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Effects of Reservoir Formation on the Annual Growth Rings of *Artemisia tridentata*

Abstract

This study investigated whether annual growth rings of big sagebrush (*Artemisia tridentata*) bordering Wanapum Reservoir in eastern Washington reflected a change associated with the formation of the reservoir in 1963. There is evidence that the growth of big sagebrush within 2 m elevation above the highwater level of the reservoir was modified.

Introduction

The effect of reservoirs on surrounding vegetation has not been well studied. In the last 20 years, large irrigation, hydroelectric, and holding reservoirs have been built in the arid regions of eastern Washington, providing a seemingly excellent opportunity for such research.

The native vegetation of this area is largely a shrub steppe; big sagebrush (*Artemisia tridentata* Nutt.) is the main component of this association (Daubenmire, 1970). Recent dendrochronological investigations have indicated that big sagebrush reflects changes in moisture status by variations in the width of the xylem layers in the stem. Ferguson (1964) found a correlation between the xylem layers of big sagebrush and winter precipitation. Daubenmire (1975) reported that xylem layer growth in big sagebrush is closely related to November through June precipitation and to soil moisture in May. Fowler and Helvey (1974) detected a growth response of big sagebrush to irrigation, as well as a correlation between variation in xylem layer growth and August through July precipitation.

The objective of the present study was to determine any changes in the annual growth rings of big sagebrush that might be associated with the 1963 establishment of Wanapum Reservoir in Grant County, Washington. The hypothesis was that the formation of the reservoir resulted in an improved water regime for big sagebrush in the immediate vicinity of the reservoir which would be reflected in the annual growth rings.

Methods and Materials

The reservoir site was selected according to three criteria. These were that big sagebrush extend to the highwater level, that there be a gradual elevational gradient away from the reservoir, and that there be no visible fire, construction, or recreational disturbance. Four plots (1-4) adjacent to the reservoir were established at this site.

A control site (plot 5) was established approximately 100 m above the reservoir on a plateau about 2 km away from the reservoir site. Another site (plot 6) that had burned in July 1967 was established about 11 km west of Quincy, Washington. It was anticipated that this plot would provide information on the response of big sagebrush to fire, a common range practice in shrub steppe areas (Pechanec, 1944).

Selection of big sagebrush specimens was based on the condition of the stem and the elevation and distance of the plant from the reservoir highwater level. Many specimens were too decayed or too young to be used for analysis. Approximately 30 years of growth rings were required so as to avoid using the potentially anomalous rings near the pith (Duff and Nolan, 1953) and yet allow 10 years pre- and post-1963 for the statistical tests.

Big sagebrush specimens from all six plots were prepared and crossdated by standard dendrochronological techniques as described by Ferguson (1964) and Stokes and Smiley (1968). Ring widths were measured to .01 mm on an incremental measuring apparatus. A Fortran program developed by Harold Blair of the College of Forest Resources, University of Washington, was utilized to check the crossdating. Crossdating facilitated the assignment of a year date to each ring.

Results and Discussion

Fifty-two (of 78) big sagebrush plants collected were appropriate for analysis. The ring widths of each specimen were graphed against year of formation. Plot composites were prepared by averaging the ring widths for each year (Fig. 1). An analysis of variance was run on the data for each plot. It indicated that the variation due to years was significantly ($P=.02$) greater than the variation due to individuals for all plots except plot 2. With the exception of plot 2, the composite graphs therefore indicate ring width variations are due to years; they are not unduly influenced by unusually erratic specimens.

Plot 1 exhibits a dramatic increase in ring width in 1961; plots 3 and 4 exhibit a similar increase in 1956. These increases tended to be sustained in plots 2 and 5. Plots 1-5 exhibit a decrease in ring width in 1955, followed by a large increase in 1956. The ring width fluctuations of plot 6 (fire site) do not correspond with any of the dramatic fluctuations exhibited on the other plots. Plots 2 and 3 exhibit a large ring width fluctuation in 1964, the first growing season after reservoir formation.

Since the main purpose of this study was to determine if there is a relationship between the formation of Wanapum Reservoir and a growth response in big sagebrush, the next step was to test if the mean ring width for the 10 annual growth rings previous to reservoir formation (1953-1962) was significantly different from that for the 10 years (1964-1973) after reservoir formation. T-tests (Campbell, 1974) were run to compare these pre- and post-10 year segments for each individual plant. If the post-1963 segment was significantly greater at the $P=.05$ level than the pre-1963 segment, a +S was assigned that segment; if it was significantly less, a -S was assigned (Table 1).

When the reservoir site (plots 1-4) is compared with the control and fire sites, approximately 20 percent of the individual plants within each site exhibit a significant

TABLE 1. Results of t-tests (in percent) for radial segments for 10 years pre- and post-1963 ($P=.05$).

Site	n	Length Differences Significance	
		% +S	% -S
Reservoir	33	18	6
Control	10	20	20
Fire	9	22	22

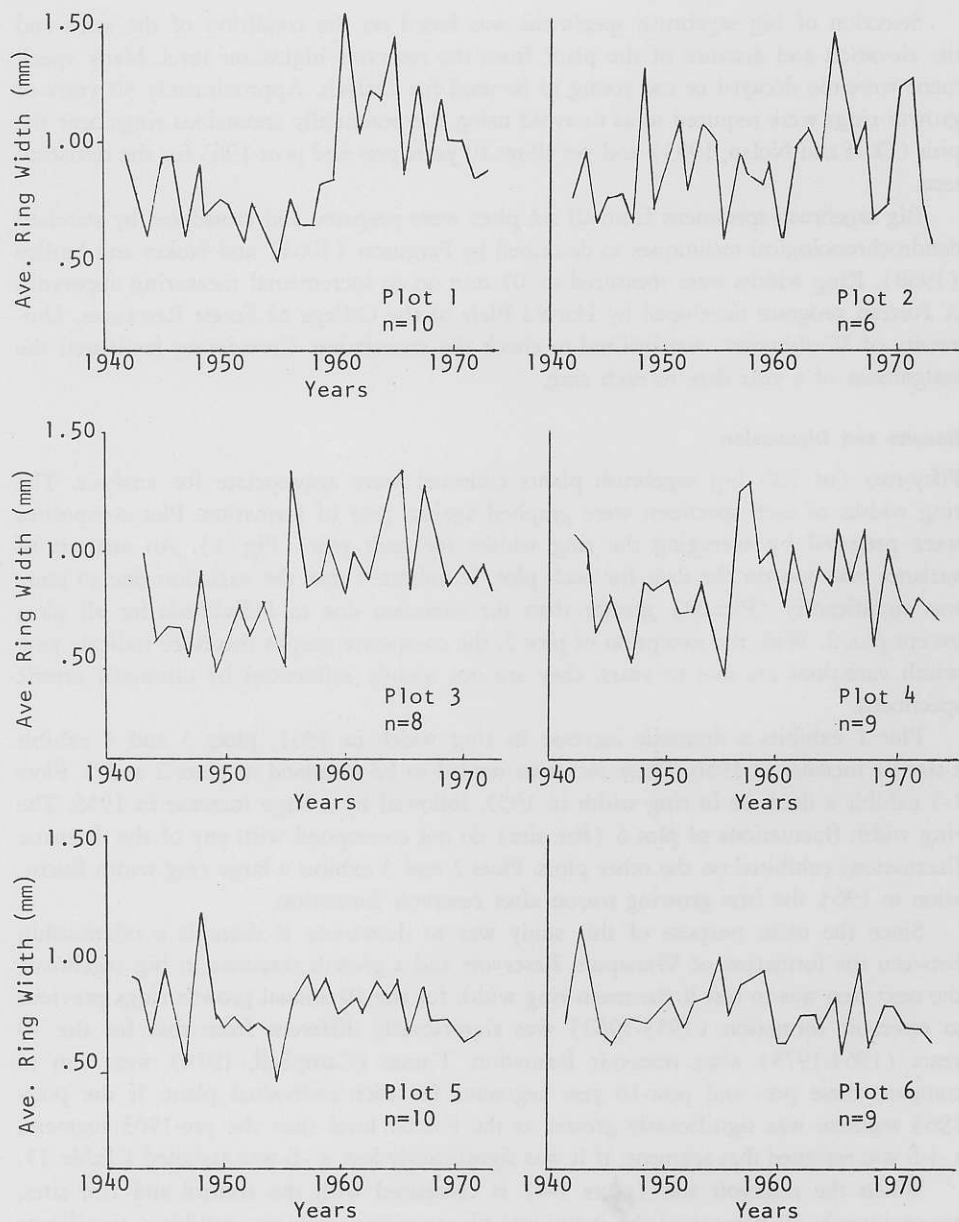


Figure 1. Composite site graphs of yearly ring width fluctuations.

increase in the radial segment length after reservoir formation. However, only 6 percent of the plants on the reservoir plots exhibited a significant decrease in the radial segment length after reservoir formation, while on the control and fire sites 20 percent and 22 percent respectively exhibited a decrease (Fig. 2).

These data (Fig. 2) seem to indicate a mitigating influence of the reservoir for plants whose growth is marginal or decreasing relative to the growth of the other plants. It also seems to indicate that the 1967 fire at plot 6 did not retard or enhance the growth

of the surviving plants based on the similarity of the changes in the radial segment length of the control and fire sites.

The postulated mitigating influence of the reservoir and the extent of the hypothesized reservoir effect were further investigated. Meredith (1965) developed a graph to indicate the extent of reservoir influence on adjacent ponderosa pine. Figure 3 shows similar data for big sagebrush. The length of the 10 year pre-1963 segment is subtracted from the length of the 10 year post-1963 segment. This difference is graphed against elevation. Individual specimens are labeled with their identification numbers. Figure 3 shows a dramatic drop in the growth differences at 2 to 2.5 m in elevation above the reservoir highwater level. This elevation could be interpreted as the extent of reservoir influence on big sagebrush.

To substantiate further the extent of reservoir influence on big sagebrush, elevational groups were delineated. The results of the t-tests for each specimen were placed within each group; however, the results were inconclusive.

Meredith (1965) found that the differences in annual growth ring variance for pre- and post-reservoir segments were more distinctive than the differences in the length of the pre- and post-reservoir segments. The annual growth ring variance of the 10 year pre- and post-1963 segments of big sagebrush was analyzed using an F-test (Campbell, 1974). Table 2 contains the results of the t-tests and the F-tests at 0-2 m and >2 m elevation. It also has a summary of the F-tests at all three sites.

Although the t-tests indicate no difference in 10 year segment length with proximity to the reservoir, the F-tests indicate that plants less than 2 m in elevation above the reservoir significantly increase their annual growth ring variation, while those >2 m in elevation significantly decrease their annual growth ring variation. Meredith (1965) found the same trend in variance with ponderosa pine. A comparison of the three sites without the elevational gradient masks this difference.

Conclusions

T-tests performed on the length of big sagebrush radial segments for the 10 years pre- and post-reservoir formation indicated a mitigating influence of the reservoir on the plants on the reservoir plots. The mechanism for the observed difference in the plants exhibiting a significant decrease in radial growth was unclear, as elevation groupings at the reservoir plots did not correlate with this decrease. However, only 6 percent of the plants at the reservoir site exhibited a decrease in radial growth while 20 percent of the plants at the control site exhibited this decrease.

TABLE 2. Results of statistical tests (in percent) for radial segments for 10 years pre- and post-1963 (P=.05).

Test	Site	Elevation in m	n	Significance	
				% +S	% -S
t-test	Reservoir	0-2	18	17	6
	Reservoir	2	15	20	7
F-test	Reservoir	0-2	18	22	—
	Reservoir	2	15	—	20
F-test	Reservoir		33	12	9
	Control		10	10	10
	Fire		9	—	—

F-tests performed on the same big sagebrush segments indicated that all the significant increases in annual growth ring variation (22 percent) occurred 0-2 m in elevation above the reservoir highwater level while all the significant decreases in annual growth ring variation (20 percent) occurred at >2 m in elevation. This difference in

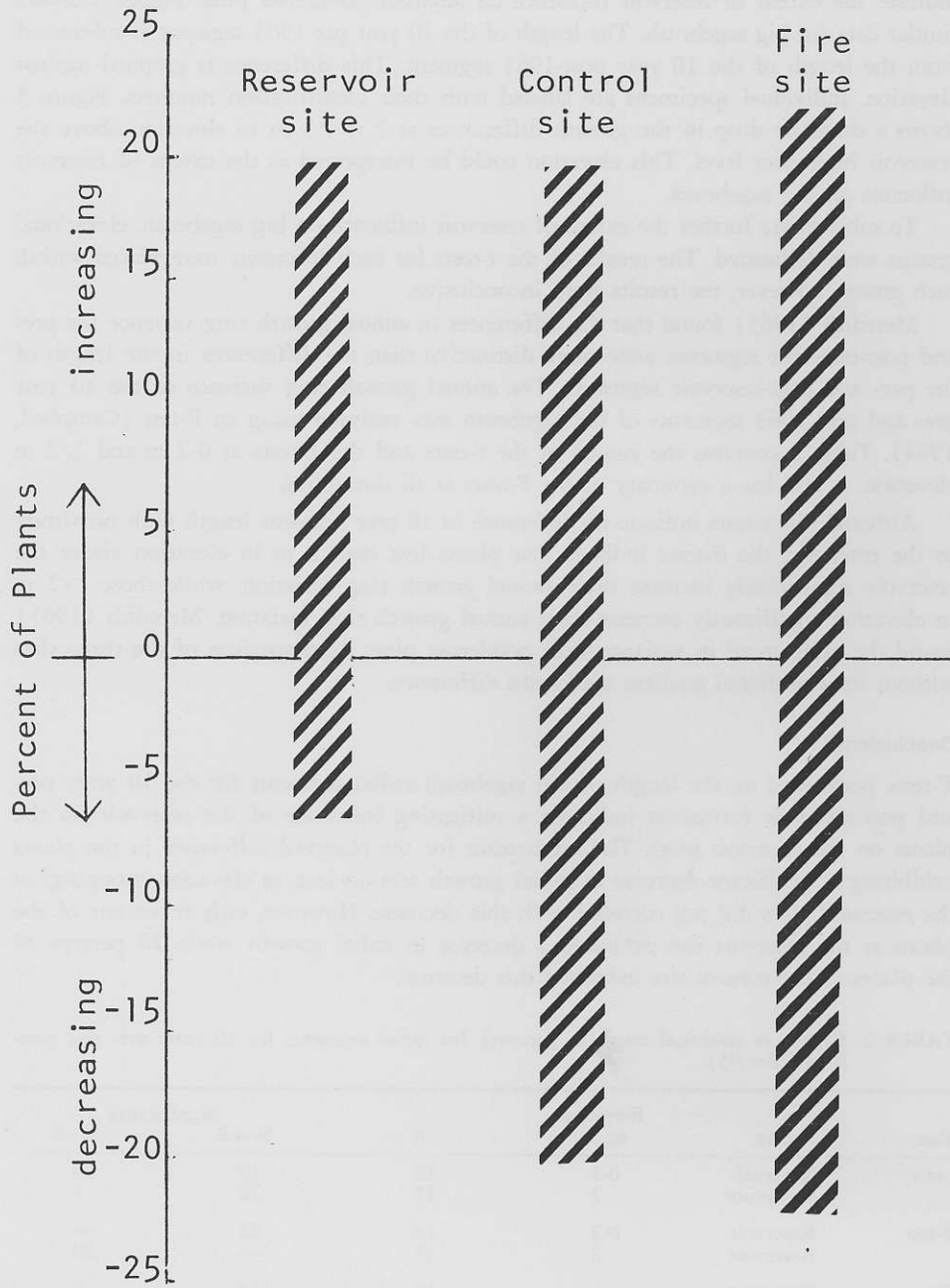


Figure 2. Percent of plants exhibiting a significant increase or decrease in radial segment length after 1963.

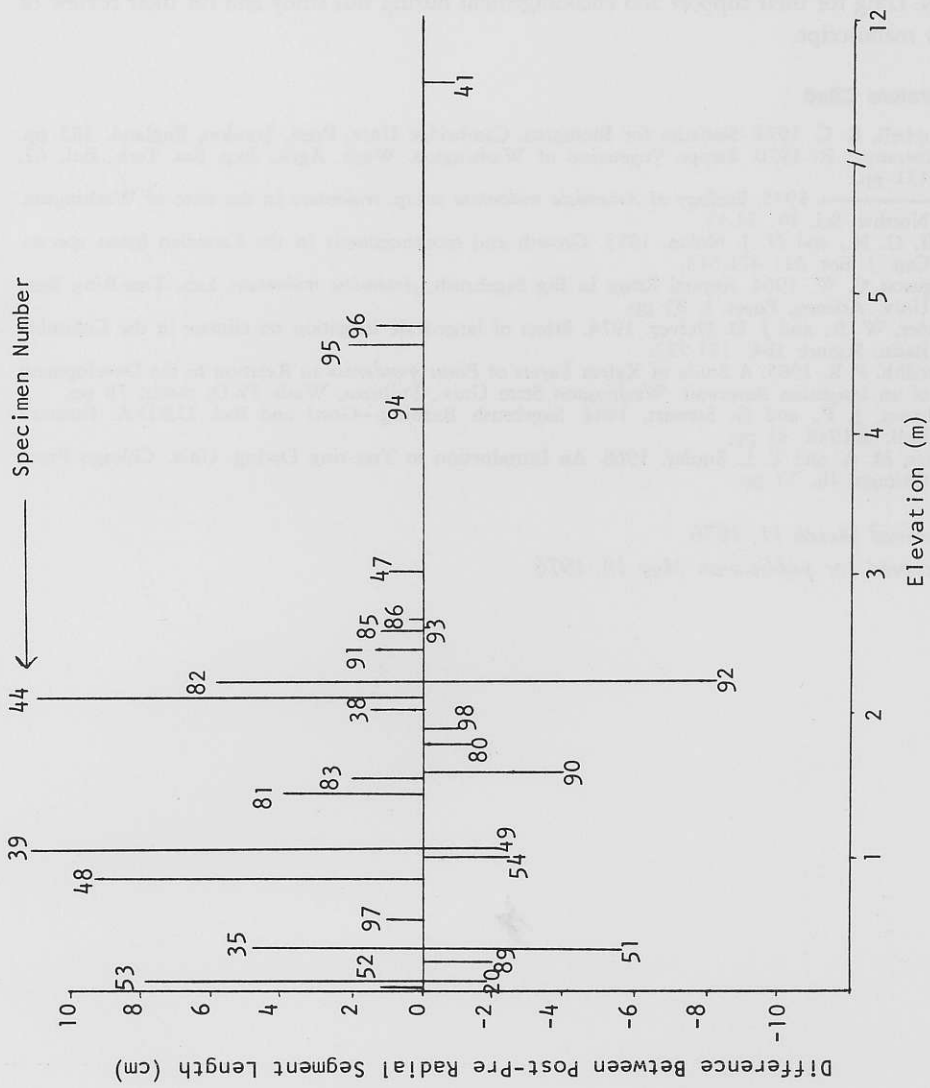


Figure 3. Relationship between elevation and post-1963 radial segment length minus pre-1963 radial segment length.

variance due to elevational gradient was masked when the reservoir site (without elevational groupings) was compared with the control site.

A graph representing the increase or decrease of the 10 year segment length post-reservoir over that of the pre-reservoir segment indicated that the extent of reservoir influence was 2 to 2.5 m.

Acknowledgments

I would like to thank Dr. D. R. M. Scott, Dr. L. Brubaker, Dr. D. A. Manuwal and J. N. Long for their support and encouragement during this study and for their review of this manuscript.

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Received March 11, 1976

Accepted for publication May 19, 1976