on Deadman Flat were lower than the estimated annual growth rate of 6.4 cubic feet for all Arizona pinyon-juniper woodlands (Conner and others 1990). However, the growth rates presented by Conner and others included all pinyon-juniper and pure juniper woodlands of all age and size classes on all productivity sites and ownerships. Gottfried and Ffolliott (1995), in their study of stand dynamics on the Beaver Creek watershed, reported average annual growth rates of 0.2 cubic feet per acre for pinyon trees, 13.5 cubic feet per acre for the dominating alligator juniper, and 3.4 cubic feet per acre for Utah juniper. However, the alligator juniper trees in the stands measured by Gottfried and Ffolliott were much larger than the trees measured on Deadman Flat, ranging up to 50 inches in stem diameter and 35 feet in height. The Beaver Creek stands sampled also receive a higher amount of annual precipitation than Deadman Flat because of their location immediately below the Mogollon Rim, a major topographic feature that influences storm activities.

Table 1—Total heights (in feet) of pinyon and one-seed juniper trees on Deadman Flat in 1938, 1948, 1958, and 1991 (means and standard errors).

Year	Pinyon	One-seed juniper
1938	1.3 ± 0.10	2.3 ± 0.10
1948	2.0 ± 0.11	3.0 ± 0.10
1958	2.3 ± 0.12	3.6 ± 0.12
1991	5.0 ± 0.45	6.5 ± 0.13

Gender

One-seed juniper are *dioecious*, that is, berries are found on female trees and pollen on male trees. Essentially, equal numbers of female and male trees were observed in 1991. It is believed, therefore, that the one-seed juniper component of the stand studied on Deadman Flat will likely be able to sustain itself into the future.

Management Implications

Information on stand dynamics can help determine the proper time for harvesting trees for fuel and other products, predict future stand conditions and silvicultural treatments needed to maintain the production of forage species, maintain healthy wildlife habitats, and protect fragile watershed values (Aldon and Shaw 1993; Everett 1987; Gottfried and Pieper 2000; Monsen and Stevens 1999; Shaw and others 1995). The information presented in this paper follows the half-century development of a pinyon-juniper woodland stand from relatively immature trees estimated to be about 20 to 30 years of age into a maturing stand in which the trees are approaching 80 years of age. The annual increase of 1.2 trees per acre does not reflect the "massive invasion" of trees suspected by many people (Gottfried 1992). The common perception that pinyon-juniper woodlands are occupying more land might be related more to the observed increases in crown diameter and total height of existing trees than to an

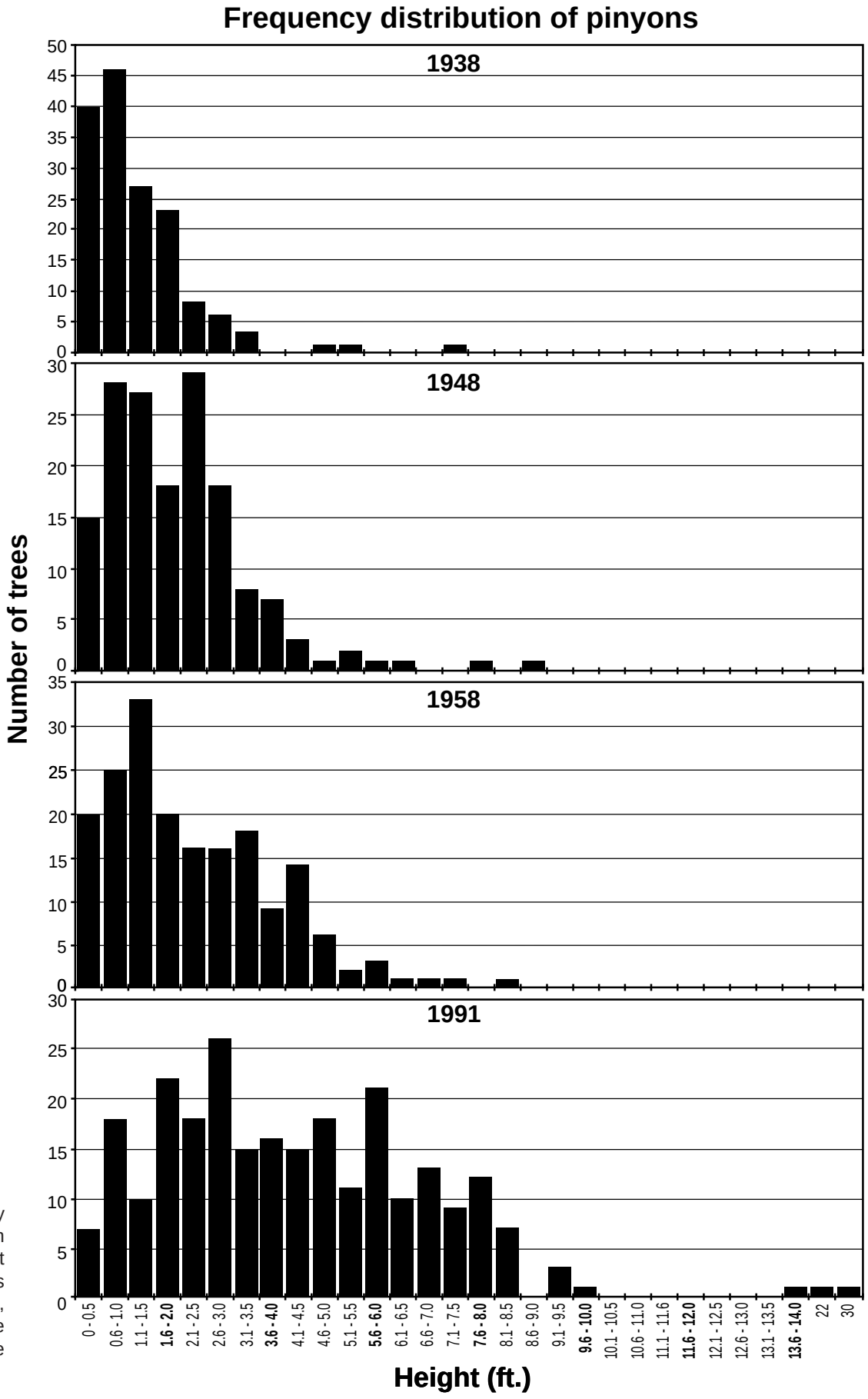


Figure 5—Frequency distributions of pinyon trees on Deadman Flat by total height classes for 1938, 1948, 1958, and 1991. Note that the y-axis is not the same in each panel.

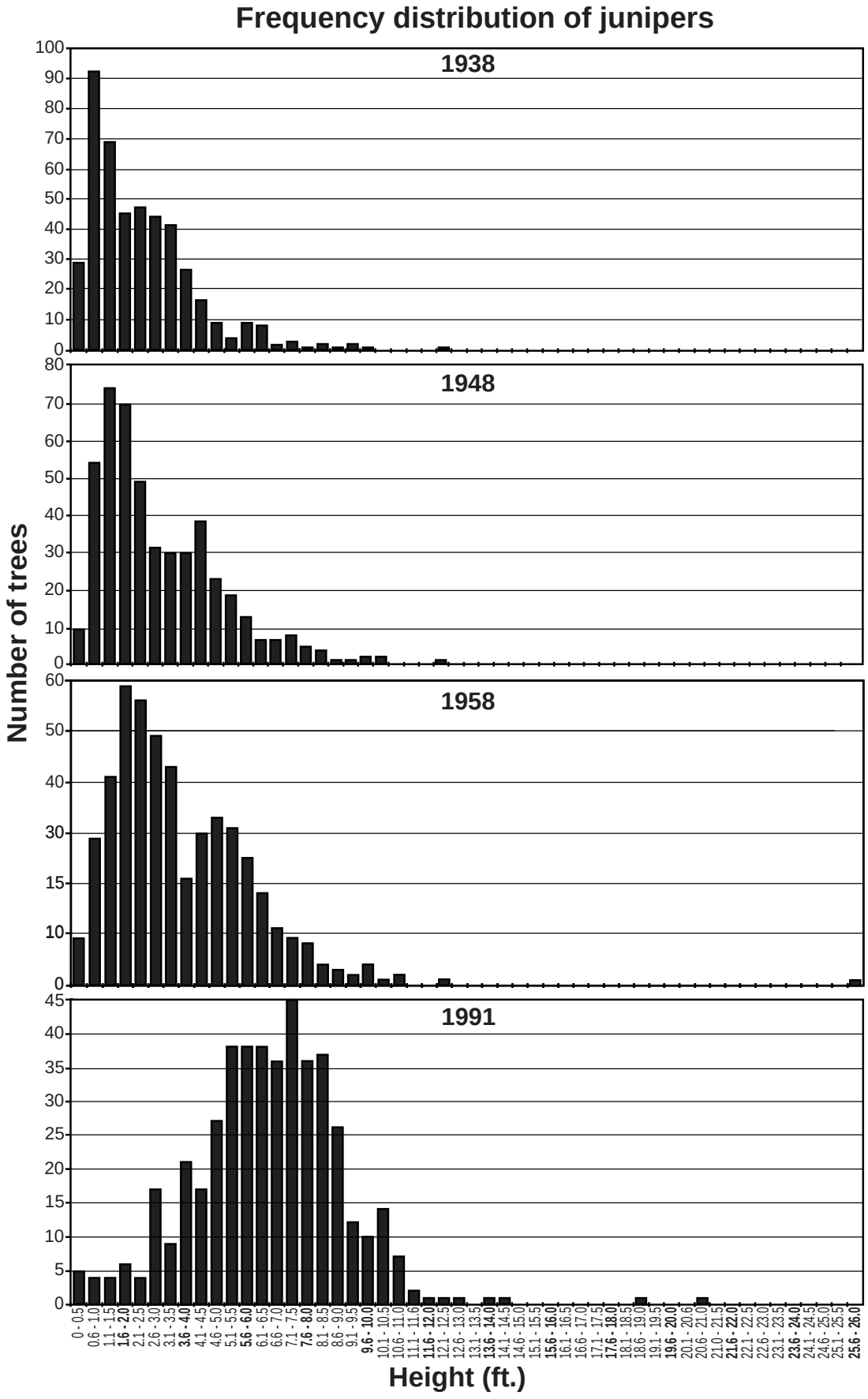


Figure 6—Frequency distributions of one-seed juniper trees on Deadman Flat by total height classes for 1938, 1948, 1958, and 1991. Note that the y-axis is not the same in each panel.

increase in tree numbers. The information in this paper could be applicable to other stands on sites with similar climatic and physiographic characteristics and land-use histories. Land-use planners and land managers should note that conditions in their areas may be different from conditions on Deadman Flat.

References

Aldon, E. F., and D. W. Shaw, technical coordinators. 1993. Managing pinon-juniper ecosystems for sustainability and social needs. USDA Forest Service, General Technical Report RM-236.

Avery, T. E., and H. E. Burkhart. 1994. Forest measurements. John Wiley & Sons, Inc., New York.

Barger, R. L., and P. F. Ffolliott. 1972. Physical characteristics and utilization of major woodland tree species in Arizona. USDA Forest Service, Research Paper RM-83.

Cinnamon, S. K. 1988. The plant community of Cedar Canyon, Wupatki National Monument as influenced by prehistoric and historic environmental change. Master's Thesis, Northern Arizona University, Flagstaff, Arizona.

Conner, R. C., J. D. Born, A. W. Green, and R. A. O'Brien. 1990. Forest resources of Arizona. USDA Forest Service, Resource Bulletin INT-69.

Everett, R. L., compiler. 1987. Proceedings—pinyon-juniper conference. USDA Forest Service, General Technical Report INT-215.

Gottfried, G. J. 1992. Ecology and management of the southwestern pinyon-juniper woodlands. In: Ffolliott, P. F., G. J. Gottfried, D. A. Bennett, V. M. Hernandez C., A. Ortega-Rubio, and R. H. Hamre, technical coordinators. Ecology and management of oak and associated woodlands: Perspectives in the southwestern United States and northern Mexico. USDA Forest Service, General Technical Report RM-218: 78–86.

Gottfried, G. J., and P. F. Ffolliott. 1995. Stand dynamics on upper elevation pinon-juniper watershed at Beaver Creek, Arizona. In: Shaw, D. W., E. F. Aldon, and C. LoSapio, technical coordinators. Desired future conditions for pinon-juniper ecosystems. USDA Forest Service, General Technical Report RM-258: 38–45.

Gottfried, G. J., and R. D. Pieper. 2000. Pinyon-juniper rangelands. In: Jemison, R., and C. Raish, editors. Livestock management in the American Southwest: Ecology, society, and economics. Elsevier Science B.V., Amsterdam, The Netherlands: 153–211.

Herman, F. R. 1953. A growth record for Utah juniper in Arizona. Journal of Forestry 51:200–201.

Howell, J., Jr. 1940. Pinyon and juniper—A preliminary study of volume, growth, and yield. USDA Soil Conservation Service, Region 8, Bulletin 71, Albuquerque, NM.

Husch, B., C. I. Miller, and T. W. Beers. 1982. Forest mensuration. John Wiley & Sons, Inc., New York.

Jameson, D. A. 1965. Arrangement and growth of pinyon and one-seed juniper trees. Plateau 37:121–127.

Little, E. L., Jr. 1987. Pinyon trees (*Pinus edulis*) remeasured after 47 years. In: Everett, R. L., compiler. Proceedings—pinyon-juniper conference. USDA Forest Service, General Technical Report INT-215: 65–68.

Miller, G., N. Ambos, P. Boness, D. Reyher, G. Robertson, K. Sealzone, R. Steinke, and T. Subirge. 1995. Terrestrial ecosystem survey of the Coconino National Forest. USDA Forest Service, Albuquerque, NM.

Monsen, S. B., and R. Stevens. 1999. Proceedings: Ecology and management of pinyon-juniper communities within the Interior West. USDA Forest Service, Proceedings, RMRS-P-9.

Myers, C. A. 1962. Twenty years growth of Utah juniper in Arizona. USDA Forest Service, Research Note RM-71.

Pearson, G. A. 1950. Management of ponderosa pine in the Southwest. USDA Monograph 6.

Schubert, G. H. 1974. Silviculture of southwestern ponderosa pine: The status of our knowledge. USDA Forest Service, Research Paper RM-123.

Shaw, D. W., E. F. Aldon, and C. LoSapio, technical coordinators. 1995. Desired future conditions for pinon-juniper ecosystems. USDA Forest Service, General Technical Report RM-258.

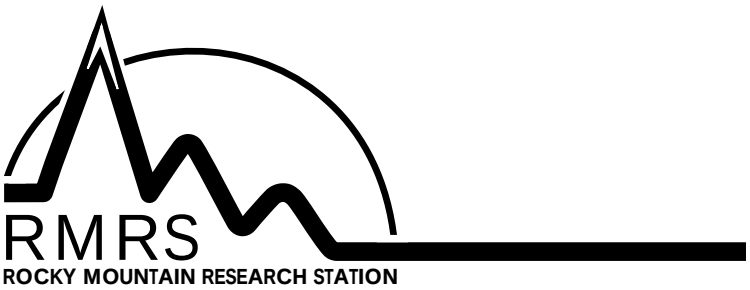
Trimble, M. 1982. CO Bar: Bill Owens depicts the historic Babbitt Ranch. Northland Press, Flagstaff, AZ.

USDA Forest Service. 1997. Plant associations of Arizona and New Mexico: Volume Two. USDA Forest Service, Albuquerque, NM.

Woodhouse, S. W. 1853. Report on the natural history of the country passed over by the exploring expedition under command of Brev. Capt. L. Sitgreaves, U.S. Topographical Engineers, during the year 1851. In: Sitgreaves, Captain L. Report of an expedition down the Zuni and Colorado Rivers. Senate Executive Document No. 59, 32nd Congress, 2 Session: 33–40.

Wyllys, R. K. 1960. Arizona: The history of a frontier State. Hobson and Herr, Phoenix, AZ.

Federal Recycling Program  Printed on Recycled Paper



The Rocky Mountain Research Station develops scientific information and technology to improve management, protection, and use of the forests and rangelands. Research is designed to meet the needs of National Forest managers, Federal and State agencies, public and private organizations, academic institutions, industry, and individuals.

Studies accelerate solutions to problems involving ecosystems, range, forests, water, recreation, fire, resource inventory, land reclamation, community sustainability, forest engineering technology, multiple use economics, wildlife and fish habitat, and forest insects and diseases. Studies are conducted cooperatively, and applications may be found worldwide.

Research Locations

Flagstaff, Arizona
Fort Collins, Colorado*
Boise, Idaho
Moscow, Idaho
Bozeman, Montana
Missoula, Montana
Lincoln, Nebraska
Reno, Nevada
Albuquerque, New Mexico
Rapid City, South Dakota
Logan, Utah
Ogden, Utah
Provo, Utah
Laramie, Wyoming

*Station Headquarters, Natural Resources Research Center,
2150 Centre Avenue, Building A, Fort Collins, CO 80526

The U.S. Department of Agriculture (USDA) prohibits discrimination in all its programs and activities on the basis of race, color, national origin, sex, religion, age, disability, political beliefs, sexual orientation, or marital or family status. (Not all prohibited bases apply to all programs.) Persons with disabilities who require alternative means for communication of program information (Braille, large print, audiotape, etc.) should contact USDA's TARGET Center at (202) 720-2600 (voice and TDD).

To file a complaint of discrimination, write USDA, Director, Office of Civil Rights, Room 326-W, Whitten Building, 1400 Independence Avenue, SW, Washington, DC 20250-9410 or call (202) 720-5964 (voice or TDD). USDA is an equal opportunity provider and employer.