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Thomas R. Vale
Department of Geography, University of Wisconsin, Madison

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INVASION OF BIG SAGEBRUSH (ARTEMISIA TRIDENTATA) BY WHITE FIR (ABIES CONCOLOR) ON THE SOUTHEASTERN SLOPES OF THE WARNER MOUNTAINS, CALIFORNIA

Thomas R. Vale

ABSTRACT.- White fir (Abies concolor) appears to be invading vegetation dominated by big sagebrush (Artemisia tridentata) on the southeastern slopes of the Warner Mountains of extreme northeastern California. The time of initial tree establishment within the shrubs was determined by increment borings. Possible causes of the invasion involving specific climatic conditions, fire history, and grazing use of the area during years of the establishment were explored. Heavy grazing by domestic livestock, particularly sheep, appears responsible for altering the sagebrush-grass vegetation and allowing tree invasion.

The Warner Mountains of extreme northeastern California rise to 3,000 m above sea level and support a forest dominated by white fir (Abies concolor) and ponderosa pine (Pinus ponderosa) (Fig. 1). The adjacent valleys lie at 1,220 m and, where not irrigated for pasture or hay crops, are covered by thick stands of big sagebrush (Artemisia tridentata) with an understory of herbaceous plants. In the southeastern portion of the range, the transition zone between coniferous forest and shrubs is characterized by populations of small fir trees within the brush, suggesting a recent downslope movement of the trees (Fig. 2). The cause of this invasion of sagebrush by white fir in the Warner Mountains is the focus of this paper.

Relation to Other Studies

Many observers have noted invasions of sagebrush by tree species in various parts of the Intermountain West. Although pinyon pines (Pinus monophylla and P. edulis) and junipers (Juniperus spp.) are the most common invaders of sagebrush (Arnold et al., 1964; Blackburn and Tueller, 1970; Burkhardt and Tisdale, 1969; Cottam and Stewart, 1940; Wright and Fisser, 1968), lodgepole pine (Pinus contorta) also has been found expanding into stands of Artemisia (Patten, 1969). Moreover, young trees of ponderosa pine in eastern Oregon and Jeffrey pine (Pinus jeffreyi) in eastern California may be readily observed within sagebrush areas along forest edges. Although all the above vegetation changes imply a recent establishment of trees in environments formerly unsuited to them, studies have not yet documented the invasion of the relatively xeric big sagebrush by so mesic a species as white fir.

In these previous studies, the initiation of tree establishment is often found to correlate with periods of intense livestock grazing. Cattle may deplete the herbaceous plants in the vegetation, thereby reducing the full utilization of the habitat's resources (e.g., soil moisture); this "opening" of a formerly "closed" plant cover...

Fig. 1. The Warner Mountains area of extreme northeastern California.

1Assistant Professor. Department of Geography, University of Wisconsin, Madison, Wisconsin 53706.
may permit the establishment of species previously excluded (Robertson and Pearse, 1943). In a lodgepole pine invasion of grassy meadows, Vankat (1970) determined that most invasive trees were established immediately after, rather than during, a time of grazing by sheep. Trampling by the animals apparently killed seedling trees, but the heavy browsing and grazing did make the meadows susceptible to successful invasion after the sheep were removed.

Another cause sometimes invoked to explain tree advances into sagebrush is climatic fluctuation. Patten (1969) and Arnold et al. (1964) both suggest that, during abnormally wet periods, trees may become established in shrub environments typically too dry for them. Johnsen (1962) offers a variation on this theme by speculating that long droughts may initiate the invasion by reducing the cover of brush and herbaceous plants; when moist conditions return, trees are able to sprout and survive in the "opened" vegetation stand. This sequence of events is analogous to the "opening" of a "closed" plant community by livestock grazing.

Fire suppression is often invoked to explain the invasion of woody growth, usually trees, into grasslands in the southern Intermountain West (e.g., Foster, 1917; Pearson, 1931; Johnsen, 1962). Blackburn and Tueller (1970), moreover, suggest that a decrease in fires, together with overgrazing, accounts for the invasion of pinyon pine and juniper into brush in eastern Nevada. Abundant evidence exists suggesting that fires retard the spread of woody plants in the southern Intermountain West, although interpretation of tree invasion into sagebrush as a response to fire suppression is complicated by the fact that both the trees and the shrubs suffer from frequent fires.

**Methods**

A site 35 km south of the town of Cedarville was selected for sampling the age structure of the young trees. The site appeared to be representative of the exposure, slope, and vegetation characterized by invading white fir in the southeastern Warner Mountains. Five plots, each 30 m by 60 m, were located at intervals of 0.5 km along the lower limit
of young trees; an additional plot was located in a stand of young fir trees at a higher elevation where a southeastern exposure caused a higher forest-shrub transition. The selection of plots along the lower limit of these trees was designed to establish the period during which white fir invaded that portion of the area usually considered least hospitable to it. Within each plot, all trees greater than 20 cm dbh were cored with an increment borer, while the time elapsed since tree establishment was estimated to be eight years plus those indicated by the tree rings. Trees with diameters smaller than 20 cm were recorded by estimated height.

RESULTS AND DISCUSSION

Although invasion began between 1915 and 1919, most white fir became established between 1925 and 1944 (Table 1). After 1944 a decrease in successful tree establishment is suggested by a gap in the age structure. More recent reproduction seems improved, judging from the relatively large number of trees between 0.5 and 2 meters in height. The absence of dead trees of any size precludes the possibility that older cohorts suffered mortality, an event which would compli-
mesic species, but when drought should have hindered its establishment. The notion that dry conditions might have favored tree invasion by reducing the sagebrush-grass cover is untenable, because a drought so severe as to decrease the xeric sagebrush could not possibly simultaneously increase the mesic white fir.

The coincidence of drought and initial establishment of the white fir in this study, then, suggests that the trees invaded in spite of the weather rather than because of it. Moreover, it is apparent that nonclimatic factors prevented tree invasion during the more moist periods existing in the study area prior to 1910.

Fire Suppression.— Although the Modoc Forest Reserve was established in 1904, wildfires in the Warner Mountains apparently continued to be common until after the creation of the Civilian Conservation Corps in 1933; the year 1924, for example, is reported to have been a particularly serious fire year (Cook, n. d.). More specifically, information from the U.S. Forest Service indicates that the area immediately adjacent to the study plots was burned by wild fires between 1921 and 1930, and that fires were common within the national forest during that decade (U.S. Forest Service, 1974).

Supporting the impression that fire suppression was not well developed in the region by the time of tree invasion, the rangeland outside of the forest reserve, and in which the white fir became established, was not given official protection until passage of the Taylor Grazing Act in 1934. The Bureau of Land Management office in Susanville, California, out of which the federal rangelands in the region are administered, reports no records of fire suppression activities on the east slope of the Warner Mountains prior to 1950 (U.S. Bureau of Land Management, 1974).

The State of California was not, and is not, responsible for fire control in the study area, although it presently protects private rangelands west of the Warner Mountains (California Division of Forestry, 1975). Moreover, the state did not have any system for fire suppression during the initial years of tree establishment, and its fire protection policies cannot be considered to have been effective until after 1945 (Clark, 1969; Davis, 1965).

It seems valid to conclude that successful fire suppression on the east slope of the southern Warner Mountains was not effective until after the period of initial tree establishment. Although subsequent fire control has probably aided the maintenance of the trees, it cannot be invoked to explain the initiation of tree advance downslope.

Grazing.— The intensity of grazing by domestic livestock in the southeastern Warner Mountains has varied greatly since the initial settlement of Surprise Valley, immediately east of the Warner Range, in 1864. The number of cattle on ranches in Modoc County as a whole was little changed between 1890 and 1945, but it doubled in the following twenty years; resident sheep, by contrast, increased rapidly between 1890 and 1930, but by 1940 they had declined precipitously (Fig. 4).

Much of Modoc County is heavily forested, thus restricting grazing by domestic livestock to areas of brush or grass. Such habitats in the Warner Mountains and adjacent valleys have supported large numbers of animals, particularly sheep, over the last century. Contributing to the heavy grazing of these rangelands was the seasonal migration of sheep from the mountains in summer to the semiarid lowlands of northern Nevada in winter, a pattern well established by the 1870s (Olmsted, 1957). Moreover, sheep drives from Idaho and Oregon to shipping points in western Nevada passed through the Warner Mountains (Olmsted, 1957).

![Fig. 4. Numbers of cattle and sheep on ranches in Modoc County. Data source: U.S. Bureau of Census.](image-url)
By 1900 the ranges of Modoc County are said to have been greatly overgrazed (Brown, 1951; Pease, 1965). Establishment of federal forest reserves (later to become national forests) in the early 1900s apparently did little to reduce immediately the grazing pressures in the higher elevations of Modoc County, including the Warner Mountains. Transient sheep continued to be driven across national forest land from Oregon until the Forest Service banned such use in 1914 (Tierney, 1946). Pease (1965) suggests that the elimination of grazing by transients prompted the establishment of new sheep ranches, with resident flocks, in Surprise Valley; this contributed to the rapid increase of resident sheep in Modoc County between 1910 and 1920. Also accentuating the heavy grazing pressures at this time, the Forest Service intentionally allowed overstocking on national forest lands in northeastern California during World War I to help meet war demands for food and wool; even after the war, heavy stocking continued because it was felt abrupt reductions in livestock numbers might have created economic hardship for area ranchers (Tierney, 1946). Even while the national forest lands were under nominal regulation, the public domain continued to be completely free and open range. These latter federal lands in northwestern Nevada served, in part, as wintering grounds for sheep that were moved from California during the autumn season. Olmsted (1957) claims that 150,000 sheep were grazed in Surprise Valley in 1920, and, when compared to resident sheep reported on ranches in all of Modoc County in that year (109,000), it is apparent that much use of Surprise Valley ranges, including much public domain acreage, was by transient flocks. The peak in grazing pressure by sheep in the 1920s was apparently even greater than that suggested by the numbers of resident sheep.

The end of uncontrolled sheep grazing on the public domain came with the passage of the Taylor Grazing Act in 1934 (Olmsted, 1957; Pease, 1965). With more stringent regulations against transient flocks, the public lands could no longer be used by migratory sheep herders.

The grazing history suggests that the white fir invasion coincided with the peak, and the period immediately following the peak, of sheep grazing in the region. Sheep may have reduced the coverage of grass and shrubs, thereby increasing the availability of soil moisture and allowing the establishment of seedling trees. Sheep browse shrubs, but not conifers, on winter range, thus encouraging the tree invasion.

Conclusions

The evidence suggests that grazing by domestic livestock altered the sagebrush-grass vegetation on the east slope of the Warner Mountains and allowed the establishment of white fir seedlings. Yet, while grazing seems responsible for the initiation of tree invasion, the accelerated rate of tree establishment during the period 1935-1944 may have been the result of increased precipitation on the openings in the vegetation cover produced by grazing. Such an explanation would account for the decrease in tree establishment after 1944 because, by that time, the plant cover would have sufficiently recovered from the effects of the earlier heavy grazing to minimize the availability of suitable seedbeds and soil moisture. The cause of the present abundance of seedling trees is more obscure, but may be related to a resurgence of grazing pressure due to increasing numbers of cattle in recent years (Fig. 1).

In the northern Intermountain West generally, grazing by domestic livestock may be adequate to explain the widespread invasion of trees into sagebrush-grass vegetation during the late nineteenth and early twentieth centuries. The example from California, discussed in this paper, suggests that fire suppression has been too recent, except perhaps locally, to correlate with these tree invasions. Control of fire may account for tree establishment in other vegetation types, however, during this time. Regional climatic fluctuations, by themselves, also seem inadequate to account for the expansion of trees into sagebrush-grass vegetation during the latter half of the 1800s, a time characterized by "fluctuating but below average moisture" in western North America (Fritts, 1965). This portrayal of climate does not suggest conditions sufficiently wet to favor tree
growth in formerly xeric brush. Moreover, tree invasion in the Warner Mountains began, not during a wet period, but during an extended time of below average precipitation. Grazing by domestic livestock, then, remains the most likely general cause, applicable on a regional basis, to account for the widespread invasion of sagebrush vegetation by tree species. Periods of extended drought may, in certain places, accentuate the plant cover deterioration caused by grazing, thus encouraging tree establishment once more moist conditions return.

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