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SEASONAL DISTRIBUTION AND HABITAT USE BY SITKA BLACK-TAILED DEER IN SOUTHEASTERN ALASKA

By

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Progress Report
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PROGRESS REPORT (RESEARCH)

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Period Covered: 1 July 1983-30 June 1984

SUMMARY

Relationships between snow depth and overstory characteristics were studied on 19 0.4 ha old-growth plots and 1 60-year-old 2nd-growth plot near Juneau during winter 1983-84. Overstory characteristics were measured using variable plot and point-centered quarter techniques, and included: mean tree diameter at breast height, number of stems per hectare, percent Sitka spruce (*Picea sitchensis*), mean tree height, percent defect, basal area, and net timber volume. Canopy cover was measured from photographs of the overstory taken at each snow measurement point.

Snow depth in a high-volume stand monitored daily throughout the study period averaged 29% of that in an adjacent forest opening. All overstory parameters were negatively correlated with snow depth, and were highly correlated with each other. Snow depth was most highly correlated with mean net inventory volume ($r = -0.90$), followed by tree height ($r = -0.85$), basal area ($r = -0.79$), percent canopy cover($r = -0.76$), percentage spruce ($r = -0.66$), and mean tree diameter ($r = -0.65$). Old-growth plots with high overstory biomass (e.g., greater than 170 m^3/ha) had the lowest snow depths. The low snow depths observed in high-volume, old-growth stands are attributed to the large-diameter limbs and deep crowns of older, dominant trees.

Topographic factors being equal, sites characterized by high-volume stands of old-growth, hemlock (*Tsuga heterophylla*)-spruce forest provide superior habitat for Sitka black-tailed deer (*Odocoileus hemionus sitkensis*) during periods of high snowfall. Large, dominant trees characteristic of old growth appear better able to intercept snow than younger, even-aged, 2nd-growth trees and provide deer access to some forage even under deep snow conditions. Depletion of

high-volume, old-growth stands by logging in southeast Alaska will have adverse impacts on deer in areas subject to periodic, deep snowfall.

CONTENTS

BACKGROUND

Over the past decade, research on Sitka black-tailed deer and their habitat indicates that converting old-growth forests to even-aged, managed forests will result in decreased carrying capacity for deer. This reduction is generally attributable to a decrease in forage production, forage quality, and when snow is present, forage availability in even-aged, managed stands. This study provides data on snow-overstory interactions, and discusses the implications for the management of deer in southeast Alaska. Additional background and justification for this study were outlined previously by Schoen et al. (1979). The information contained in this report has been submitted to the Journal of Wildlife Management.

OBJECTIVES

To develop capture and telemetry techniques for Sitka black-tailed deer, and to evaluate seasonal distribution and preference within natural (unlogged) and modified (logged) habitats.

STUDY AREA

The study area has been previously described by Schoen et al. (1979).

EFFECTS OF FOREST COVER ON SNOW: IMPLICATIONS FOR DEER IN SOUTHEAST ALASKA

INTRODUCTION

Snow is an important component of the winter environment of Sitka black-tailed deer (*Odocoileus hemionus sitkensis*) in southeast Alaska. Because snowfall reduces the availability of forage and increases the energetic costs of locomotion, it strongly influences deer habitat selection and survival (Edwards 1956, Klein and Olson 1960, Jones 1975, Bunnell 1978, Harestad and Bunnell 1979, Parker 1983). Although the effects of forest cover on snow accumulation have been studied intensively in many diverse locations (see references in Harestad 1979, Shank and Bunnell 1982), relatively few studies have been conducted in uneven-aged, old-growth forests. Preliminary research in southeast Alaska indicates that snow is generally 2-4 times deeper in the open than beneath old-growth forest (Merriam 1971, Schoen and Wallmo 1979), yet we have little understanding of how structural characteristics of the overstory influence snow accumulation. Knowledge of the relationships among forest overstory characteristics and snow conditions on the ground will help in identification of important deer winter range, and may suggest silvicultural treatments needed to improve the snow interception qualities of even-aged, 2nd-growth stands.

METHODS

Twenty 0.4 ha sample plots were selected on a 2 km^2 study area on the Mendenhall Peninsula near Juneau in December 1983. Plots were subjectively selected to represent a wide range of western hemlock-Sitka spruce (*Tsuga heterophylla*-*Picea sitchensis*) forest types, ranging from unproductive, open-canopied stands, to tall, vigorous stands of high-volume timber. One plot was located in a 60-year-old 2nd-growth forest. All others were located in uneven-aged, old-growth forest (*en sensu*, Franklin et al. 1981, Schoen et al. 1981*a*).

Plot centers were located to ensure homogeneous vegetative and topographic conditions (Mueller-Dombois and Ellenberg 1974). Among-plot variability was maximized with respect to vegetative parameters (e.g., canopy, timber volume, basal area, etc.) and minimized with respect to topographic parameters (e.g., slope, aspect and elevation). Sites ranged from 170 to 260 degree exposure, 10-60 m elevation, and 0-15 degree slope. Total snowfall, as it might be measured above the influence of the forest canopy, was assumed constant throughout the relatively small study area. Differences in measured snow accumulation beneath the canopy, therefore, are presumably attributable to characteristics of the forest stands rather than incident snowfall.

From the center of each plot, 5 sample points were located using random distances measured along random azimuths. A 1.2 m stake, marked in 3.0 cm increments, was permanently set at each sample point. Stakes were also located in each of 3 openings, at the beginning, in the middle, and near the end of the transect route through the 20 plots. Size of the openings was relatively small (approximately 0.1 ha). All openings were on relatively flat terrain, with no overhanging shrubby vegetation to intercept or deflect snow.

Point-centered quarter sampling (Cottam and Curtis 1956) was used to determine mean tree diameter at breast height (dbh) and stem density (number per ha) on each plot. Variable plot sampling (Dilworth and Bell 1971) was used to determine percent spruce, mean tree height, percent defect, basal area, and net timber volume on each plot. At each sample point, a compass was used to delineate 4 quadrants bounded by N-S and E-W azimuths. Within each quadrant, the closest tree over 5 cm dbh (diameter at breast height) was identified and the species, distance to, and dbh of that tree was recorded. A relaskop with basal area factor 40 was used to select trees for additional measurement. The species, estimated defect (Farr et al. 1976), and total height of all such measurement trees were recorded. Height of 1 codominant tree was measured at each point using the relaskop, and the height of nearby "measurement" trees was estimated. Timber volume was computed from tables relating total tree height to timber volume for spruce and hemlock trees in coastal Alaska (U.S. Forest Service, 1979). The mean of measurements at the 5 sample points was used to characterize the vegetative characteristics of each plot.

To determine canopy cover, black and white photographs of the canopy were taken directly above each sample point from a height of 1.2 m using an 80 mm focal length lens. Because the projection angle of an 80 mm lens is small (about 8 degrees) compared to that of a spherical densiometer (90 degrees) (Lemmon 1956) or canopy camera (typically 15-90 degrees) (Brown 1962, Brown and Worley 1965), resultant canopy cover estimates should be relatively accurate (Bonner 1967). A 100-dot grid was superimposed on each 9 X 9 cm photograph, and the number of points that overlapped canopy was recorded.

Snow depth measurements were made on all 20 plots (100 points) 6 times between 29 December and 3 February; incomplete surveys (each 7 plots, 35 points) were conducted on 28 and 29 January. This sampling period encompassed the main period of snow accumulation and melt during the 1983-84 winter. In addition to periodic surveys, snow conditions on a single plot (No. 16) and a forest opening were monitored daily from 19 January through 3 February 1984.

Snow measurements were read directly from the permanently located stakes at each sample point. On occasion, snow was observed to have drifted against the stake, and following rainy or warm weather, snow was usually lower at the stake than several cm away. Such deviations were usually less than 2-3 cm and were compensated for visually when the stakes were read. Snow depth in the openings was recorded in the same manner. The average of these readings was used to represent snow depth in the open for the study area as a whole. Snow depth within any given plot was represented by the mean of the snow measurements at the 5 sample points.

The relative importance of individual variables was determined using nonparametric correlation analyses in favor of multiple regression. The latter approach was precluded by the high degree of intercorrelation among the independent variables (Nie et al. 1975). Regressions between snow depth and individual overstory variables were computed.

RESULTS

Eleven of 19 old-growth plots (58%) were located in high volume, commercially important forestland (over 170 m^3/ha [over 30,000 bf/acre]). The 60-year-old 2nd-growth plot (No. 17) had the highest number of stems/ha and the second lowest mean tree diameter of any plot. Plot 16, which was monitored daily, had the highest percent canopy cover (90%). Canopy cover for all plots averaged 72%, with most plots clumped at the high end of the range (75-90%). The forest characteristics of each study plot are summarized in Table 1.

The 1983-84 winter was relatively mild in Juneau, with a total snowfall (recorded at Juneau Airport, 2 km from the study area) of 166 cm compared with the 40-year mean of 219 cm (National Weather Service, Juneau, unpubl. data). Light snow which fell during the latter half of December had disappeared by 1 January. Measurable snowfall was next recorded on 18 January, followed by 8 consecutive days of generally heavy snow accumulation. Maximum snowpack, in the open, on our study area occurred on 22 and 25 January (53 cm). No measurable snowfall was recorded after 28 January. Subsequent heavy rains reduced the snowpack to zero in the forest, and in the open, by 1 February and 4 February respectively.

Snow accumulation on the plot monitored daily (No. 16) was at all times lower than snow depth in the open (Fig. 1). Plot 16 had the 3rd lowest mean snow accumulation (over the 6 complete snow measurement periods) of the 20 plots in our study area. With 1 exception, an increase or decrease in snow depth in the open was paralleled by a change in the forest; however, the relative magnitude of the change was much less beneath the forest canopy. Excluding the last 4 measurement points when snow beneath the canopy was nonexistent, the average snow depth in the open was 3.4 times greater than the snow depth beneath the canopy.

All overstory parameters were negatively correlated with mean snow depth, and were highly correlated with each other (Table 2). Mean snow depth was correlated most highly with net inventory volume, followed by mean tree height, basal area, percent canopy cover, percent spruce, and tree diameter. Scatterplots showing the degree of correlation between these overstory variables and mean snow depth are presented in Fig. 2-7. Regression equations for these variables are given in Table 3. A quadratic term significantly improved the regression fit in 1 instance (net inventory volume).

To assess the influence of time-specific environmental conditions (e.g., amount of snow, ambient air temperature, etc.) on forest/snow relationships, we examined scatterplots of snow depth as a function of individual forest characteristics for each of the 6 complete snow surveys. For example, Fig. 8 contrasts the relationship between net inventory volume and mean snow depth under low snow conditions (29 December) and following a rapid accumulation to maximum snow depth (22 January). Although the relative snow interception ability of individual stands shifted slightly under such contrasting snow conditions, we found no major departures from the general, over-winter relationships.

For each forest attribute, the snow depth in the single 2nd-growth plot is identified with a solid data point (Fig. 2-7). Second growth appears to accumulate more snow than would be expected in old-growth plots of comparable mean canopy cover, volume, basal area and tree height, but less snow than would be expected in old-growth plots with comparable mean tree diameter.

Coefficients of variation for snow depth measurements within each old-growth plot and the single 60-year-old 2nd-growth stand indicated the 2nd-growth plot had the least variable snow depths of the 20 plots sampled. Variability in the 2nd-growth plot was significantly lower (Mann-Whitney U-test, $P < 0.05$, $\underline{n}_1 = 6$, $\underline{n}_2 = 114$) when compared with old growth as a group.

DISCUSSION

Most investigations of snow/forest relationships agree that crown closure, or canopy cover, exerts a strong influence on snow depth (e.g., Kittridge 1953, Packer 1962, Jones 1975, Harestad and Bunnell 1981). Quantitative data on other less commonly measured parameters such as foliage area, canopy mass, and overstory structure, however, often constitute more meaningful predictors of snow throughfall (Miller 1964). In our study, canopy cover was significantly correlated with snow depth, yet 3 other forest parameters--net inventory volume, tree height and basal area, showed stronger correlations. Of these, net inventory volume appears to offer the single most useful predictor of snow throughfall in old-growth forest.

Unlike canopy cover, which is relatively difficult to quantify and subject to significant biases depending on the measurement technique used (Bonner 1967), net inventory volume is specifically defined and can be accurately and precisely measured (Bones 1968). Stand attributes such as tree height, percentage of spruce, dbh, and defect, all influence volume calculations and contribute to the high correlation between volume and snow depth. Net inventory volume is a widely used descriptor of stand condition (e.g., U.S. Forest Service 1978) and inventory information is currently available for all Tongass forestland (Timber-type maps, on file, U.S. Forest Service, Juneau).

Structural and compositional differences between low and high-volume old-growth stands are pronounced. Low-volume stands, commonly found on poorly drained organic soils, are characterized by a relatively open canopy, shorter, smaller-diameter trees (predominantly hemlock), and an understory dominated by shrubs (*Vaccinium spp.*, *Menziesia ferruginea*). In contrast, high-volume, hemlock-spruce, old-growth stands are dominated by tall, large-diameter trees, a multi-layered, relatively closed canopy, a higher proportion of spruce, and an understory with proportionally more forbs (e.g., *Cornus canadensis*, *Rubus pedatus*, *Tiarella trifoliata*) and fewer, shorter shrubs. High-volume stands are generally found at lower elevations (e.g., <200 m) on deep, well-drained, mineral soils (Stephens et al. 1969, Hutchison and Labau 1979). Crowns typically are deep and spreading on the older (over 300 years old) trees and branch diameters are large (Franklin et al. 1981). These structural characteristics infer an increased capacity to intercept and hold heavy snow loads (Miller 1964).

Snow held aloft in the canopy exposes increased surface area to precipitation, wind, and ambient air temperatures, resulting in increased rates of melting (Miller 1964, 1966). In southeast Alaska, where average winter temperatures are near freezing and winter rains not uncommon, snow melt rates in the canopy layer and on the ground may differ significantly. Also, when snowfall is wet, it tends to cling to the foliage and a greater proportion of total snowfall is intercepted (Miller 1964, Fitzharris 1975). For these reasons winter snowfall and temperature regimes typical of southeast Alaska may amplify differences in snow accumulation between forested and nonforested (or clearcut) areas.

It has been suggested that the function of the forest canopy in intercepting snow can vary depending on environmental conditions associated with individual snow events (e.g., amount of snow, rate of snowfall, snow density, wind speed, ambient temperature, etc.) (Miller 1964, Fitzharris 1975, Harestad and Bunnell 1979). Although we detected no major changes in snow/forest relationships under conditions sampled in this study, with more intensive sampling and given a broader range of snow conditions, we hypothesize real differences would become apparent. Such considerations are important if development of a quantitative, predictive relationship between snow and overstory characteristics is the primary objective. In a qualitative sense, however, the relationships documented in this study are probably valid for typical snow conditions in southeast Alaska.

In contrast to old growth, 2nd-growth stands are characterized by high stem density, even-aged trees, dense canopy cover, low light penetration, and little understory vegetation (Wallmo and Schoen 1980; Alaback 1982, 1984). The crown volume and limb diameter of individual 2nd-growth trees are small compared to dominant old-growth trees, and their ability to support heavy snow loads is correspondingly limited. The ability of 2nd-growth stands to effectively intercept snow probably increases with increasing stand age and mean tree size.

In this study, as well as in earlier studies (Schoen and Wallmo 1979, Wallmo and Schoen 1980), snow depth in old-growth stands is described as more variable than that in 2nd-growth. By virtue of the variable tree age, size, and spacing in an old-growth stand, individual trees will display differing capacities to hold snow aloft. In general, the amount of snow an individual tree can support is related to its crown strength and structure. Because under increasing snow conditions the strongest limbs shed their snow last, minimum mean depth and maximum variability of the forest snowpack is generally found beneath uneven-aged, old-growth stands having the largest trees.

Silvicultural treatments which promote an uneven height distribution, strong, broad crowns, and large lateral limb development should improve the snow interception ability of 2nd-growth. A consequence of thinning 2nd-growth stands will be increased snow accumulation, and a decline in winter habitat value over the short term. Over a long time period (e.g., >100 years), repeated thinning in managed stands may promote a multilayered canopy with large, dominant trees similar to old growth in function and appearance. Silvicultural treatments to improve snow interception capacity, therefore, should be directed at stands on productive sites which are scheduled for long (e.g., greater than 150-year) rotations.

Snow affects deer in 2 major ways: by limiting food supply, and by increasing the difficulty of locomotion (Bunnell 1978). In Alaska, at the northwestern extreme of the natural deer range (Wallmo 1981), the ability of the forest overstory to intercept snow becomes vitally important for deer survival. Snow accumulations of 5-10 cm on the forest floor can make much of the low-lying, herbaceous, evergreen vegetation unavailable. Evergreen forbs, a major component of Sitka black-tailed deer's diet (Schoen and Kirchhoff 1983, Hanley and McKendrick 1985), are high in energy, nitrogen, and digestibility (Hanley and McKendrick 1983). When herbaceous vegetation is unavailable due to deep snow, deer turn to woody browse (Schoen and Kirchhoff 1983, Hanley and McKendrick 1985). This forage is available when snow is deeper, but the nutritional quality is lower (Hanley and McKendrick 1983). In old growth, lichens are also regularly available via arboreal litterfall (Rochelle 1980).

High-volume, old-growth stands will accumulate less total snow, and become free of snow earlier than low-volume old-growth stands or small openings, given similar topographic conditions. Although the highest-quality forage (evergreen forbs) may be largely unavailable to deer in all stands in mid-winter, that forage is available for the greatest length of time in high-volume stands. This advantage may be significant, particularly in harsh winters when overwinter mortality in the deer population is high.

Winter track counts, pellet-group surveys, and radiotelemetry data show that high-volume, old-growth stands are heavily utilized by deer during periods of high snowfall (Bloom 1978, Barrett 1979, Schoen and Kirchhoff 1983). Winter use, however, is not restricted to high-volume stands. Deer maximize available food resources throughout the year by expanding their range when snow conditions permit (Schoen and Kirchhoff 1985). If deer are unable to leave high-volume winter range periodically because of adjacent clearcuts or unusually severe winters, forage depletion and excessive winter mortality may result (Schoen et al. 1981b, Schoen et al. 1984).

In southeast Alaska, high-volume old-growth stands are relatively scarce. Old-growth stands with greater than 285 m^3/ha (50,000 bf/acre) constitute less than 2% of the Tongass National Forest (U.S. Forest Service 1978). Historically, timber harvesting in southeast Alaska has concentrated in these low-elevation, high-volume, old-growth stands (Hutchison and LaBau 1975), and based on current scheduling, over half of the highest-volume-class stands (over 285 m^3/ha) remaining today will be harvested within 40 years (USDA Forest Service, unpubl. data). This level of harvest, concentrated in stands with high snow interception capabilities, will have adverse impacts on deer in areas subject to periodic, deep snowfall.

ACKNOWLEDGMENTS

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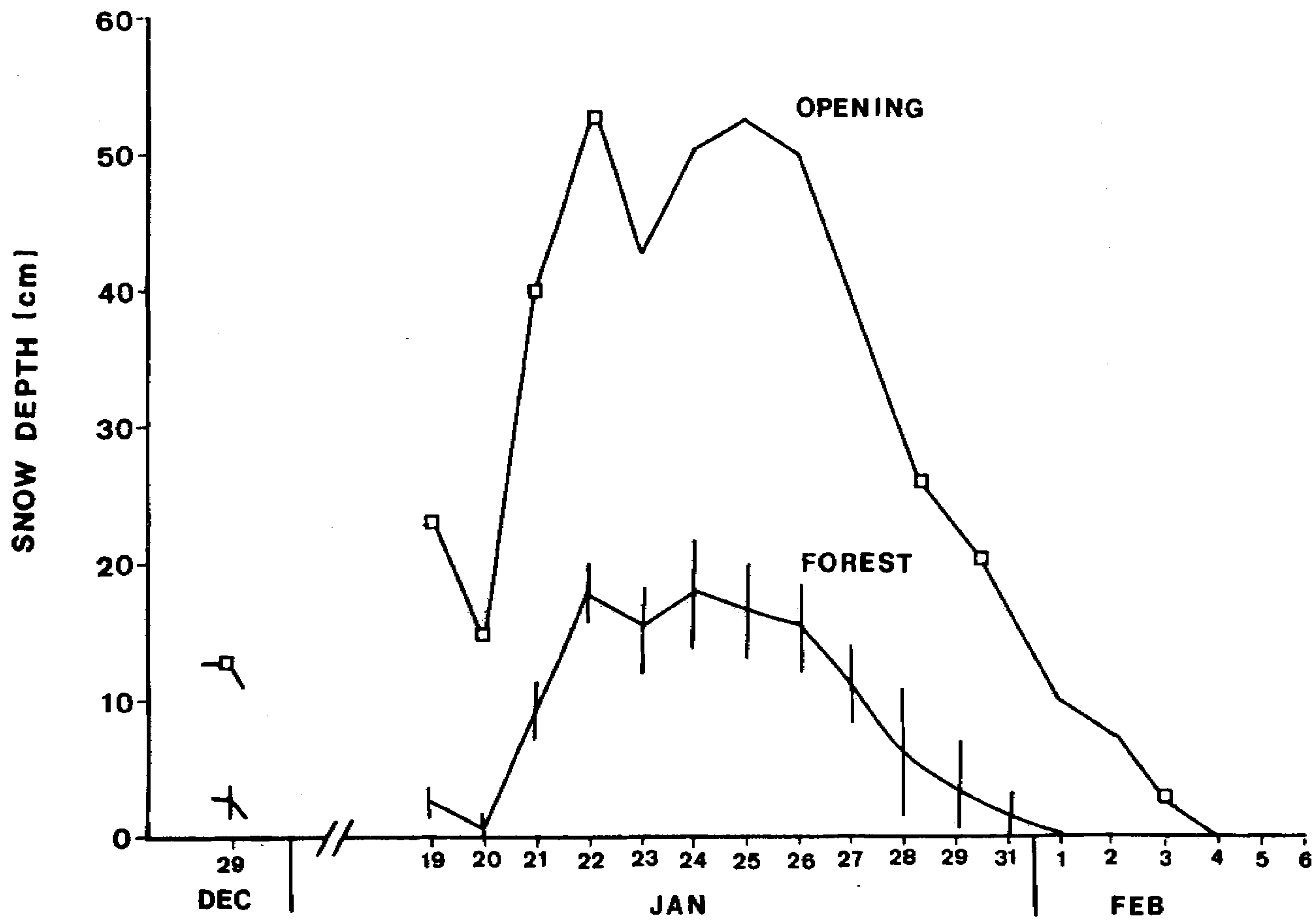

Fig. 1. Daily snow depth in an opening and beneath plot No. 16 from 29 December-3 February 1983-84, Juneau, Alaska. Boxes indicate complete surveys (all 20 plots, 100 points), except for 1/28 and 1/29 which were complete surveys (7 plots each). Vertical bars show standard deviation.

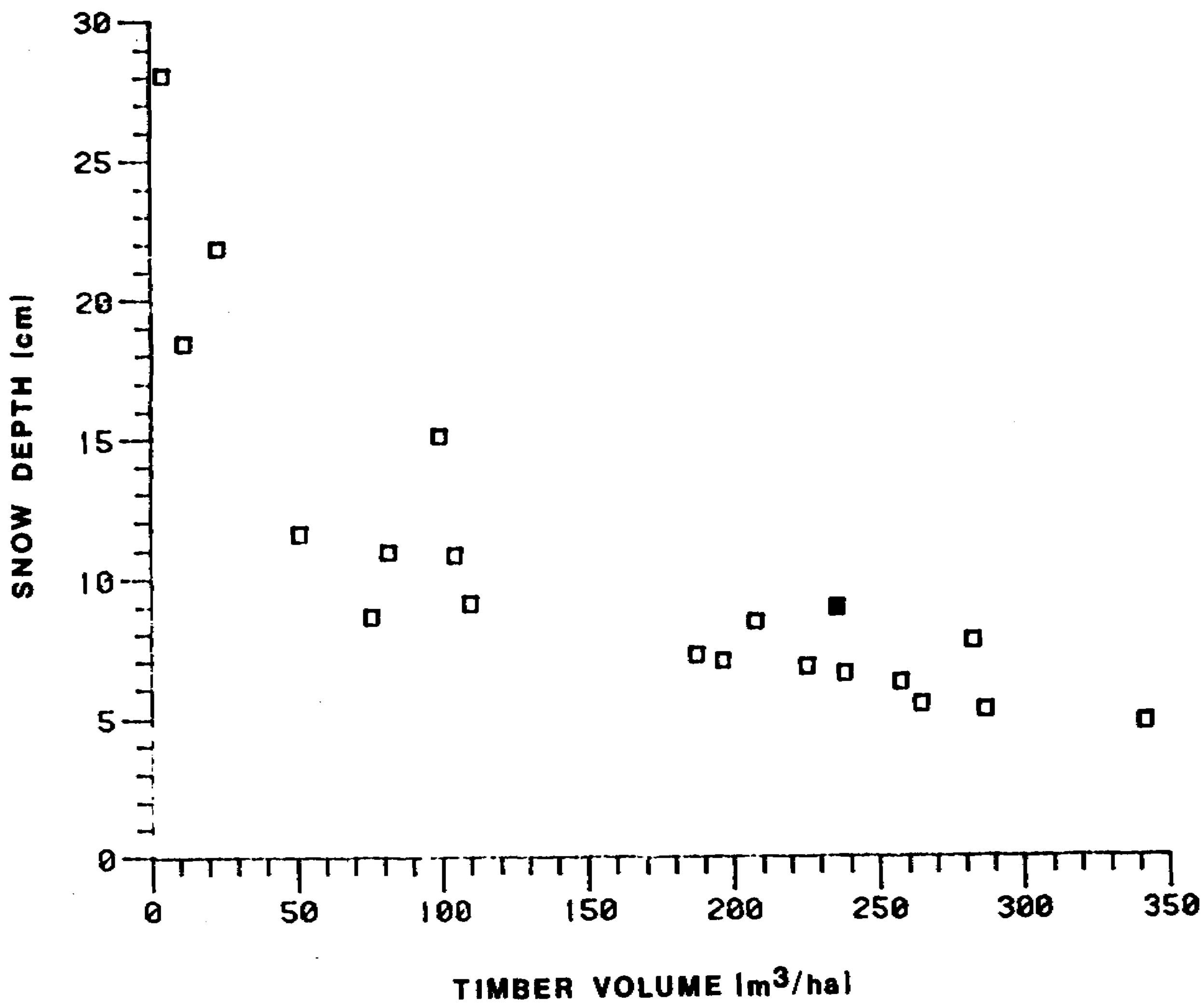

Fig. 2. Relationship of mean snow depth to mean net inventory volume (m^3/ha, Scribner scale) on 20 forest plots (100 points) near Juneau, Alaska, winter 1983-84. The 60-year-old growth plot is represented with a solid data point. See Table 3 for regression equation and Table 2 for Spearman correlation coefficient.

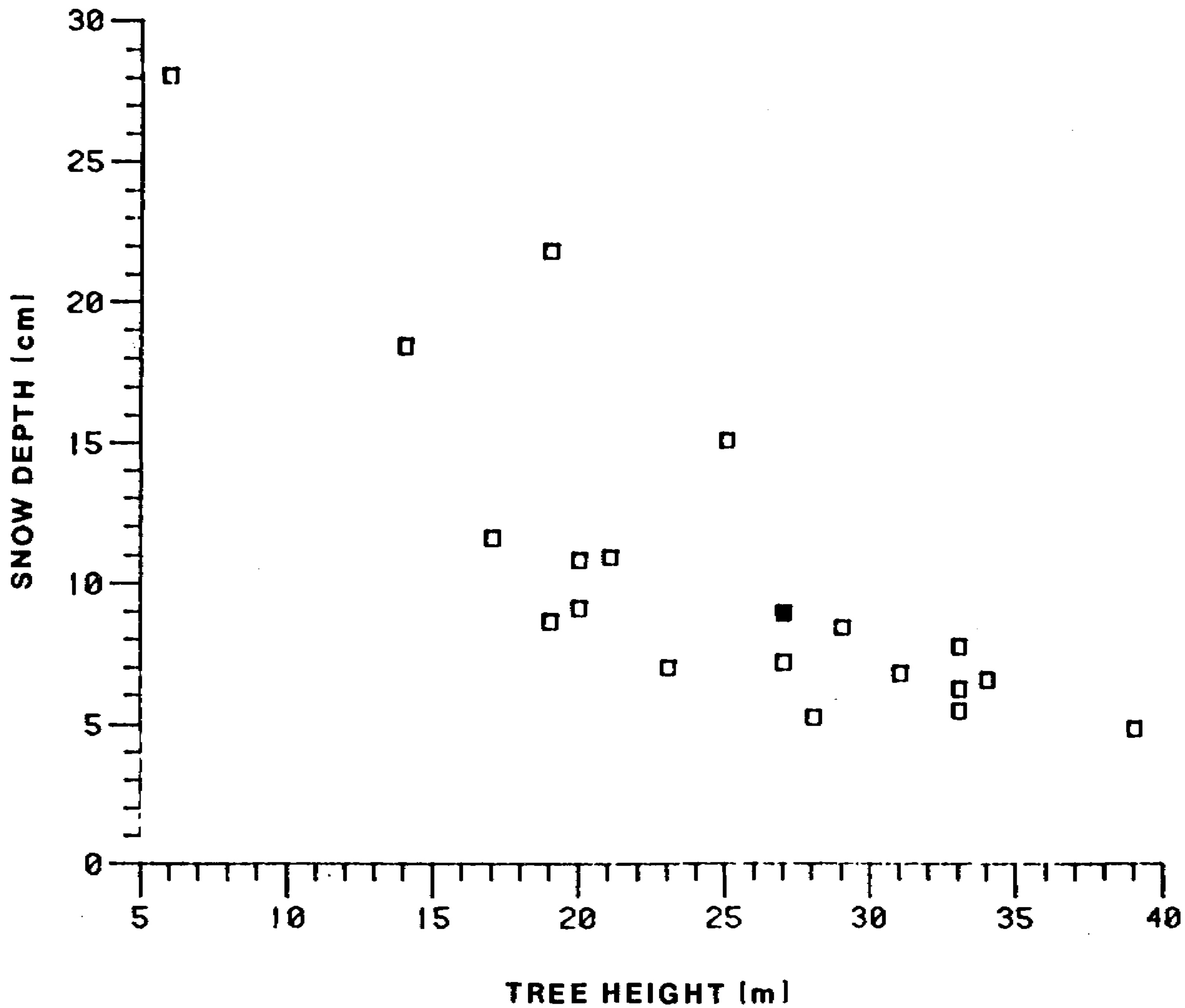

Fig. 3. Relationship of mean snow depth to mean tree height on 20 forest plots (100 points) near Juneau, Alaska, winter 1983-84. The 60-year-old second-growth plot is represented with a solid data point. See Table 3 for regression equation and Table 2 for Spearman correlation coefficient.

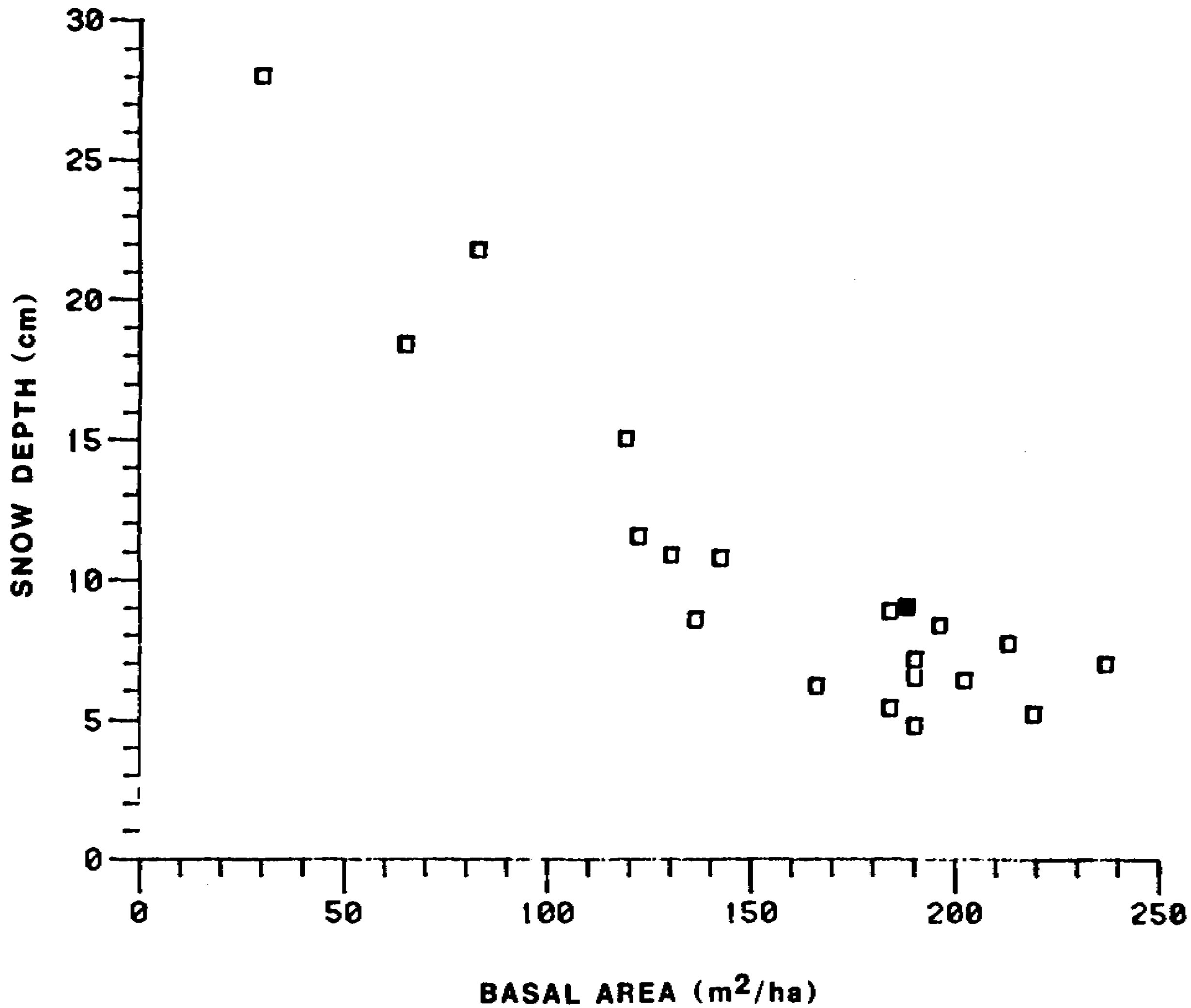

Fig. 4. Relationship of mean snow depth to mean basal area on 20 forest plots (100 points) near Juneau, Alaska, winter 1983-84. The 60-year-old second-growth plot is represented with a solid data point. See Table 3 for regression equation and Table 2 for Spearman correlation coefficient.

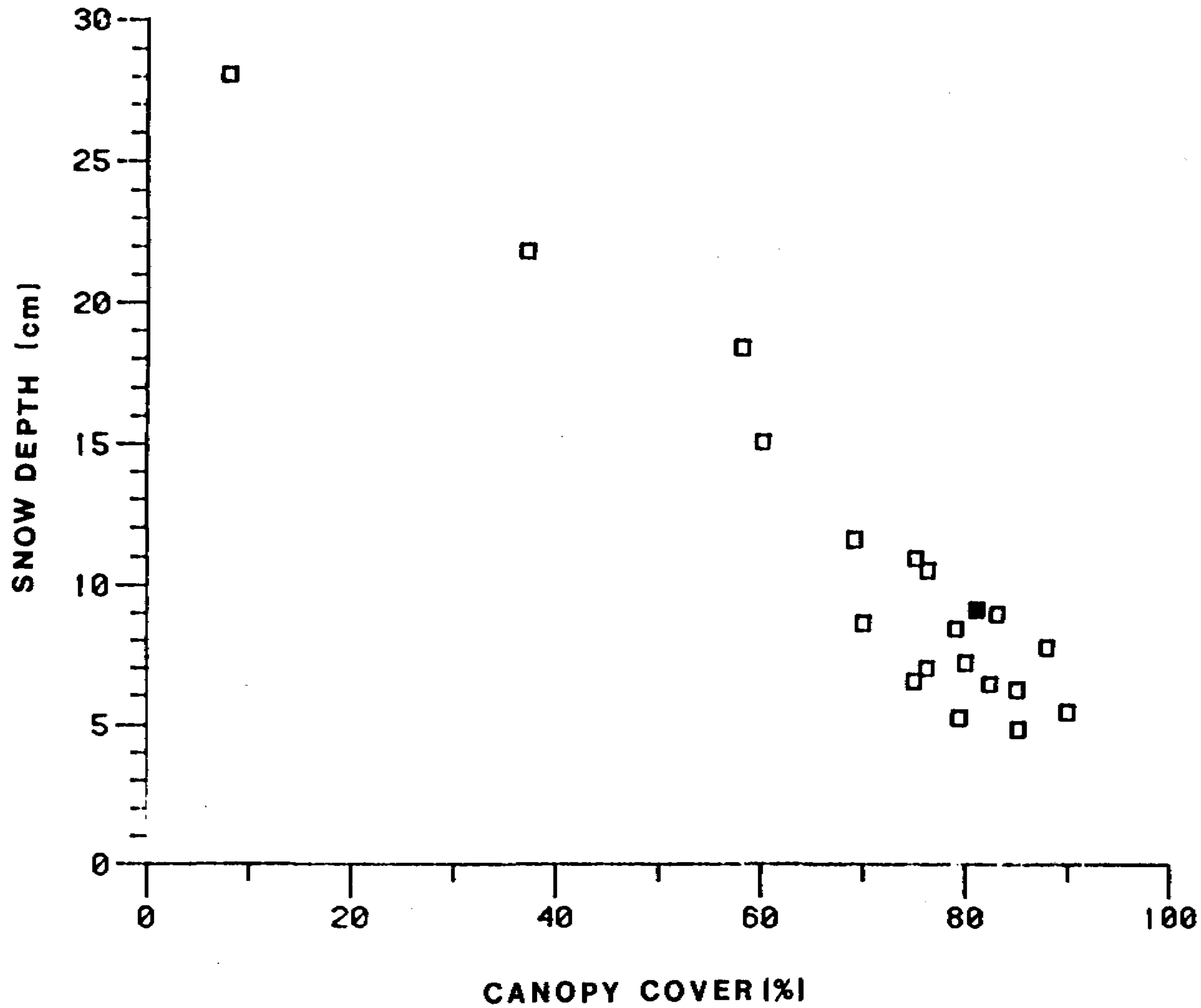

Fig. 5. Relationship of mean snow depth to mean canopy cover on 20 forest plots (100 points) near Juneau, Alaska, winter 1983-83. The 60-year-old second-growth plot is represented with a solid data point. See Table 3 for regression equation and Table 2 for Spearman correlation coefficient.

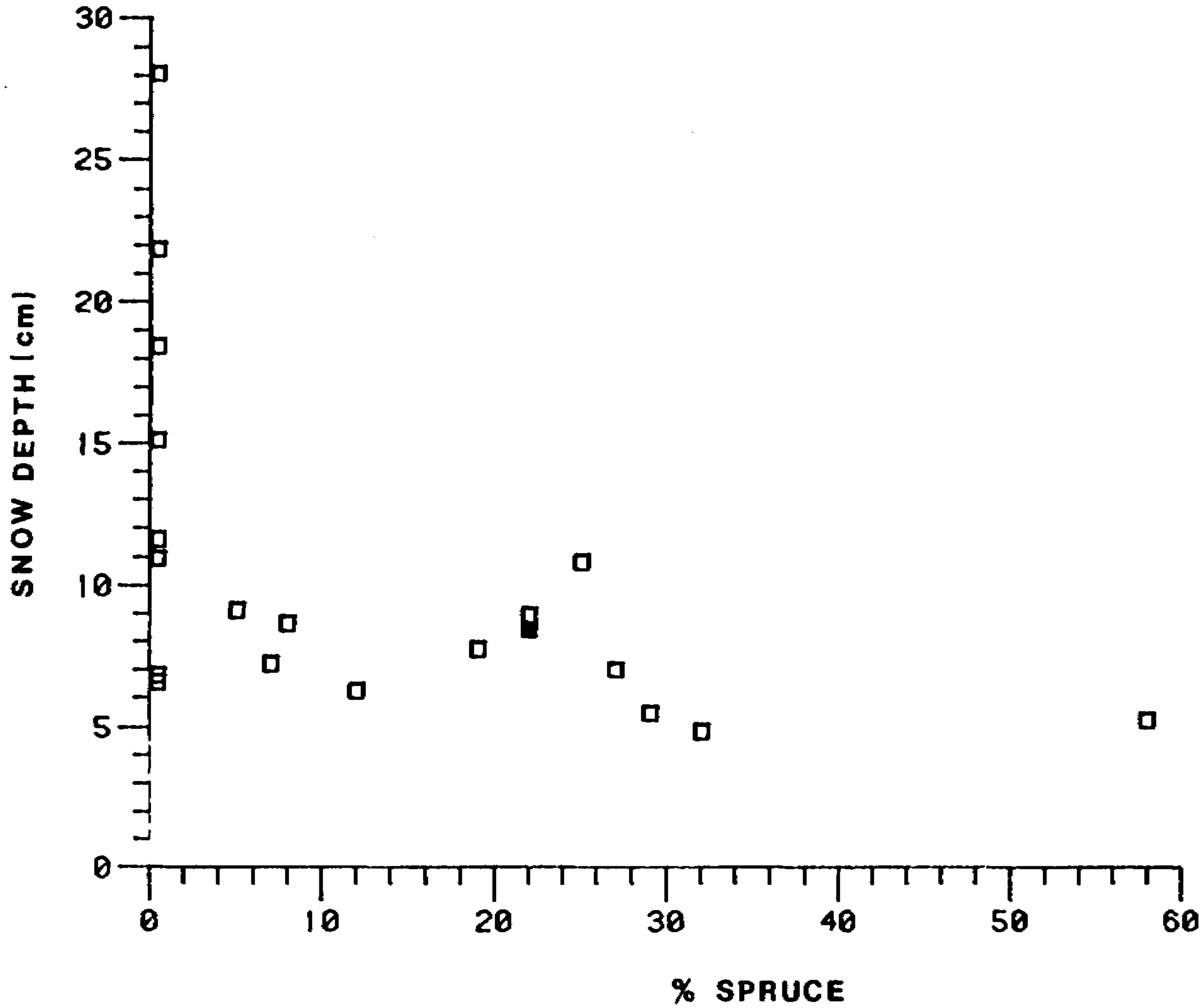

Fig. 6. Relationship of mean snow depth to mean percentage of spruce on 20 forest plots (100 points) near Juneau, Alaska, winter 1983-84. The 60-year-old second-growth plot is represented with a solid data point. See Table 3 for regression equation and Table 2 for Spearman correlation coefficient.

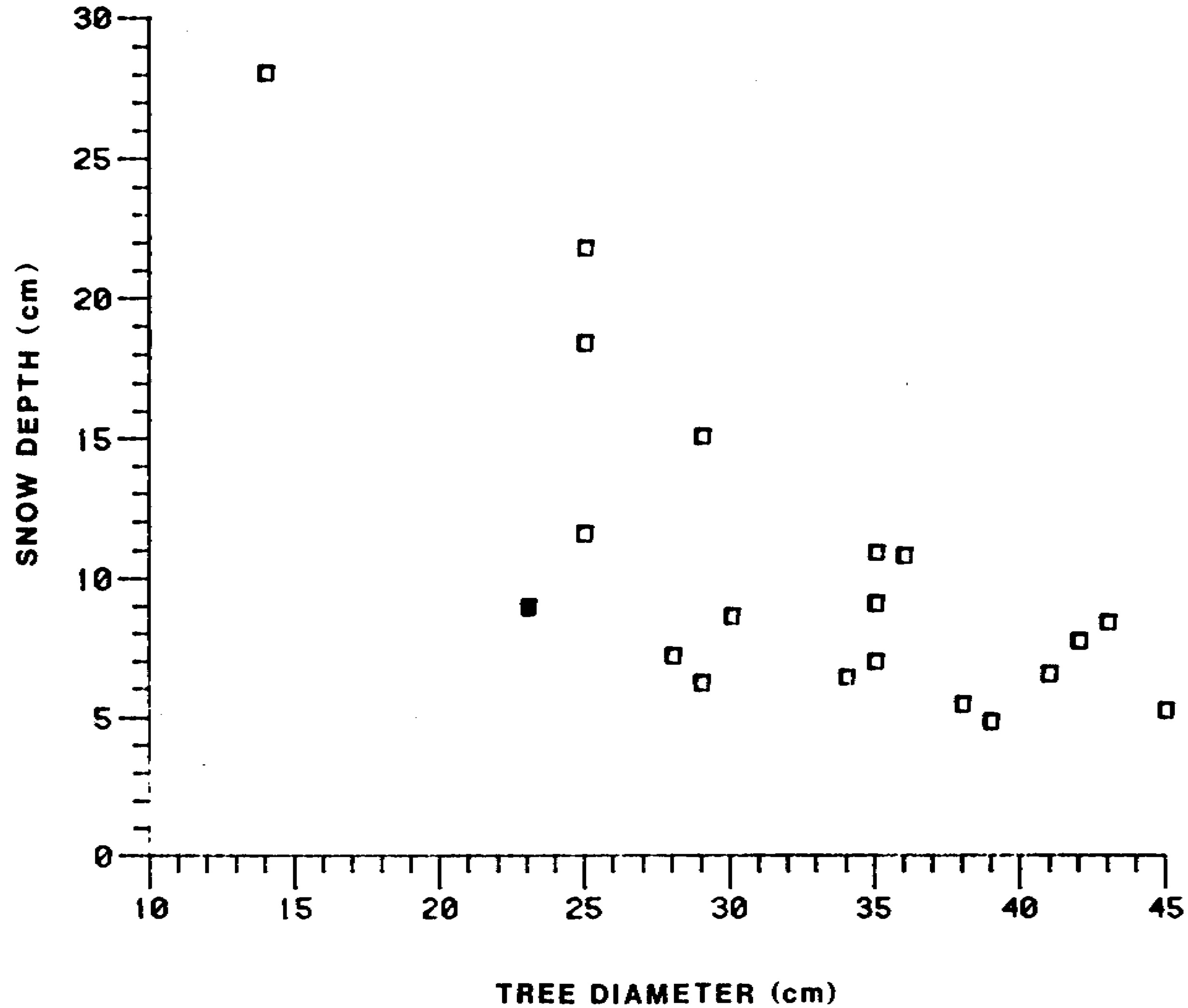

Fig. 7. Relationship of mean snow depth to mean tree diameter (dbh) on 20 forest plots (100 points) near Juneau, Alaska, winter 1983-84. The 60-year-old second-growth plot is represented with a solid data point. See Table 3 for regression equation and Table 2 for Spearman correlation coefficient.

Table 1. Summary of overstory characteristics on 20 0.4 ha forest plots near Juneau, Alaska, 1983-84.

Plot No.	Density stems/ha	dbh cm	Canopy %	Spruce %	Height m	Basal m^2/ha	Volume m^3/ha
1	661	41	75	0	34	190	238
2	700	42	88	19	33	213	282
3	512	39	85	32	39	190	341
4	1,157	28	80	7	27	190	187
5	880	29	85	12	33	166	257
6	811	34	82	0	31	202	225
7	929	43	79	22	29	196	207
8	724	35	76	0	21	130	81
9	636	25	37	0	19	83	23
10	271	14	8	0	6	30	2
11	642	25	58	0	14	65	11
12	1,348	25	69	0	17	119	51
13	922	29	60	0	25	119	99
14	710	35	82	5	20	184	109
15	767	36	76	25	20	142	104
16	939	38	90	29	33	184	264
17[a]	1,469	23	82	22	27	184	235
18	1,337	35	76	27	23	237	196
19	874	30	70	8	19	136	75
20	690	45	79	58	28	219	286

[a] 60-year-old second-growth plot.

Table 2. Spearman correlation coefficients of forest overstory parameters and mean snow depth on 20 forest plots near Juneau, Alaska, 1983-84.

Variable	dbh	% Canopy	% Spruce	Tree height	Basal area	Net inven. volume	Avg. snow depth
Density	-0.14	0.26	0.21	0.09	0.22	0.09	-0.13
dbh		0.48[a]	0.56[b]	0.64	0.72	0.69	-0.65
% Canopy			0.63	0.75	0.65	0.84	-0.76
% Spruce				0.48	0.60	0.69	-0.66
Tree height					0.68	0.92	-0.85
Basal area						0.79	-0.79
Net inventory volume							-0.90

[a] $P \leq 0.05$ when coefficient is greater than 0.39.
[b] $P \leq 0.01$ when coefficient is greater than 0.52.

Table 3. Regression equations between individual forest overstory parameters and mean snow depth on 20 forest plots near Juneau, Alaska, 1983-84.

Independent variable	Regression equation	Significance
Stem density	$y = 17.4 - 0.008x$	0.04
dbh	$y = 29.1 - 0.575x$	<0.001
% Canopy	$y = 31.8 - 0.298x$	<0.001
% Spruce	$y = 13.1 - 0.200x$	<0.01
Tree height	$y = 25.7 - 0.614x$	<0.001
Basal area	$y = 23.8 - 0.050x$	<0.001
Net inventory volume	$y = 8.6 - 0.285x + 0.003x^2$	<0.001