PINYON GROWTH CHARACTERISTICS IN THE SWEETWATER MOUNTAINS

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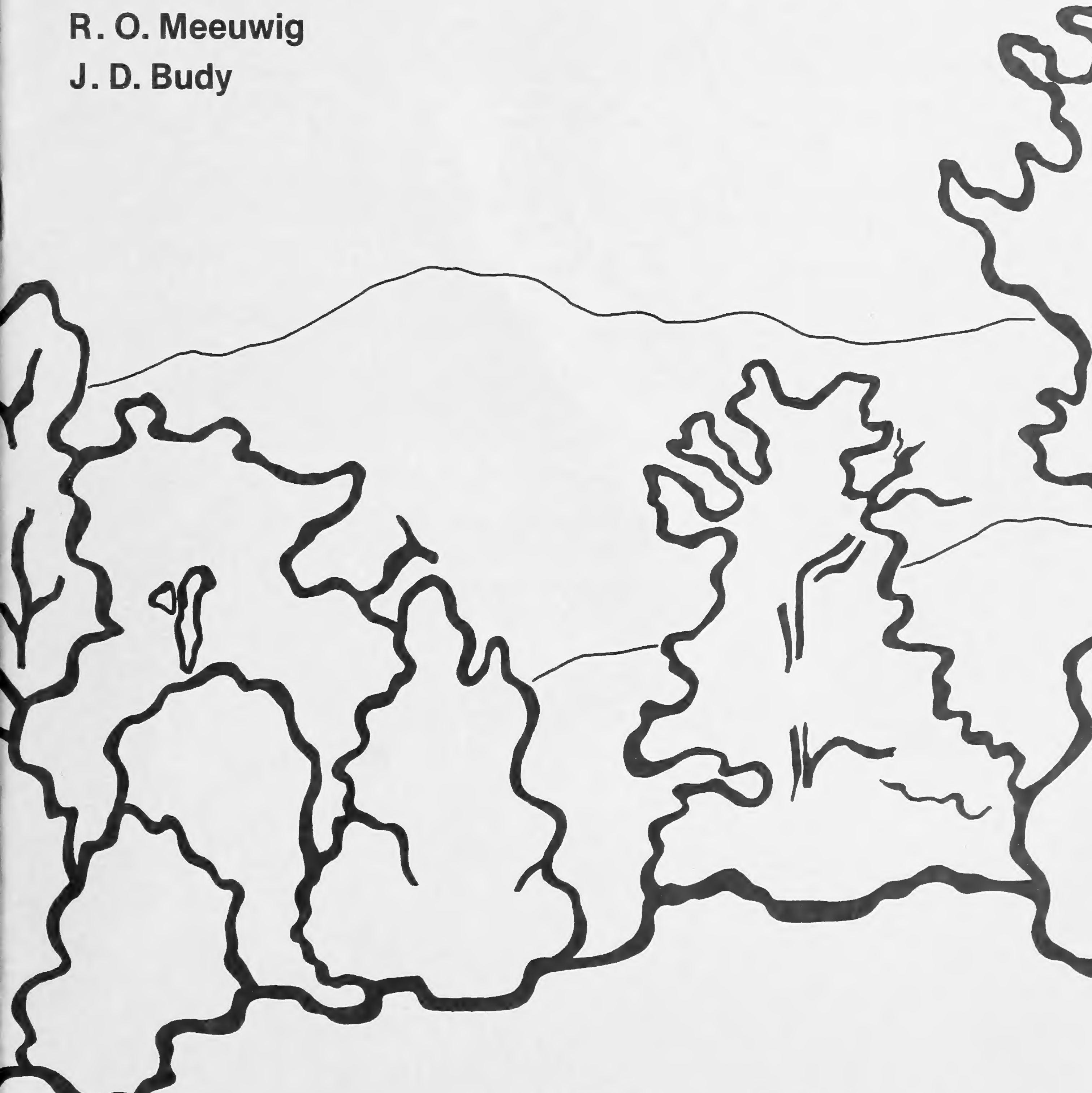

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RESEARCH SUMMARY

Stem analyses of singleaf pinyon (*Pinus monophylla*) indicate that height growth rates of dominants and codominants are little affected by age or competition. Each tree grows in height at an essentially constant rate throughout most of its life, but height growth rates vary considerable among dominant trees on the same site. This variation is probably because of genetic differences. Diameter growth rate appears to be unaffected by age but is sensitive to competition. Stand basal area increases at an exponential rate until the understory shrubs are suppressed; then the rate of stand basal area increase becomes relatively constant. Stand biomass accumulation rates follow a similar pattern, tending to become constant after the understory shrubs have been suppressed.

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INTRODUCTION

The singleleaf pinyon (*Pinus monophylla*)-Utah juniper (*Juniperus osteosperma*) woodland of the Great Basin has had a long history of use; but because of the noncommercial status of the two species, there has been little research on their silvical characteristics. Reveal (1944) reported on the stand and tree characteristics of singleleaf pinyon and Utah juniper in the Pine Nut Range in western Nevada. Herman (1953, 1956) studied the phenology and growth characteristics of Utah juniper in central Arizona. Daniel and others (1966) made an extensive study of pinyon-juniper woodlands in Utah, Arizona, northwestern New Mexico, western Colorado, and eastern Nevada, but they dealt lightly with tree growth rates.

Other species of pinyon and juniper have received more attention than singleleaf pinyon and Utah juniper. Howell (1940) studied the growth and yield of Colorado pinyon (*Pinus edulis*), one-seed juniper (*Juniperus monosperma*), and Rocky Mountain juniper (*J. scopulorum*) in New Mexico and Arizona. The silvical characteristics of Colorado pinyon, Rocky Mountain juniper, and western juniper (*J. occidentalis*) were summarized in Agricultural Handbook No. 271 (Fowells 1965).

As the demand for firewood and other pinyon-juniper products continues to increase, the harvesting of these trees can be expected to increase dramatically, and more specific information will be needed for productive management of pinyon-juniper woodlands. In 1977, we began a study to obtain silvical information on singleleaf pinyon and Utah juniper. A secondary objective of the study has been to obtain data on intensively measured plots to provide standards for checking the accuracy of sampling methods that have been or will be developed for studying or inventorying pinyon-juniper stands.

This paper contains the results of the first year of study in a predominantly pinyon woodland in the Sweetwater Mountains along the California-Nevada border. Singleleaf pinyon growing in these mountains were studied to determine their rates of height and diameter growth in relation to tree age and competitive position, the basal area increment patterns of these pinyon stands, and the rates of wood, foliage, and aboveground biomass increments of both individual trees and stands. Similar data will be obtained on other pinyon-juniper woodlands in the Great Basin during the course of this project.

STUDY AREA AND PLOT DESCRIPTIONS

This study was made in a pinyon firewood sale area on the Bridgeport Ranger District, Toiyabe National Forest. The area is approximately 12 miles north of Bridgeport, California, between Green Creek and Frying Pan Creek on the east slope of the Sweetwater Mountains. Three plots--Green Creek, Cattle Trough, and Monte Cristo--were established in the study area; the aspect, slope, elevation, and percentage of overstory cover of each plot are presented in table 1. All three plots are on stony soils derived from rhyolitic colluvium. The stands at Green Creek were younger than those at Cattle Trough, but the oldest trees were found at Monte Cristo (table 2).

There has been a great deal of mining activity in the Sweetwater area and most of the stands are second-growth, dating from cuttings that furnished fuel and timber to the miners in the early 1860's (Wilson 1941). The absence of stumps in the area raises some question as to the past cutting, but Lord (1883) reported that Chinese laborers followed the woodcutters, pulling up the stumps, roots, and shrubs from the cutover hills.

Table 1.--*Aspect, slope, elevation, and overstory cover of the Sweetwater plots*

Plot name	Aspect	Slope	Elevation	Overstory cover
		Percent	*Meters*	*Percent*
Green Creek	N80°E	5	2200	49
Cattle Trough	N40°E	20	2100	64
Monte Cristo	S60°E	15	2300	60

Table 2.--*Age distribution of trees more than 1 m tall on the Sweetwater plots*

Age class (Years)	Green Creek	Cattle Trough	Monte Cristo
41- 50	2		
51- 60		3	1
61- 70	10	1	1
71- 80	7	8	8
81- 90	9	6	8
91-100	2	3	1
101-110		4	2
111-120		5	3
121-130	1	1	1
131-140		5	1
141-150	1	6	1
151-160	2	9	
161-170		6	3
171-180		6	
181-190			
191-200	1	1	
241-250			1
251-260			1
261-270			1
431-440			1
All trees	35	64	34

Each plot is 30 m square with an area of 900 m^2 (0.22 acre). All plot trees are singleleaf pinyon; a few juniper (*Juniperus osteosperma*) are in the study area but none are on or near the plots. Several Jeffrey pine (*Pinus jeffreyi*) are in the vicinity of the highest plot (Monte Cristo), but none are on or immediately adjacent to the plot.

Closed stands were deliberately chosen so that the influence of understory vegetation on tree growth would be negligible. The understory was sparse and of low vigor, especially on the lower two plots. Ephedra (*Ephedra viridis*), bitterbrush (*Purshia tridentata*), and mountain mahogany (*Cercocarpus ledifolius*) were the principal understory species on the Monte Cristo plot. Sagebrush (*Artemisia tridentata*) and gooseberry (*Ribes velutinum*) were the principal understory species on the other two plots.

METHODS

The boundaries of the 30 m by 30 m plots were laid out with staff compass and tape. Control lines at 5 m intervals parallel to the lower boundary were used in the mapping of tree stem locations and crown outlines. The foliage class of all trees taller than 1 m was estimated on a scale of 1 to 9. A vigorous tree with dense foliage on all sides was rated 9, and a tree with very sparse foliage was rated 1.

All trees taller than 1 m were felled and their total height (including stump) was measured with a tape. Stump height was about 15 cm for all but a few trees that could not be cut at that height because of large limbs or other irregularities.

From 6 to 9 trees on each plot, representative of the range in stump diameters, were selected for weighing. Each of these trees was separated into four components that were weighed with a load cell on a boom mounted on a pickup truck. The four components were:

1) live material larger that 76 mm diameter outside bark (d.o.b.),

2) live material 25 to 76 mm d.o.b.,

3) foliage and other live material smaller that 25 mm d.o.b.,

4) deadwood.

The relative proportions of foliage, twigs less than 6.4 mm d.o.b., and branches 6.4 to 25 mm were determined by subsampling about 10 percent of the <25 mm component. Cross-sectional disks were taken of each of the components and, along with samples of foliage and twigs, were analyzed in the laboratory for moisture content and bark percentage. These data were used to calculate ovendry mass of foliage, ovendry mass of wood larger than 76 mm, and total aboveground ovendry biomass in each tree.

On the weighed trees, stem sections were taken at stump height and at approximately 1-m intervals on the dominant stem up to a 3-cm diameter on the dominant leader. On the unweighed trees, stem sections were taken at the stump, at 3 cm on the dominant leader, and at one or two intermediate points on the dominant stem. The annual rings on all of these sections were counted and height-age curves were plotted for each tree. These curves were extrapolated to ground level to estimate tree age, and interpolated to determine past height at any particular time. False rings and missing rings are known to occur in pinyon and can make age determinations difficult, but comparisons of ring width patterns among trees and with Bridgeport precipitation data failed to indicate either false or missing rings in the trees on the Sweetwater plots.

Stump diameters, both inside- and outside-bark, were measured with a diameter tape. If there was more than one stem at stump height, the diameter of each stem was measured and the equivalent stump diameter was calculated by:

$$D = \sqrt{D_1^2 + D_2^2 + \ldots D_n^2},$$

(eq. 1)

in which D is the equivalent diameter and the subscripted D's are individual stem diameters.

Since pinyon butt cross-sections are usually out of round and the width of each annual ring is rarely uniform, it was necessary to develop special procedures to determine past diameters. Each stump cross-sectional disk was inspected and a line was drawn on the radial that appeared to best represent the growth pattern. Ring widths were measured to the nearest 0.1 mm along this line. The stump diameter (outside bark) at any particular time in the past was calculated by:

$$D_t = \frac{D_p \Sigma_t r_i}{\Sigma_p r_i}$$

(eq. 2)

in which D_t is past diameter (outside bark) at any time t, D_p is present diameter (outside bark), $\Sigma_t r_i$ is the sum of the ring widths from the pith to time t, and $\Sigma_p r_i$ is the sum of all ring widths along the radial line on the section. This equation corrects for changing bark thickness and for systematic errors in the measurement procedure.

Foliage, wood larger than 76 mm diameter, and total aboveground biomass of all unweighed trees were calculated using regression equations developed from data obtained in a companion study[1]. These equations are based on 68 pinyon trees, 18 of which are weighed trees from the Sweetwater plots. The remaining 50 are from 13 study sites throughout Nevada. Input variables include stump diameter, crown diameter, height, and foliage class. These equations are presented in appendix I.

Past biomasses (foliage, wood, and total) of each tree were estimated for each decade from 1860 to 1970, and for 1965 and 1975. These biomasses were calculated using regression equations that expressed past biomass as a function of present biomass and past height, diameter, and age. These equations, which were also derived from data obtained in the companion study, are presented in appendix II.

Basal area per hectare and biomass per hectare for each plot through time were calculated by adding the values for the individual trees and dividing the sum by the plot area (0.09 ha).

RESULTS AND DISCUSSION

Comparisons of tree sizes, ages, and diameter growth rates (appendix III) with their relative locations (figs. 1, 2, and 3) indicate varying degrees of competition among trees and suppression of the smaller trees. This paper will deal primarily with the growth of dominant and codominant trees and with the growth of stands, postponing a more detailed discussion of competition to another paper after more data have been acquired.

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[1]Miller, E. L., J. D. Budy, and R. O. Meeuwig. Biomass of singleleaf pinyon and Utah juniper (manuscript in preparation).

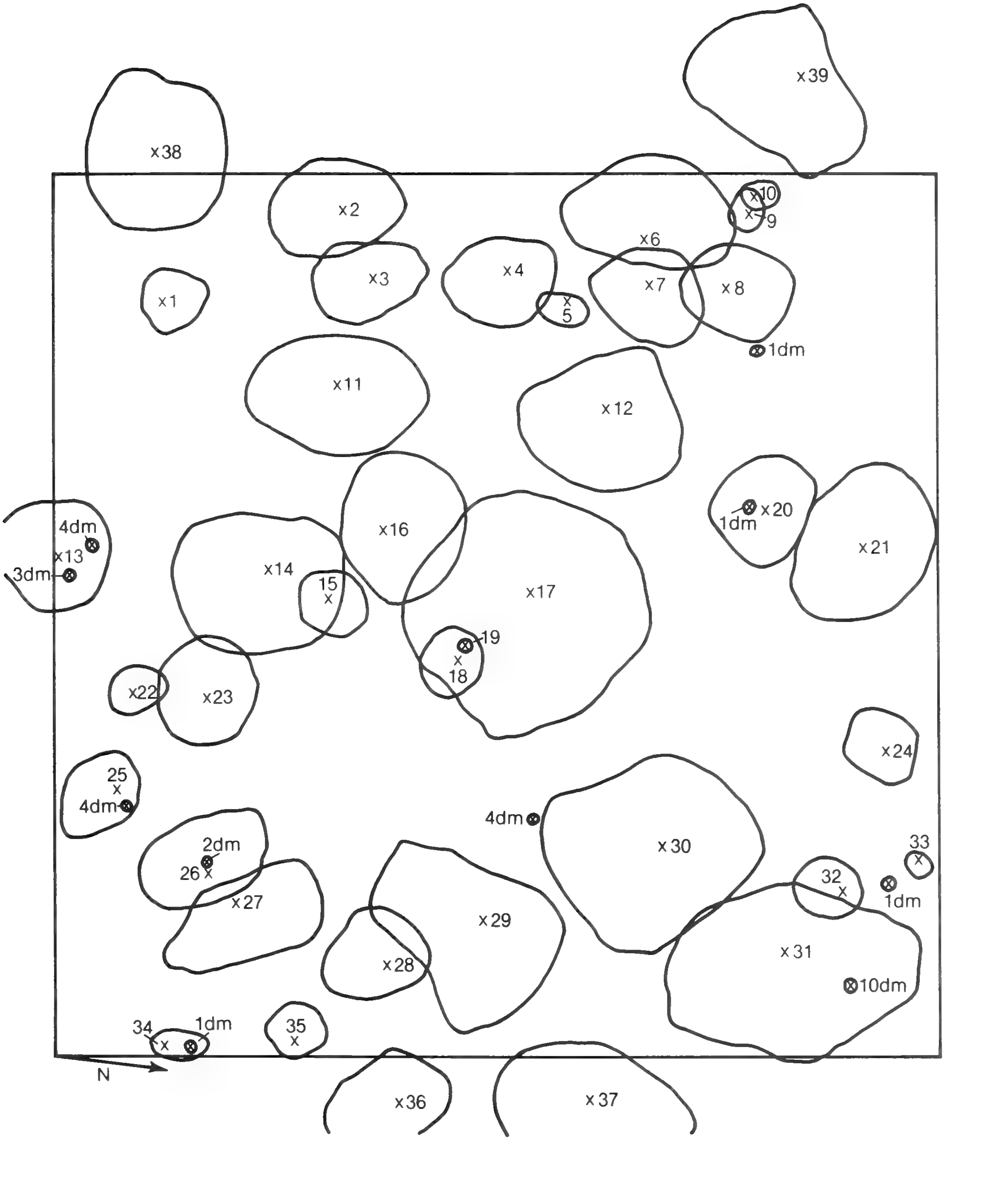

Figure 1.--Map of crown outlines and stump centers on the Green Creek plot. All trees taller than 1 m are numbered. The heights of the unnumbered trees are noted on the map in decimeters (dm).

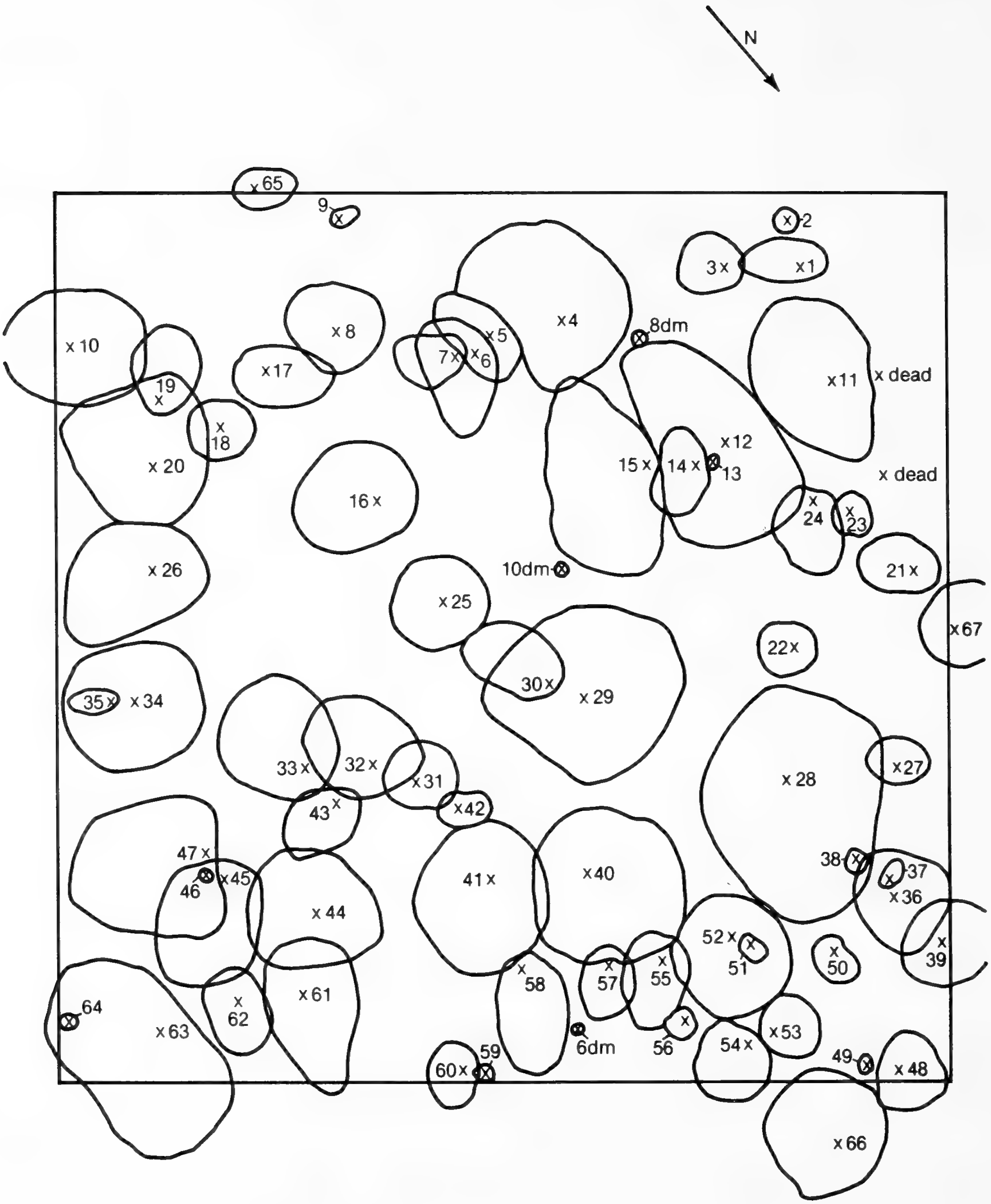

Figure 2.--Map of crown outlines and stump centers on the Cattle Trough plot. All trees taller than 1 m are numbered. The heights of the unnumbered trees are noted on the map in decimeters (dm).

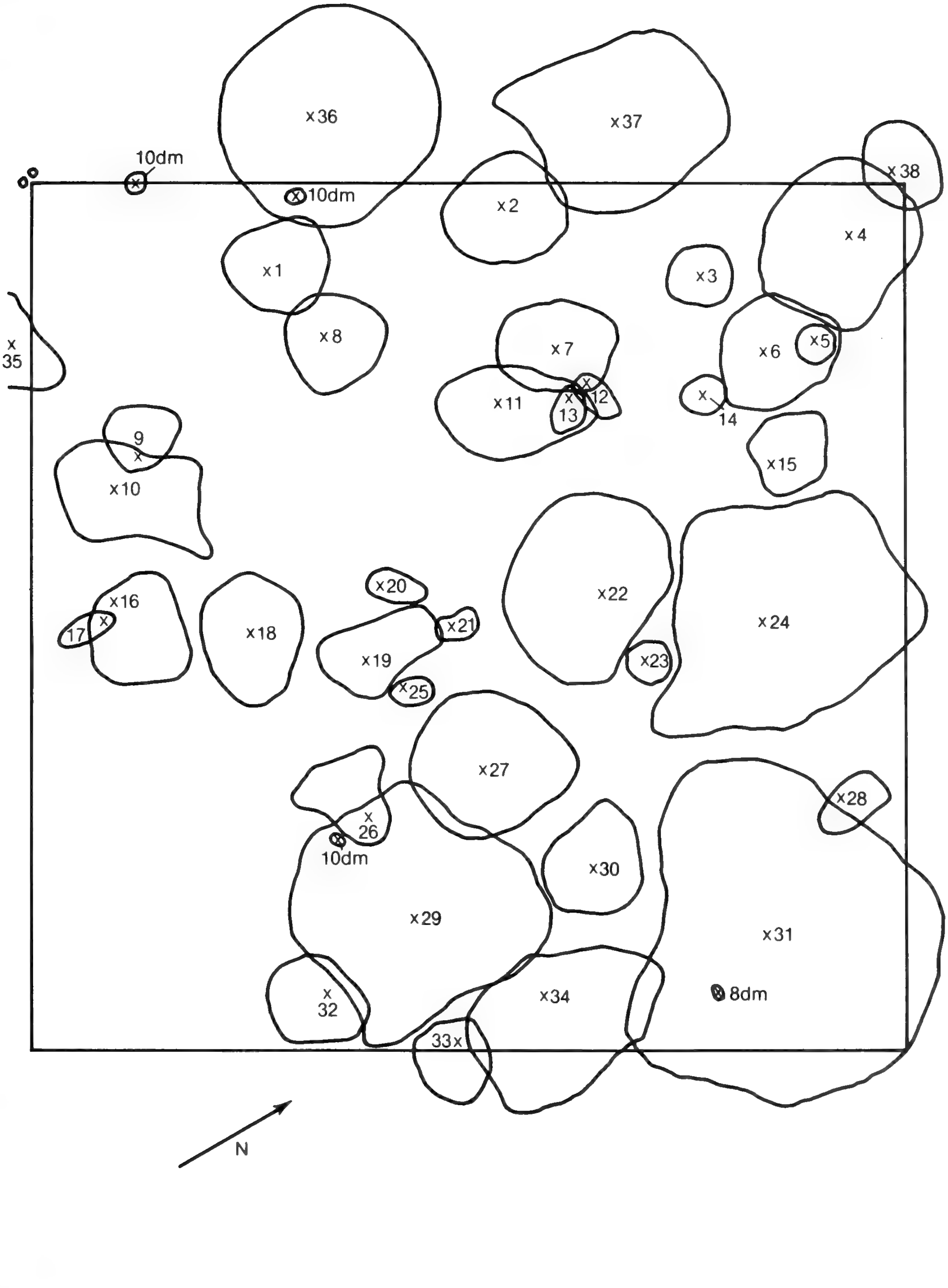

Figure 3.--Map of crown outlines and stump centers on the Monte Cristo plot. All trees taller than 1 m are numbered. The heights of the unnumbered trees are noted on the map in decimeters (dm).

Height

Tree heights of several dominants and codominants on each plot are shown through time in figures 4, 5, and 6. Each dot represents a measurement of a cross-sectional disk. The dots are connected by straight lines for simplicity. Few of these curves approximate the conventional S-curve, in which height growth increases initially and then tends to decrease as the tree matures. Most of the trees have had fairly constant height growth rates throughout their lives with a tendency for slightly lower initial growth rate. None appear to be approaching culmination of height growth. Tree #27 at Green Creek (fig. 4) and tree #32 on the Cattle Trough plot (fig. 5) come the closest to the conventional S-curve but #27 is still a young tree and the height growth rate of #32 does not appear to have decreased in the past 70 years.

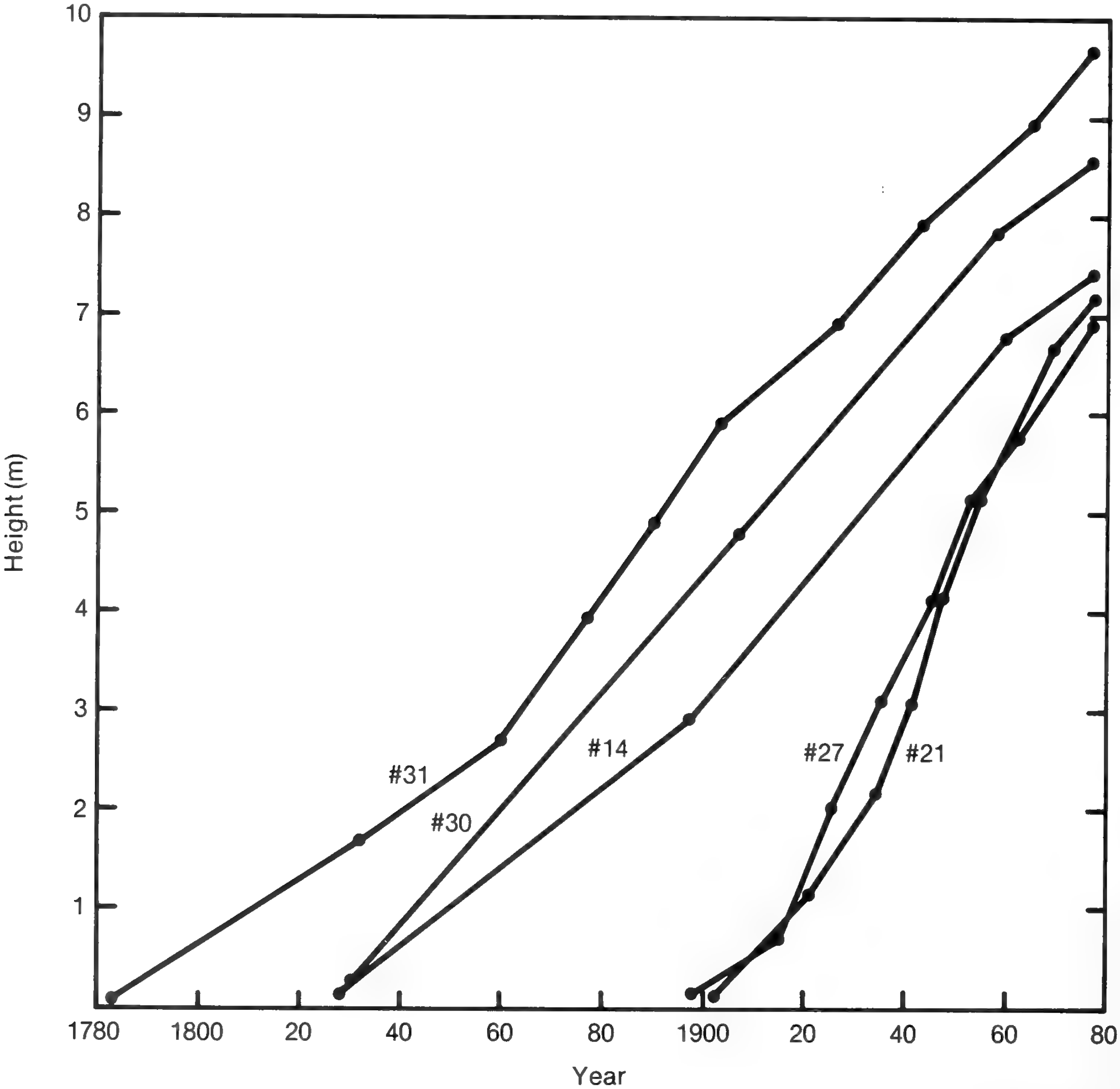

Figure 4.--Heights of five dominant and codominant pinyons on the Green Creek plot from 1780 to 1977. Tree #6 is not shown because its curve coincides with those of trees #21 and #27.

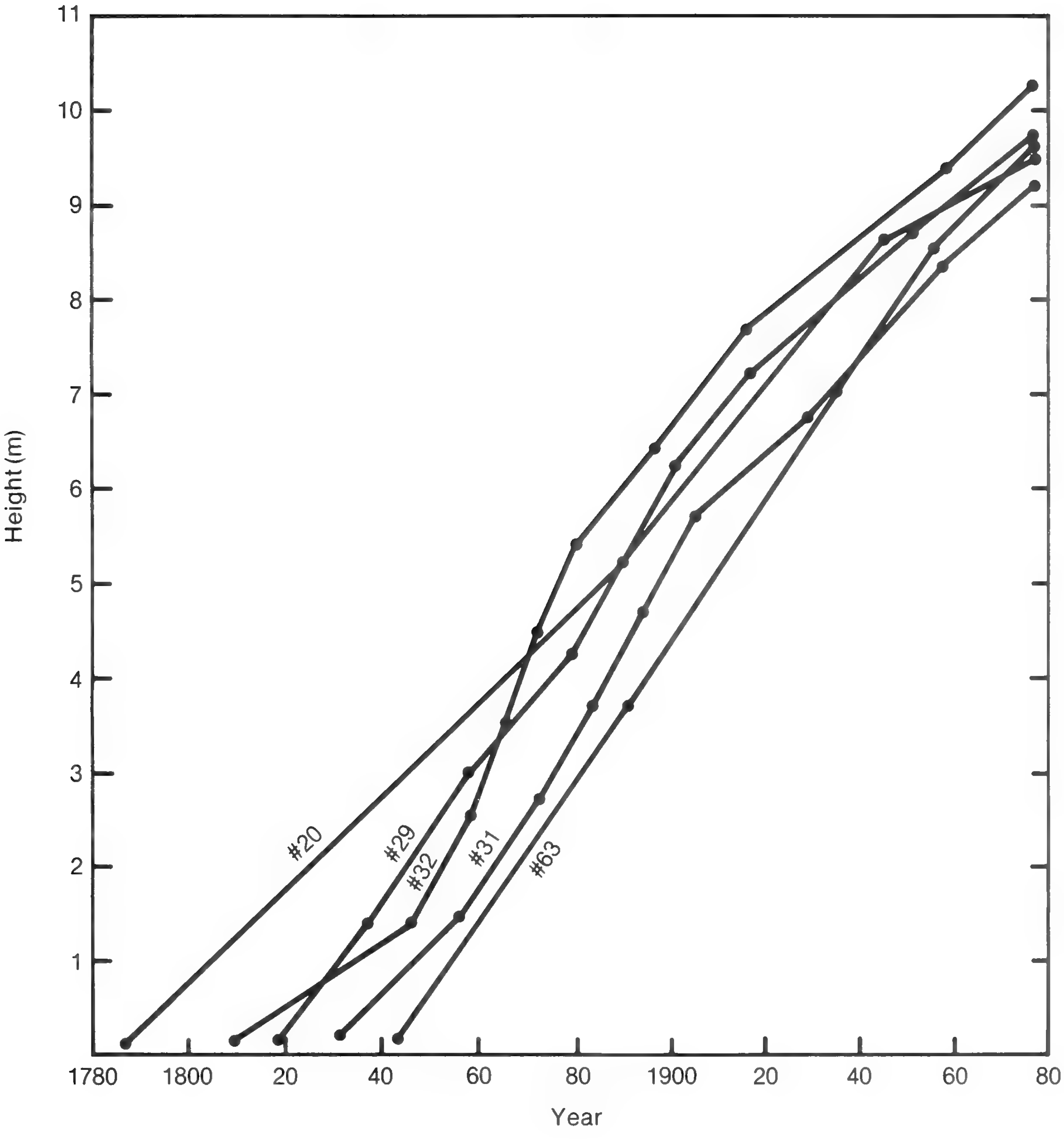

Figure 5.--Heights of five dominant and codominant pinyons on the Cattle Trough plot from 1780 to 1977.

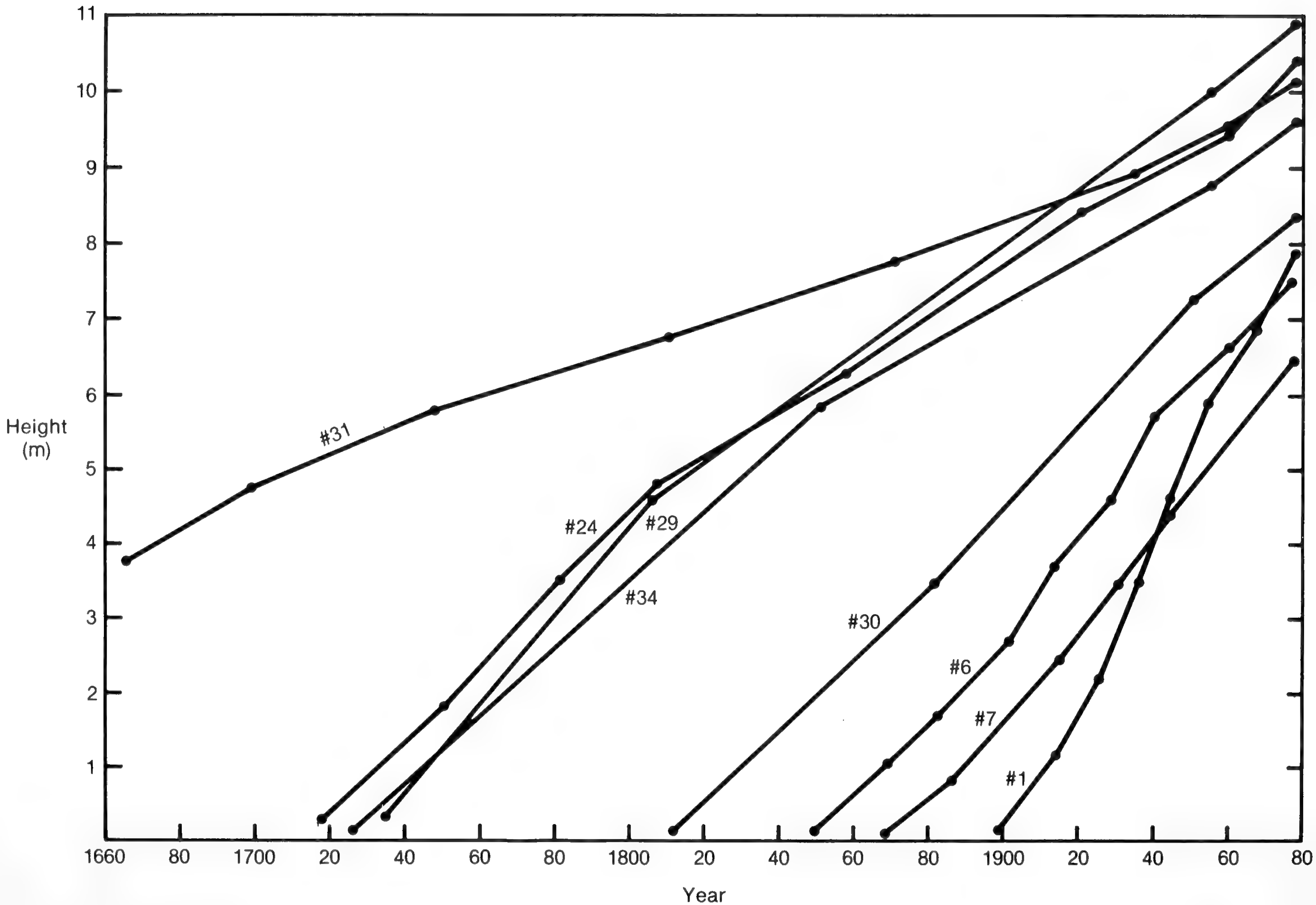

Figure 6.--Heights of eight dominant and codominant pinyons on the Monte Cristo plot from 1660 to 1977.

Height growth rates vary considerably among dominants on the same plot, especially on the Monte Cristo plot. The younger dominants are growing faster than the older trees are growing now or grew at the same age. It is probable that these faster-growing trees are genetically superior, but where are their parents? Pinyons taller than 12 m are rare in the study area and in most other pinyon-juniper stands in the Great Basin. A plausible explanation of this anomaly is that faster-growing trees were present in the stands but were logged off in the 19th century, leaving the shorter (slower-growing) trees that are now the oldest trees in the stand.

Diameter

Stump diameters of several dominants and codominants on each of the three plots are plotted through time in figures 7, 8, and 9. The diameters were calculated at 10-year intervals through 1960 and then at 5-year intervals until 1975. The Cattle Trough plot (fig. 8) has the expected S-curves: diameter growth increased initially and then decreased as competition among trees increased. Trees #31 and #32 on this plot provide a good example of the effects of competition. These trees are close together (fig. 2) and obviously in competition. As these trees developed and competition between them increased, diameter growth of both decreased but the reduction was greater in the younger, smaller tree (#31). The competition had no apparent effect on height growth rates of either tree (fig. 5).

In contrast to the Cattle Trough plot, none of the dominants and few of the codominants on the other two plots have S-shaped curves (figs. 7 and 9). The diameter growth rates of most of these trees have remained essentially constant from the time they attained a diameter of about 10 cm up to the time they were felled and measured. In general, the larger trees on these two plots are not competing with each other but with smaller trees. In the absence of appreciable competition, there appears to be no diminution of diameter growth regardless of tree size or age. The older trees on the Monte Cristo plot demonstrate this point. Tree #34 is suffering from competition with trees #29 and #31, but trees #24, #29 and #31 have essentially straight-line diameter growth (fig. 9).

Tree #31 on the Monte Cristo plot is a special case that requires further explanation. Unfortunately, the butt of this old tree was badly rotted and it was necessary to extrapolate the radial growth pattern of a section 2 m high on the dominant stem to calculate past diameters at stump height. Thus, the past diameters plotted for this tree are based on the assumption that the ratio of radial growth at 15 cm to radial growth at 2 m is constant. In any case, diameter growth of this tree has been essentially constant for more than three centuries.

Reveal (1944), reporting on a study in the nearby Pine Nut Range, stated: "Diameter growth (of pinyon) is maintained at approximately one inch per decade for the first 100 years. As maturity advances, the diameter growth decreases to 0.25 inch at the end of the second century. The life span is seldom over 250 years."

The results from the Sweetwater Mountains indicate that average diameter growth of pinyons is roughly 1 in (25 mm) per decade but that competition, not age, is the primary cause of reduction in diameter growth. These results also suggest that the natural life span of singleleaf pinyon can be well over 250 years.

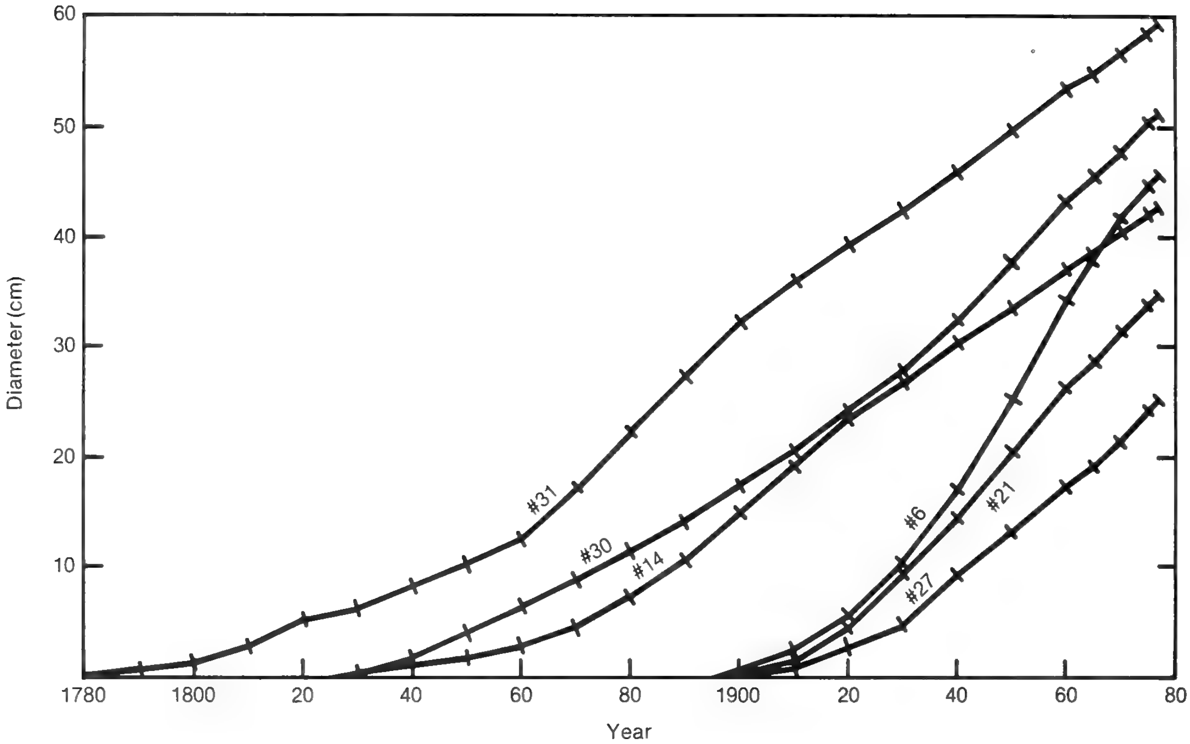

Figure 7.--Stump diameters (outside bark) of six dominant and codominant pinyons on the Green Creek plot from 1780 to 1977.

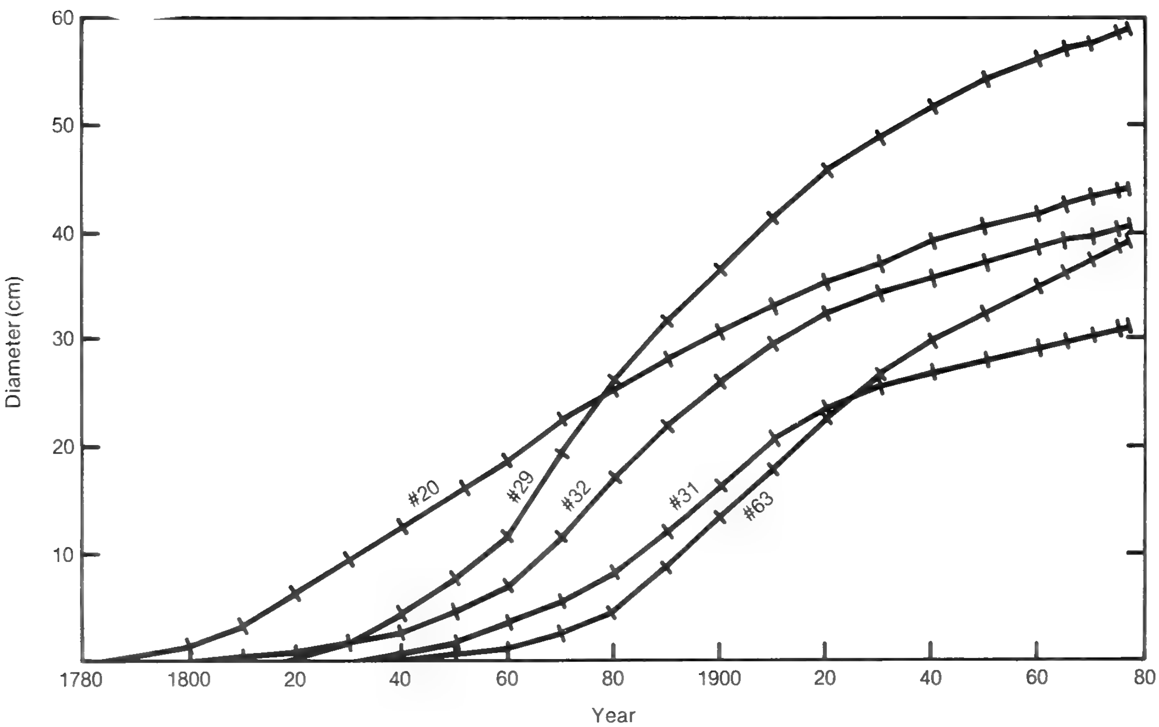

Figure 8.--Stump diameters (outside bark) of five dominant and codominant pinyons on the Cattle Trough plot from 1780 to 1977.

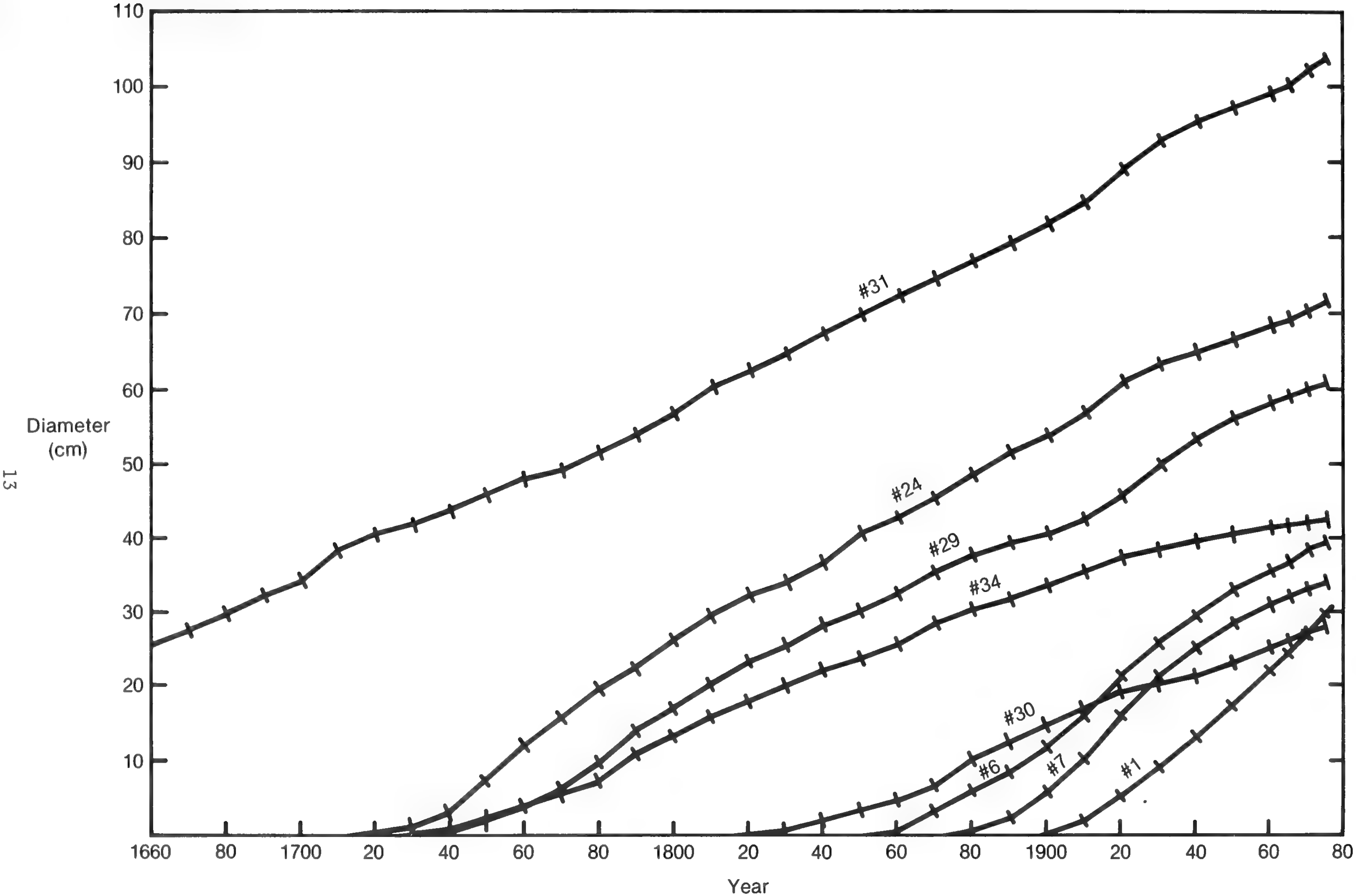

Figure 9.--Stump diameters (outside bark) of eight dominant and codominant pinyons on the Monte Cristo plot from 1660 to 1977

Stand Basal Area

Patterns of stand basal area increase are similar on all three plots (fig. 10). Stand basal area growth rate gradually increases until the trees achieve virtually complete dominance and then the rate of increase becomes constant. When the rate becomes constant, the understory is reduced to a few plants that have negligible competitive effects on the trees, and the stand can be considered closed. The constant rate of basal area growth of closed stands is probably closely linked with site potential. The growth rates prior to stand closure depend on density of trees and size distribution as well as site potential.

Obviously, there must be an upper limit on stand basal area and the rate of stand basal area growth must decrease as this limit is approached. However, there is no indication of such a decrease on these three plots. A slight decline in growth rate from 1975 to 1977 can be discerned in figure 10 and in some other figures, but this apparent decline is attributed to unusually dry conditions during this period and to the fact that the trees were cut and measured before they had completed their 1977 growth.

Pinyon trees grow so slowly that several centuries may be required to reach the upper limit on stand basal area. Few pinyon-juniper stands in the Great Basin are old enough to be approaching this limit.

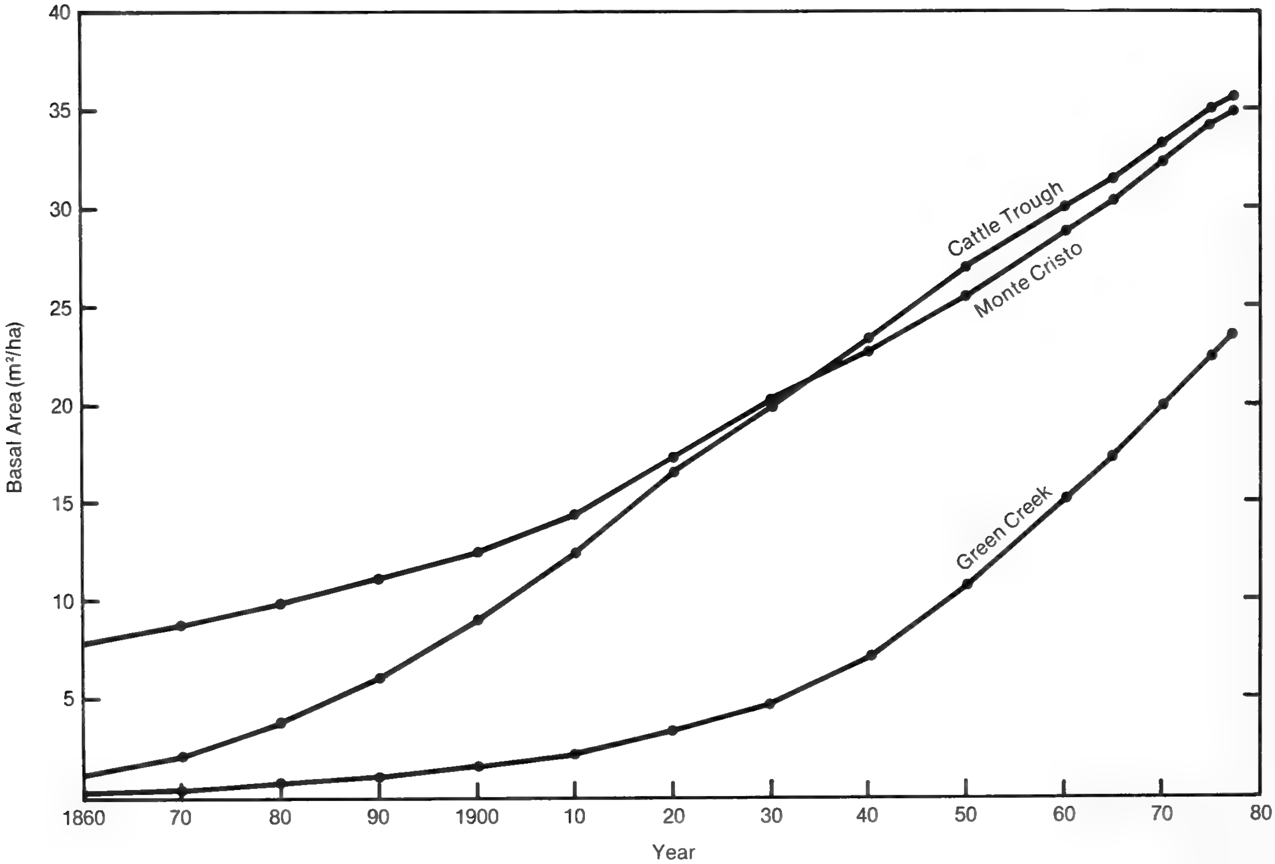

Figure 10.--Stand basal area on each of the plots from 1860 to 1977.

Biomass

Biomass components (foliage, wood larger than 76 mm diameter, and total above-ground biomass) of all trees taller than 1 m are tabulated in appendix III. Past values of these biomass components were calculated for all trees, using the regression equations in appendix II. The results of these calculations for the largest tree on each of the three plots are portrayed in figures 11, 12, and 13.

Tree #31 on the Green Creek plot (fig. 11), despite its small size in 1860, was about 78 years old at the time. Apparently, it had been suppressed, perhaps by a stand of trees that were removed about that time. If so, it responded favorably to release.

Tree #29 on the Cattle Trough plot (fig. 12) was about 40 years old in 1860 and showed no evidence of overstory suppression or competition until about 1920 when its growth rate began to decline. Unlike tree #31 at Green Creek, tree #29's foliage biomass has remained nearly constant during the past 40 years.

One of the interesting things about tree #31 on the Monte Cristo plot (fig. 13) is its lack of senescence. Its rates of diameter and height growth have not changed appreciably over the past 300 years. Up until the time the tree was measured, its rate of biomass accumulation still tended to increase somewhat, even though it was more than 400 years old.

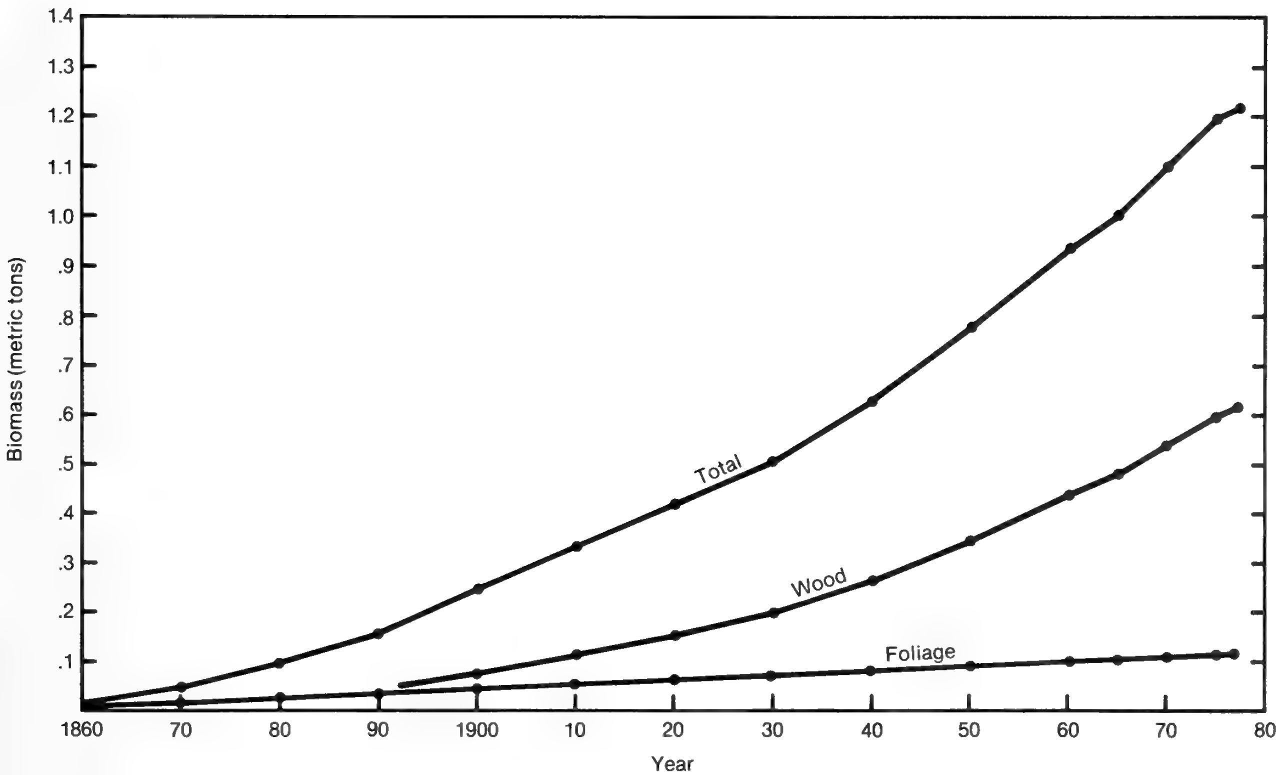

Figure 11.--Foliage, wood, and total above-stump biomasses of tree #31 on the Green Creek plot from 1860 to 1977. Foliage biomass is the ovendry mass of needles. Wood biomass is the ovendry mass of wood (bark excluded) larger than 76 mm diameter.

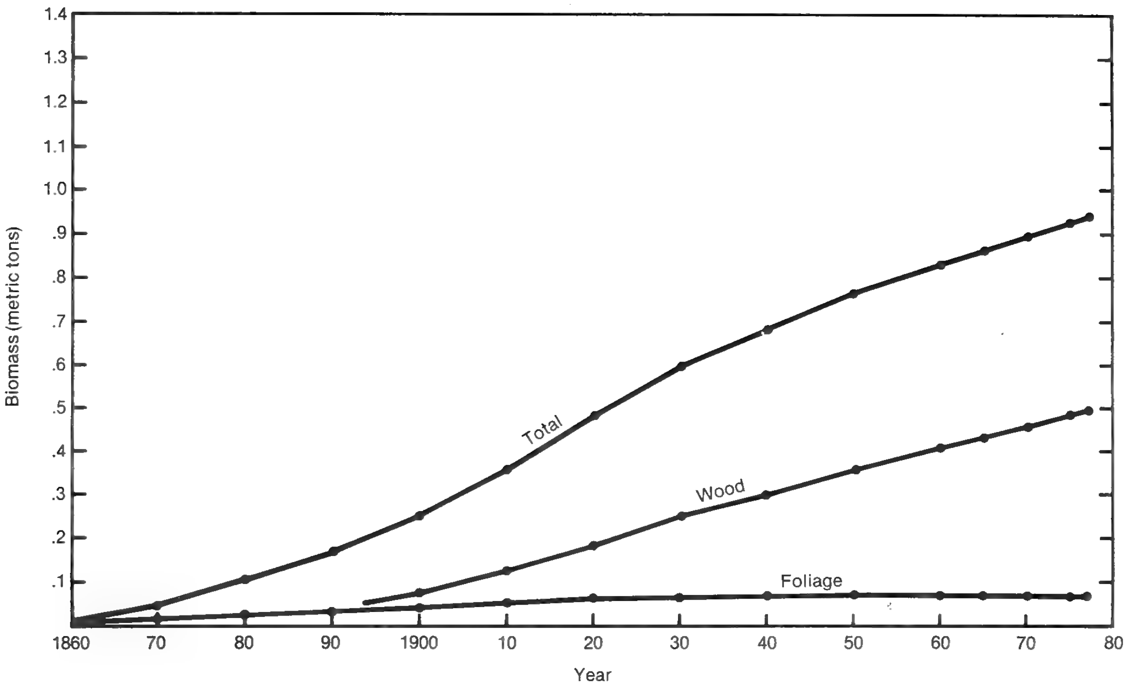

Figure 12.--Foliage, wood, and total above-stump biomasses of tree #29 on the Cattle Trough plot from 1860 to 1977. Foliage biomass is the ovendry mass of needles. Wood biomass is the ovendry mass of wood (bark excluded) larger than 76 mm diameter.

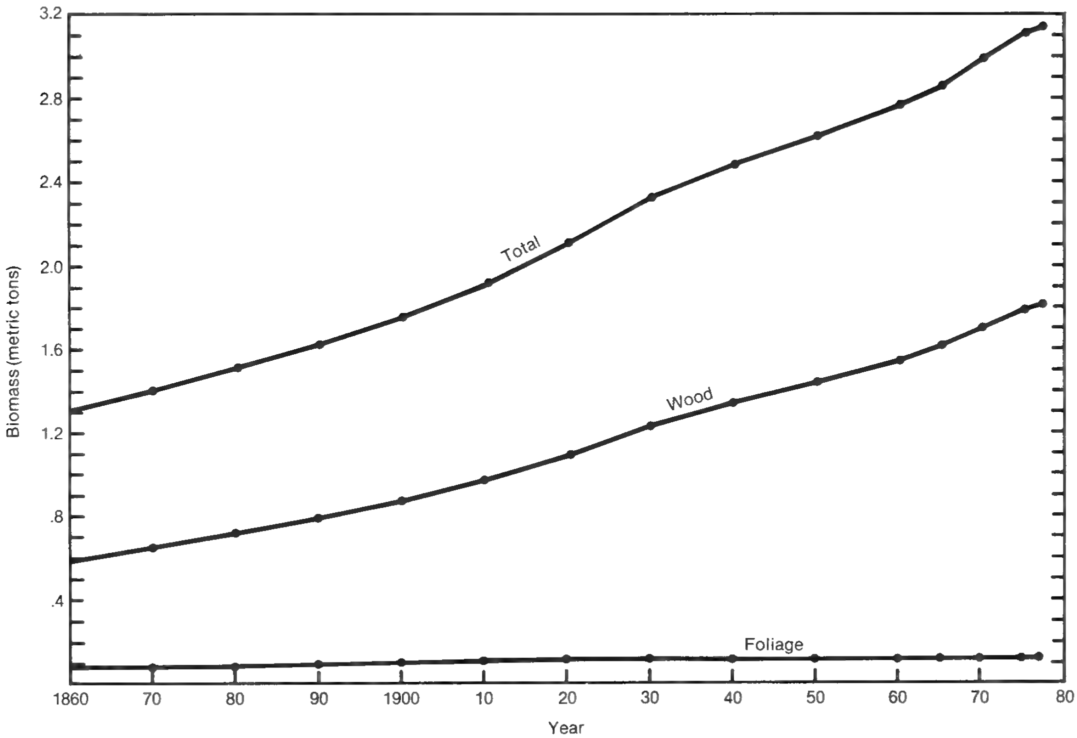

Figure 13.--Foliage, wood, and total above-stump biomasses of tree #31 on the Monte Cristo plot from 1860 to 1977. Foliage biomass is the ovendry mass of needles. Wood biomass is the ovendry mass of wood (bark excluded) larger than 76 mm diameter. This tree was estimated to be 433 years old in 1977.

On a stand basis, biomass growth follows trends similar to those of the individual large trees (figs. 14, 15, and 16). On the Green Creek plot (fig. 14), growth rates of all three components--foliage, wood, and total--continued to increase until 1975. As mentioned earlier, the slight decline in growth rates from 1975 to 1977 was probably due to the combined effects of the drought during that period and the measurement of the trees before current season growth was completed; the decline does not necessarily indicate a change in trend of growth rates.

In contrast, rates of biomass increment on the Cattle Trough plot (fig. 15) have been essentially constant since about 1920. The growth pattern on the Monte Cristo plot (fig. 16) is intermediate between the other two plots, although biomasses are greater. Growth rates at Monte Cristo were essentially constant from 1910 to 1950, but growth rates tended to increase from 1950 to the time the plot was measured.

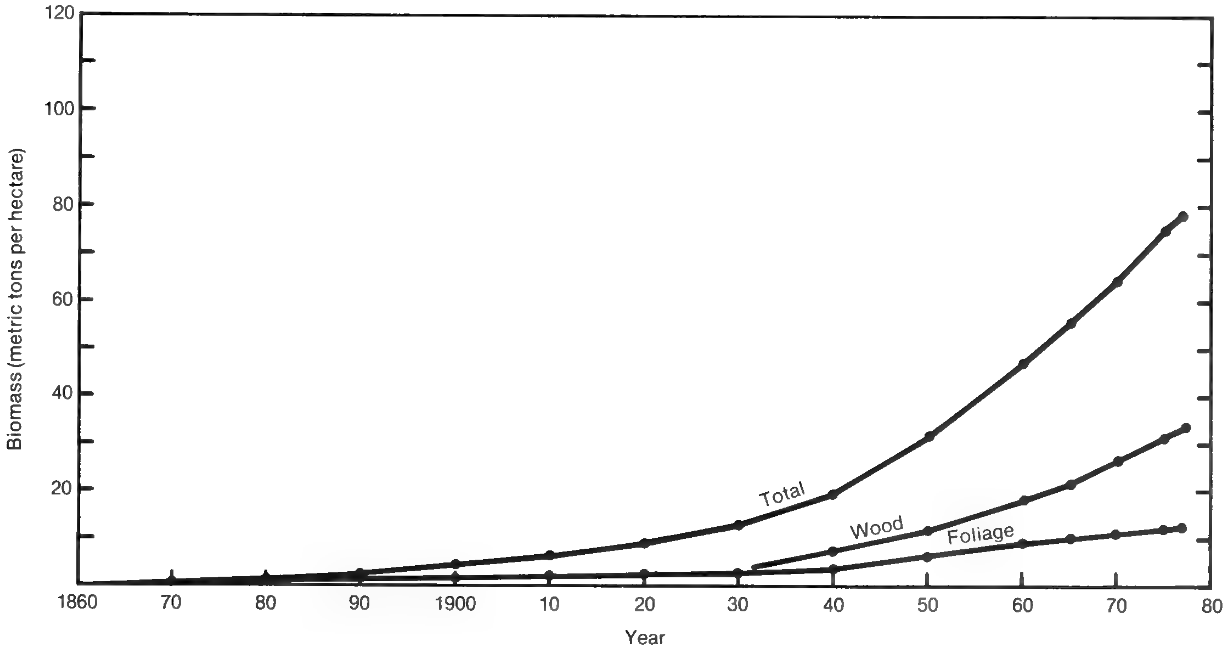

Figure 14.--Foliage, wood, and above-stump biomasses in metric tons per hectare on the Green Creek plot from 1860 to 1977.

The differences in growth patterns among these plots were caused mainly by differences in tree density and age structure. The Green Creek plot had a young stand, only five trees in the plot were more than 100 years old (table 2). The Cattle Trough plot had a dense stand essentially 80 years more advanced than Green Creek; 43 trees on this plot were more than 100 years old. The Monte Cristo plot had the greatest diversity of ages but, unlike Cattle Trough, the density was not great and many of the younger trees were not subject to competition from the older trees.

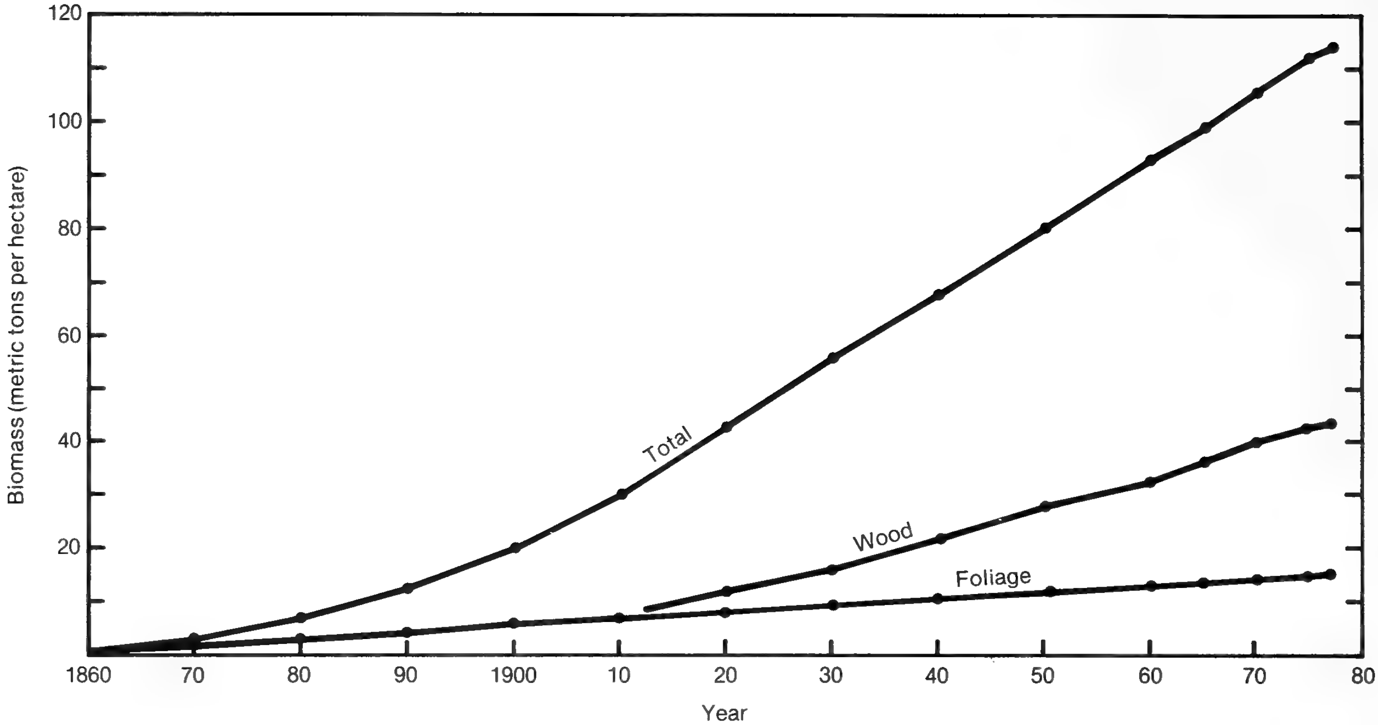

Figure 15.--Foliage, wood, and total above-stump biomasses in metric tons per hectare on the Cattle Trough plot from 1860 to 1977.

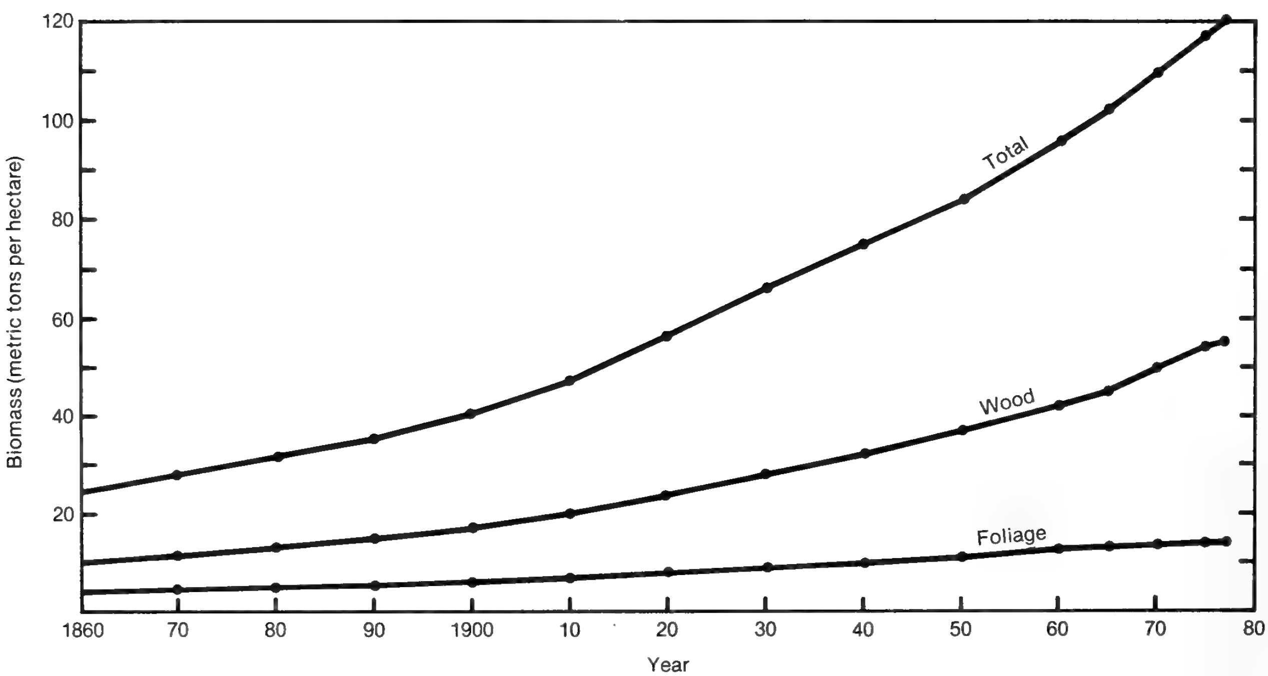

Figure 16.--Foliage, wood, and total above-stump biomasses in metric tons per hectare on the Monte Cristo plot from 1860 to 1977.

CONCLUSIONS

Since the data were obtained on only three plots in a single area and do not include juniper, the results obtained in the Sweetwater area may not apply to pinyon-juniper stands throughout the Great Basin. Pinyon-juniper stands in central and eastern Nevada will be examined in a similar manner to broaden the data base and extend the area of applicability. However, the Sweetwater results suggest a number of characteristics of singleleaf pinyon trees and stands that may be common throughout the range of this species with or without juniper association. These characteristics are as follows:

1. Height growth of dominants and codominants appears to be little affected by age or competition. Height growth rates of dominants and codominants generally remained constant during most of their lives; the only trees that were found to be approaching culmination of height growth were those trees that were severely suppressed.

2. Height growth rates can vary significantly among dominants on the same plot. Differences in height growth of dominants may be due to genetic variation. These differences appear to be linked to growth form; height growth is generally slower in trees that have a shrubby form and multiple leaders.

3. Diameter growth rate is regulated by competition rather than by age.

4. The rate of increase of stand basal area becomes relatively constant when the trees dominate the site. The rate of basal area increase of closed stands may be an accurate index of site potential, providing the stand is not decadent. Truly decadent stands are probably very rare in the pinyon-juniper type.

5. The increase in total above-ground biomass approaches a constant rate after the trees fully dominate the site. Eventually the rate of biomass increment must decrease but there was no indication of an impending decrease on the three plots in the Sweetwater study area. The rate was still increasing on two of the plots. Pinyon trees grow so slowly that maximum biomass may not be attained for several centuries. The data suggest that growth rate is essentially constant until the maximum biomass is approached.

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APPENDIX I — Regression Equations for Present Biomass

The following logarithmic equations were used to estimate foliage, wood, and total above-stump biomasses of all unweighed trees taller than 1 m on the Sweetwater plots:

$$(\ln F) = .486\ (\ln D) + .470\ (\ln H) + 1.287\ (\ln C) + .396\ (\ln K) - 5.504 \qquad \text{(eq. 3)}$$

$$(\ln W) = 3.167\ (\ln D) + 2.827\ (\ln H) - .408\ (\ln D) \cdot (\ln H) + .120\ (\ln D) \cdot (\ln C_x) - 14.141 \qquad \text{(eq. 4)}$$

$$(\ln M) = 2.416\ (\ln D) + .463\ (\ln H) + 1.776\ (\ln C_x) - .243\ (\ln D) \cdot (\ln C_x) - 8.429 \qquad \text{(eq. 5)}$$

in which:

F = foliage biomass = ovendry mass of foliage (kg)
W = wood biomass = ovendry mass of wood (bark excluded) larger than 76 mm diameter (kg)
M = total above-stump biomass = total ovendry mass above a 15 cm stump (kg)
D = diameter of outside bark at stump height (cm)
H = total height of tree (dm)
C_x = maximum crown diameter (dm)
C = average crown diameter (dm)--the geometric mean of the maximum crown diameter and the crown diameter perpendicular to the maximum.
K = foliage class as defined in the methods section.

The coefficients of determination (R^2) are 0.936 for foliage, (eq. 3), 0.991 for wood (eq. 4), and 0.988 for total (eq. 5). The standard errors of estimate are 0.267, 0.163, and 0.148, respectively.

APPENDIX II — Regression Equations for Past Biomass

Diameter, height, and age can be used to estimate past biomass because they can be determined accurately for any time in the past. Crown parameters cannot be used as they were for present biomass, because their past values cannot be estimated accurately. The following equations were developed to estimate past biomass:

$$(\ln F) = 2.229\ (\ln D) + 1.027\ (\ln H) - .201\ (\ln H) \cdot (\ln T) - 4.406 \qquad \text{(eq. 6)}$$

$$(\ln W) = 3.394\ (\ln D) + 2.433\ (\ln H) - .278\ (\ln D) \cdot (\ln H) - 13.521 \qquad \text{(eq. 7)}$$

$$(\ln M) = 2.695\ (\ln D) + .670\ (\ln H) - .0806\ (\ln D) \cdot (\ln H) - 5.258 \qquad \text{(eq. 8)}$$

The symbols are as defined in appendix I except for the introduction of T, the age (years) of the tree at stump height, in equation 6. The coefficients of determination (R^2), are 0.891 for foliage (eq. 6), 0.990 for wood (eq. 7), and 0.978 for total (eq. 8). The standard errors of estimate are 0.342, 0.173, and 0.205, respectively, and are substantially greater than their counterparts in appendix I.

The last term (the intercept) in the equations was not used in the calculation of past biomass. A new intercept was calculated for each equation and each tree such that biomass calculated for 1977 equals the measured biomass of weighed trees or the estimated biomass of unweighed trees as calculated by the equations in appendix I. For the foliage equation, for example, the proper intercept term (I) was calculated by:

$$I = (\ln F) - 2.229\ (\ln D) - 1.027\ (\ln H) + .201\ (\ln H) \cdot (\ln T) \qquad \text{(eq. 9)}$$

in which D, H, and T are 1977 values for diameter, height, and age of a particular tree; and F is foliage biomass, either weighed or calculated by eq. 3.

APPENDIX III — Tree Data

The measured and calculated data for the trees taller than 1 m on the three plots are in tables 3, 4, and 5. Diameter was measured by diameter tape outside bark at stump height (15 cm). The second column under crown diameter (min) is crown diameter perpendicular to maximum crown diameter. Age is total age, estimated by extrapolating the height-age curves to the ground surface. The biomasses in the next three columns were measured directly for the weighed trees. The regression equations in appendix I were used to calculate the biomasses of unweighed trees. A zero in these columns indicates a measured or calculated mass less than 0.5 kg. The last column is decadal diameter growth (bark included) for the years 1966 through 1975.

Table 3.--*Dimensions, foliage classes, ages, biomasses, and diameter growth rates of pinyons on the Green Creek plot*

Tree number	Stump diameter	Height	Crown diameter Max.	Crown diameter Min.	Foliage class[1]	Age	Biomass Foliage	Biomass Wood	Biomass Total	Diameter growth
	cm	*dm*	*dm*			*years*	*kg*			*mm/10 yrs*
1	18	30	24	20	2	64	6	6	34	41
2	21	60	48	32	3	64	21	30	125	34
3	22	59	41	27	3	65	17	30	113	34
4	24	52	40	30	3	69	18	29	119	27
5[2]	6	21	16	14	2	57	1	0	3	20
6	46	72	60	38	5	82	54	193	523	66
7	17	67	40	30	3	65	17	22	79	27
8	21	60	38	35	5	69	24	27	98	30
9	11	39	14	10	2	63	2	3	9	23
10	5	18	14	10	2	83	1	0	2	5
11	29	74	63	40	5	86	46	85	288	38
12	34	69	58	50	5	87	53	101	324	36
13	26	54	40	38	6	69	29	36	137	40
14	42	74	58	49	5	150	60	165	452	35
15	14	42	23	21	2	84	6	6	25	27
16	33	76	50	42	4	92	41	102	283	29
17	46	79	84	82	6	115	122	253	726	38
18	21	63	21	20	2	81	8	24	54	20
19	5	30	5	5	1	62	0	0	0	6
20	22	62	38	34	4	78	22	32	107	59
21[2]	34	69	54	50	6	79	78	126	399	51
22	14	20	20	16	3	39	4	1	15	32
23	29	53	37	34	5	72	25	42	148	43
24	16	30	28	24	2	66	7	5	34	31
25[2]	14	42	27	17	5	60	4	6	24	38
26	27	62	47	30	3	78	23	51	180	44
27[2]	25	72	55	32	2	75	35	46	170	50
28	24	61	35	30	4	95	20	35	112	46
29	39	70	64	55	5	142	64	139	432	44
30	51	86	75	70	6	147	112	324	790	50
31[2]	59	96	93	66	3	195	119	615	1,212	37
32[2]	15	32	21	17	5	81	5	3	20	23
33	4	11	10	8	2	40	0	0	0	16
34	23	40	20	7	2	62	3	14	49	47
35[2]	14	34	20	19	3	74	4	3	17	41

[1]Foliage class estimated on a scale of 1 to 9; 1 = very sparse foliage, 9 = dense foliage on all sides.

[2]Indicates trees that were actually weighed.

Table 4.--*Dimensions, foliage classes, ages, biomasses, and diameter growth rates of pinyons on the Cattle Trough plot*

Tree number	Stump diameter	Height	Crown diameter Max.	Crown diameter Min.	Foliage class[1]	Age	Biomass Foliage	Biomass Wood	Biomass Total	Diameter growth
	cm	*dm*	*dm*			*years*	*kg*			*mm/10 yrs*
1	24	52	30	15	2	107	8	26	89	16
2	4	11	9	9	2	50	0	0	1	4
3	11	30	23	22	4	86	6	2	15	21
4	42	78	61	50	5	177	64	181	484	26
5	25	86	36	20	3	177	17	65	144	10
6	22	78	41	25	4	141	21	46	129	11
7	20	15	25	19	4	148	6	2	31	3
8	24	56	32	30	3	153	16	30	98	21
9	6	13	10	6	2	80	1	0	1	6
10	26	60	49	40	5	118	34	46	175	32
11	38	84	60	43	5	129	57	165	428	21
12	43	85	78	48	5	165	77	236	643	12
13	3	10	5	4	1	78	0	0	0	3
14	26	93	30	18	4	138	17	73	132	14
15	31	71	70	42	5	147	52	95	343	13
16	25	68	43	37	6	130	33	49	154	19
17	22	73	34	21	4	147	16	39	103	12
18	22	69	23	20	3	171	11	31	67	4
19	20	52	31	23	4	163	13	18	69	11
20	44	94	50	48	5	191	61	230	475	15
21	11	22	27	20	4	73	6	1	15	20
22	20	46	20	18	4	111	8	13	41	26
23	12	43	16	14	3	80	4	4	13	19
24	22	57	31	23	4	107	15	26	84	18
25	22	52	34	32	5	139	20	23	88	12
26	35	87	51	38	5	170	46	139	334	8
27	13	46	21	17	4	81	7	6	21	19
28	40	64	81	62	7	148	90	144	529	7
29[2]	59	97	69	60	7	158	73	500	947	17
30	22	54	35	23	4	151	15	25	92	6
31[2]	**31**	92	25	23	3	146	15	96	192	11
32[2]	40	102	41	34	4	168	29	259	496	11
33	30	66	43	39	4	169	31	66	200	11
34	38	71	47	43	6	164	48	118	319	16
35	10	30	16	9	3	110	2	1	8	2
36	32	56	36	32	5	82	26	55	173	29
37	5	32	11	6	3	67	1	0	1	15
38	5	22	9	9	3	55	1	0	1	7
39	18	55	34	28	5	73	17	17	66	30
40	31	66	56	55	5	154	51	78	269	7
41	35	85	52	45	4	143	47	135	336	13
42[2]	9	36	18	11	3	115	2	1	9	8
43[2]	19	78	30	22	3	154	6	35	78	13
44	30	88	46	41	5	152	42	102	243	7
45	26	88	45	36	3	151	29	78	192	9
46	6	27	5	5	4	114	1	0	1	16
47	32	87	56	55	4	166	55	122	320	13
48	18	52	26	23	5	76	12	14	48	28
49	9	12	6	5	2	79	1	1	3	10
50	8	29	18	13	3	68	3	1	6	23
51	9	45	10	7	4	84	22	2	4	16
52	29	84	40	38	5	104	35	85	198	24
53	10	35	22	21	5	71	7	2	13	22
54	16	33	29	26	4	86	10	5	36	12
55	19	64	27	23	3	102	12	22	60	26
56	5	21	10	10	4	69	1	0	1	12
57	18	67	24	20	4	102	11	21	50	27
58	24	30	41	25	4	133	21	46	140	14
59[2]	2	13	7	6	2	56	0	0	0	6
60	12	43	22	17	4	91	6	4	19	26
61	29	92	53	32	4	136	36	108	270	14
62	27	78	29	21	3	149	15	59	125	8
63	39	96	74	45	5	134	72	226	569	26
64	3	11	6	5	6	48	0	0	0	14

[1]Foliage class estimated on a scale of 1 to 9; 1 = very sparse foliage, 9 = dense foliage on all sides.
[2]Indicates trees that were actually weighed.

Table 5.--*Dimensions, foliage classes, ages, biomasses, and diameter growth rates of pinyons on the Monte Cristo plot*

Tree number	Stump diameter	Height	Crown diameter Max.	Crown diameter Min.	Foliage class[1]	Age	Biomass Foliage	Biomass Wood	Biomass Total	Diameter growth
	cm	*dm*	*dm*			*years*	*kg*			*mm/10 yrs*
1[2]	32	79	47	36	5	78	43	81	238	59
2	26	66	45	36	5	100	31	51	168	25
3[2]	12	42	21	19	3	75	8	5	23	32
4	41	74	61	49	6	125	66	162	456	21
5[2]	6	24	16	10	3	48	1	0	3	21
6[2]	40	75	56	39	3	128	42	160	367	19
7[2]	35	64	45	34	3	109	27	76	225	21
8	27	52	35	34	2	86	16	35	125	36
9	18	64	27	22	5	78	14	20	55	37
10	29	72	62	40	5	78	45	81	280	32
11	28	57	56	32	4	101	30	52	217	22
12	18	41	19	10	1	78	3	9	31	12
13	10	39	18	15	3	4	4	2	10	19
14[2]	6	21	14	12	3	64	1	0	3	20
15[2]	22	62	35	27	3	112	9	31	82	22
16	26	61	40	36	3	85	23	43	145	27
17	7	26	20	8	2	76	2	1	5	21
18	24	55	45	35	6	80	29	33	137	41
19	22	61	42	25	5	108	21	31	112	16
20	16	38	20	12	4	69	5	6	26	25
21	10	23	15	10	3	62	2	1	7	18
22	37	77	65	55	5	140	66	144	426	24
23	9	34	14	13	3	76	3	1	6	15
24[2]	72	104	112	79	3	259	140	840	1,636	25
25	9	34	14	10	4	71	3	1	6	15
26	28	68	35	26	3	159	19	55	150	9
27	44	64	58	50	4	160	53	150	452	14
28	9	28	24	15	3	74	4	1	11	21
29	61	109	92	88	7	242	193	657	1,319	20
30	28	83	40	35	6	165	35	78	187	17
31[2]	104	101	129	114	1	433	136	1,821	3,137	33
32	24	41	36	32	6	70	21	19	96	41
33	21	57	30	25	5	94	16	23	75	28
34	43	96	72	48	3	251	158	267	635	9

[1]Foliage class estimated on a scale of 1 to 9; 1 = very sparse foliage, 9 = dense foliage on all sides.
[2]Indicates trees that were actually weighed.

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Meeuwig, Richard O., and Jerry D. Budy.
1979. Pinyon growth characteristics in the Sweetwater Mountains. USDA For. Serv. Res. Pap. INT-227, 26 p. Intermt. For. and Range Exp. Stn., Ogden, Utah 84401.

Stem analyses of singleleaf pinyon (Pinus monophylla) indicate that height growth rates vary considerably among dominants on the same site but that the rate of height growth of each tree tends to be constant throughout most of its life, regardless of age or competition. Radial growth rates are sensitive to competition but appear to be unaffected by age. Stand basal area increment and biomass accumulation rates tend to be constant in fully-stocked stands.

KEYWORDS: singleleaf pinyon, biomass, Pinus monophylla, silvics

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Headquarters for the Intermountain Forest and Range Experiment Station are in Ogden, Utah. Field programs and research work units are maintained in:

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