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Atmospheric conditions surrounding a seedfall in western Montana

Carl Ernest Fiedler
The University of Montana

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ATMOSPHERIC CONDITIONS SURROUNDING A SEEDFALL IN WESTERN MONTANA

By

Carl E. Fiedler

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Approved by

George M. Blake
Chairman, Board of Examiners

John M. Stewart
Dean, Graduate School

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Date

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TABLE OF CONTENTS

CHAPTER PAGE

LIST OF FIGURES

CHAPTER I

INTRODUCTION

The western larch Larix occidentalis Nutt. type occupies a significant part of Inland Empire forests, both in area and commercial importance. Because of the extensive nature of these forests, coupled with limited funds for personnel and management, continued dependence on natural regeneration is anticipated. Information on seed dissemination in cuttings in the western larch type is needed for planning regeneration programs. This information is needed for the following reasons:

1. Extreme variability of stocking rates on clearcuts due to uneven seed distribution, site preparation, and other factors.
2. Desirability of being able to predict seed distribution throughout a clearcut unit in order to improve natural regeneration practices.

The natural regeneration triangle consists of (1) adequate seed source, (2) receptive seedbed, and (3) suitable climate for germination and seedling establishment. Atmospheric conditions are an integral part of this triangle. Attendant with natural regeneration is the problem of variable stocking, much of which is attributable to uneven seed dispersal. Wind is the medium primarily responsible for pollination and the subsequent dispersal of seed, consequently it plays a significant, though somewhat obscure, role in the perpetuation of forests. Likewise, temperature and relative humidity interact to stimulate or prevent cone opening and seed release. Yet, to date, there is little information on these parameters in the forests of the Northern Rockies. For this reason, information on atmospheric conditions during a seedfall period would be helpful in elucidating that portion of the stocking problem related to seed dispersal.

A study of western larch and Douglas-fir _Pseudotsuga menziesii_ var. _glauca_ (Beissn.) Franco, seed dispersal into clearcuttings on the Coram Experimental Forest in Montana indicated that most seed was dispersed uphill (Boe, 1953). Boe reported that the combined action of prevailing winds and upslope thermal winds was probably responsible for this unexpected pattern. Study of larch seed dispersal on this area was continued by Shearer (1959) through 1957. Results over the six-year period suggested that thermal winds causing upslope motion during hot, dry days, and not prevailing winds, were the primary seed dispersing agent in the area. Further examination is needed to determine whether these conditions are prevalent in the larch type. If these winds are important in dispersing seeds in the Northern Rockies, it is necessary to find where and under what cutting methods they can best be used as a dispersing agent.

Because of the size of clearcut blocks and availability of seed source, the Newman Ridge area on the Lolo National Forest offered an excellent opportunity to study seed dissemination of several native conifers. The original intent of the study was to investigate the seed dissemination pattern of western larch and major associated species on Newman Ridge. Specific objectives were to study (1) cone and seed production of major species, (2) timing of seedfall, and (3) the relation of seed dissemination to major topographic and environmental factors. Due to the untimely occurrence of a poor seed crop, some modification of the original objectives was necessary.

Objectives

1. To record cone and seed production of major species.
2. To relate seed dissemination on two Newman Ridge clearcuts to major environmental factors.
3. To study the type and extent of relationships between measured environmental parameters.

In addition to the stated objectives, this study served a secondary purpose. A number of models of wind movement in the forest have been proposed (Defant, 1951; Beuttner and Thyer, 1966; and MacHattie, 1968) from a variety of areas. However, substantiation, rejection, or modification of existing models requires a considerable data base from a wide range of sites. This study broadens that base by providing information from openings of opposing aspects in mountainous terrain.

CHAPTER II

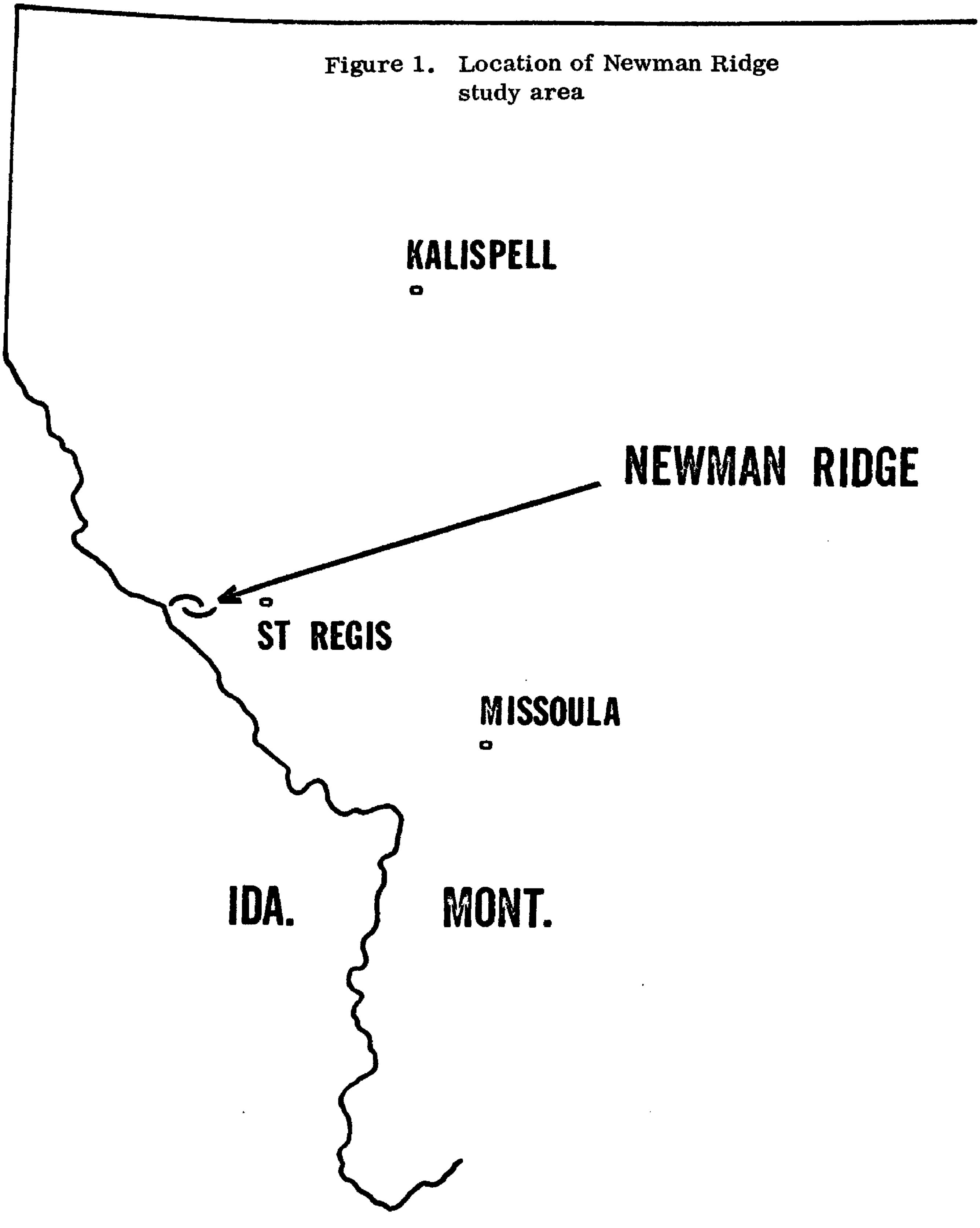
STUDY AREA DESCRIPTION

Physiography

The study was conducted at Newman Ridge, on the Superior Ranger District, Lolo National Forest. Steep terrain typifies the area, which is located approximately eight miles west of St. Regis, Montana, near the Montana-Idaho border (Figure 1). Newman Ridge lies between Two Mile Creek to the south and Ward Creek to the north, and has an east-northeast orientation. The ridge line is well defined and quite sharp throughout, with a high point at Newman Peak (elev. 5601').

The Newman Ridge area was selected as the site for a multidisciplinary prescribed fire study. Units in sections 25, 26, 34, and 35, T46N, R29W, Montana PM, Mineral County, Montana, were clearcut in 1968 and 1969 to be used in a variety of related research efforts. For this particular investigation, concentration was focused on two clearcuts, one south facing (S-3), and the other facing north (N-3). Because of their opposing aspect, proximity to each other, and rather uniform boundaries, these units were the most logical choice for instrumentation. Unit S-3 is 40 acres in size, with a rather uniform slope of about 50 to 60 per cent. The north facing unit, N-3, has an area of 23 acres, and is somewhat steeper and more variable in slope (55 to 75 per cent).

Figure 1. Location of Newman Ridge study area



Stand Description

The Newman Ridge stand varied in age from 110 to 145 years, with an average age of about 125 years. Average canopy height was about 100 feet, with dominants ranging in height from 100-120 feet, and codominants from 85-100 feet.

The seed source surrounding unit S-3 was comprised of 196 trees/acre (> 6"DBH), with a basal area of 184 ft^2/acre. Corresponding values for the north slope were 161 trees/acre and 176 ft^2/acre basal area. These values were based on a 100 per cent sample of four one-fifth acre plots situated in the timbered margin of each unit.

Species composition of the S-3 seedwall was 35 per cent lodgepole pine *Pinus contorta* Dougl., 30 per cent Douglas-fir, and 25 per cent western larch, with the remaining 10 per cent grand fir *Abies grandis* (Dougl.) Lindl., ponderosa pine *Pinus ponderosa* Laws., and western white pine *Pinus monticola* Dougl. The timbered margin surrounding N-3 was comprised of 45 per cent larch, 35 per cent Douglas-fir, and 10 per cent western red cedar *Thuja plicata* Donn, with white pine, grand fir, Engelmann spruce *Picea engelmannii* Parry, and subalpine fir *Abies lasiocarpa* (Hook.) Nutt. making up the residual 10 per cent.

Habitat Types

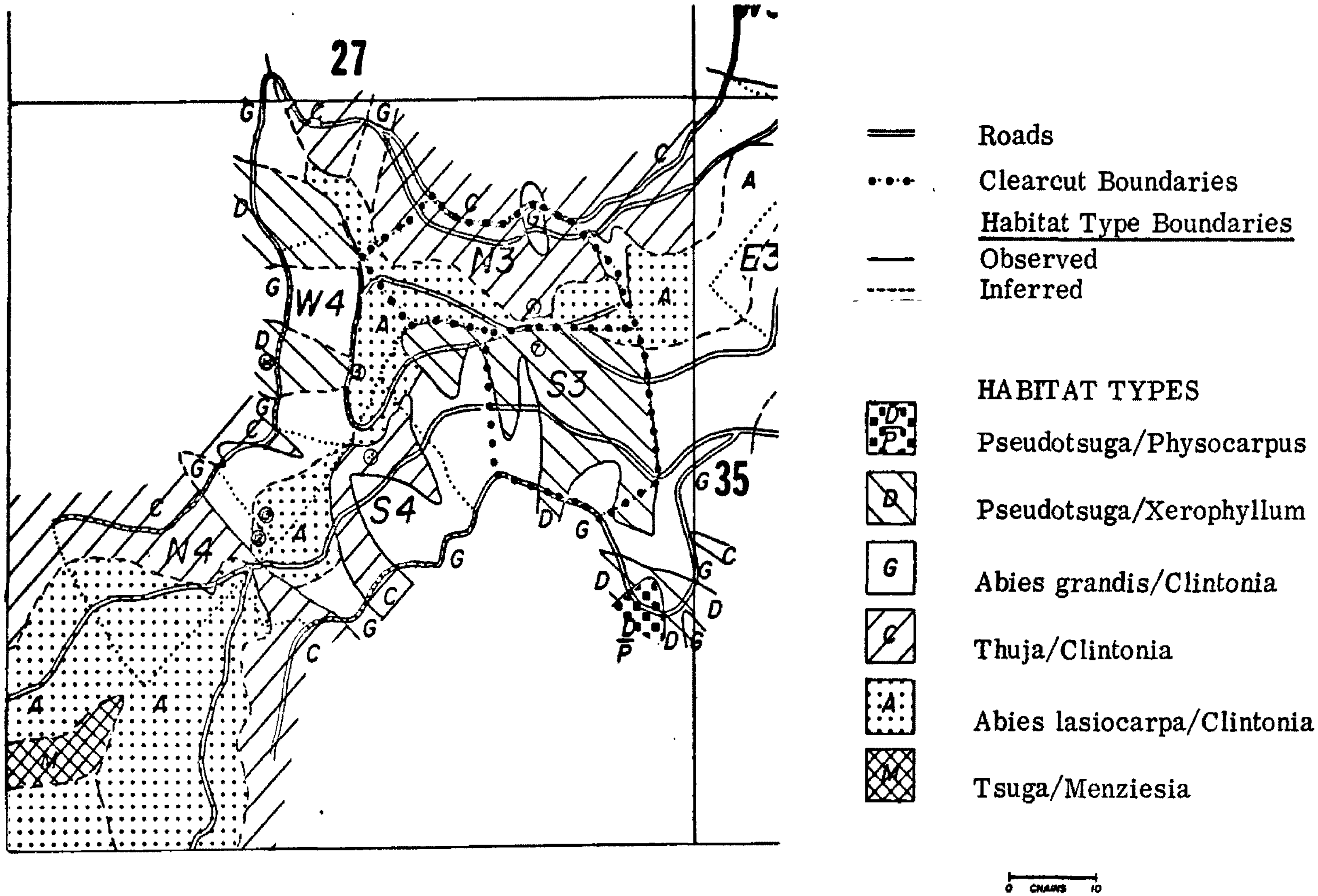
On unit S-3, Pseudotsuga menziesii/Xerophyllum tenax (Xerophyllum phase) is the dominant habitat type (Pfister et al., 1972) with lesser amounts of Abies grandis/Clintonia uniflora (Xerophyllum phase) along the lower part of the unit (Figure 2). Thuja plicata/Clintonia uniflora (Menziesia phase) is the major type on unit N-3, with a minor presence of Abies lasiocarpa/ Clintonia uniflora (Menziesia phase) on the upper third of the unit. The ecotone between the rather dry Pseudotsuga menziesii/Xerophyllum tenax (Xerophyllum phase), which covers the upper half of S-3, and the moderately mesic Abies lasiocarpa/Clintonia uniflora (Menziesia phase) on the upper third of N-3, is abrupt, and follows the ridge line almost perfectly.

Climate

Typical summer temperatures range from a low of 40° F. to a high of 80° F. Extreme low temperatures of 30° F. and extreme highs of 95° F. are reached, but only rarely. No temperature data is available for Newman Ridge during the winter months.

Average annual precipitation on Newman Ridge varies from 25-35 inches (USDA For. Serv. in Beaufait and Hardy, 1972). Rainfall is notably scarce from early July through August. Only 4.75 inches of precipitation were recorded for the period June 1-October 17, 1969. Snow covers the Ridge from mid-October or early November into May, with average late winter depths of five feet not uncommon.

Figure 2. Newman Ridge Habitat Types



CHAPTER III

PROCEDURES

Parameters Measured

Seed production, seed source, and the quantity of seed dispersed were stand-related parameters sampled, estimated, or measured.

Environmental parameters monitored were temperature, relative humidity, wind velocity, and wind direction.

Seed Production

Seed production of major species was estimated using a sequential sampling technique developed by Roe (1966) for western larch. By this method, strobili were counted on a minimum of four major branches per sample tree. Using binoculars, selected limbs were scanned and the strobili counted. Totals were reduced by 50 per cent to adjust for anticipated losses. Finally, adjusted counts were compared to the critical values derived by Roe to determine whether the crop would be classified good, medium, or poor.

Based on the sampling plan outlined above, the probability of making a wrong decision was set at 10 per cent.

Seed Source

The seed source surrounding each unit was determined by means of sample plots located within the timber. Four one-fifth acre plots were established around each study unit. Plots were rectangular (1 ch X 2 ch) in shape, situated with the long dimension bordering the clearcut at approximately the center of each timbered side (Appendix A). All trees 6" DBH and larger were measured on each plot. Trees were recorded by species, diameter, basal area, height, age, crown class, crown length, and vigor (Appendix B).

Seed Dispersal

Estimation of the quantity and pattern of seed dispersal was accomplished by use of 0.1 mil acre rectangular (1.52' X 2.87') seed traps. This size and shape was chosen for two reasons: (1) easy to transport in the field, and (2) allowed for easy conversion of data to seeds per acre bases after seed collection. Seeds dispersed in clearcuts were gathered by means of traps placed in grid fashion at three chain intervals, beginning one chain from the timbered edge. A total of 246 seed traps was placed on eight different clearcuts. With anything better than a poor seed crop, such a layout would allow development of seed dispersal patterns.

Seed dispersal within the timber was sampled by two seed traps per one-fifth acre sample plot. The traps were placed one chain apart and one-half chain from the timber-clearcut interface within each sample plot. An additional 46 traps were placed in this way in 23 timbered plots.

Large rectangular (4' X 8') seed collectors were used in an effort to determine timing of seedfall. Four such collectors were placed within the timber in areas of high dispersal potential. Three of the collectors were placed in the timber surrounding S-3, and one in the timber adjacent to N-3. These collectors were checked for seed at ten to fifteen minute intervals during prime seedfall periods (9:00 A.M. to 6:00 P.M.). With frequent checks, time of dispersal of seeds caught in the collectors could be determined within about five minutes. Later, temperature, relative humidity, wind velocity, and wind direction values were taken from the weather chart of the nearest station at the time each seed was dispersed. This procedure allowed individual seeds caught in the collectors to be closely related to the weather regime prevailing at the time of their dispersal.

The availability of a 10 ft. X 10 ft. wind tunnel at the Northern Forest Fire Laboratory near Missoula provided an ideal opportunity to model seed dispersal. The wind tunnel provided a means of measuring distance of dispersal at various wind velocities in a controlled environment. Seeds were dropped in sets of ten, with ten sets being dropped at each velocity setting. Drops were made at wind velocities of 2 mph, 5 mph, 8 mph, and at slightly less than 10 mph, the maximum setting. After each seed set was released, the dispersal distance of each of the ten seeds was recorded. Thus, a total of 100 seeds was dropped at each velocity setting.

Instrumentation

Hygrothermographs were located at each of the three stations to provide relative humidity and temperature measurements. Hygrothermographs were placed 4-1/2 feet above the ground in standard U. S. Weather Bureau instrument enclosures.

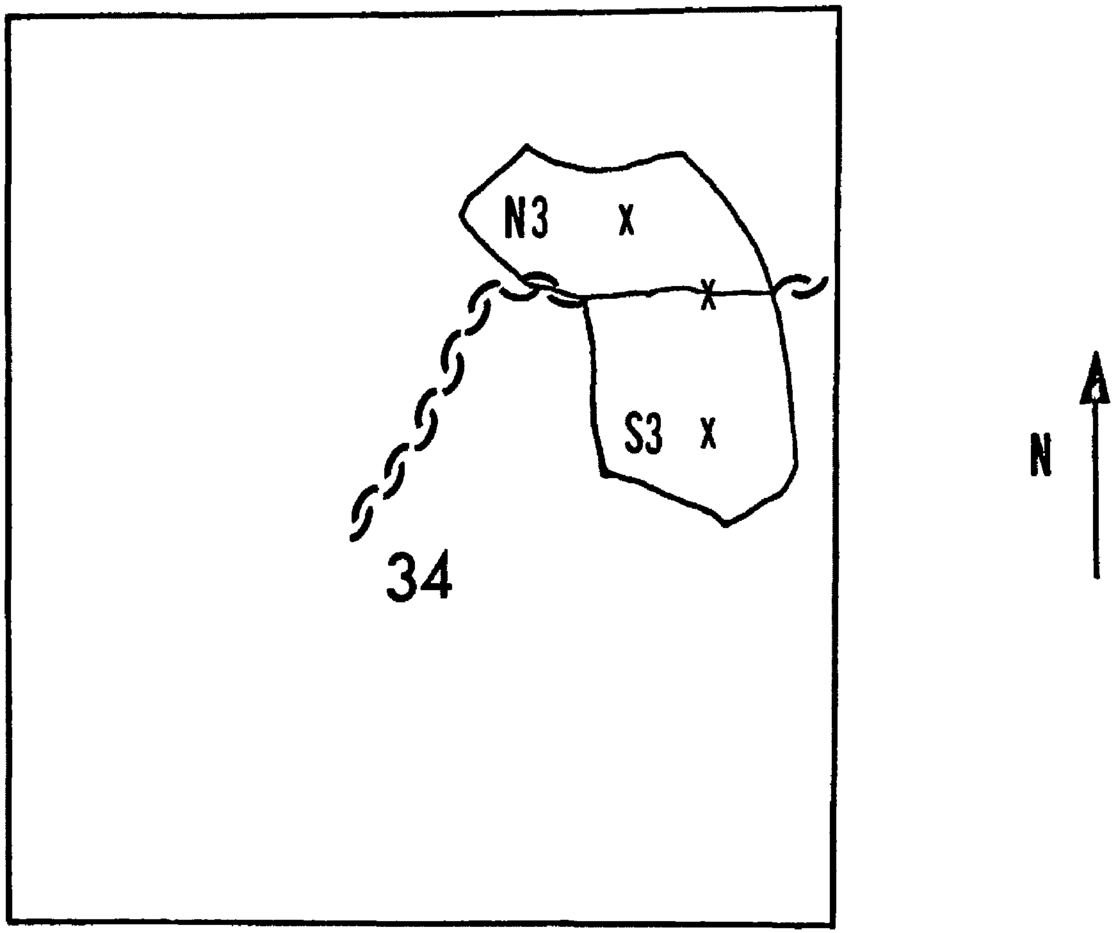
Battery-powered mechanical weather stations were used for measurement of wind speed and direction, and for supplemental temperature measurements. One weather station was installed near the center of unit S-3, one near the center of N-3, and the third on the ridge line separating the two units (Figure 3). The two stations in the clearcuts were situated near the center so as to be above the canopy level of the lower stand edge. This location also served to minimize turbulence effects from the sides and ridge top. All three weather stations were mounted eight feet above the ground. To mount them higher would have caused undue anchoring problems and made regular checks difficult.

All parameters were recorded for the period September 11 through October 17, 1969. The onset of winter weather forced the dismantling and removal of the three weather stations at this time. The 37-day study period virtually encompassed the 1969 seedfall period.

Techniques for Observing Air Movement

Time lapse photography was used along with Pibal weather balloons to obtain supplementary information on air movement along the stand edges. Pibal balloons (30" diameter) inflated with helium were tied on 100-foot lines and anchored at ground level along the clearcut edge. Fluorescent orange streamers 18 inches long were attached at 20-foot intervals along the line. The streamers allowed observation of winds at intermediate levels to 100 feet. Three balloons

Figure 3. Location of Newman Ridge weather stations



were sent up at a given time along a stand edge, one attached at the lower slope, one at midslope, and a third on the upper slope. This scheme allowed simultaneous observation of air motion to 100 feet at each slope location.

The camera was positioned so that both the weather station anemometer in the center of the clearcut and the three balloon lines were in the field of view. Later, in reviewing the film in slow motion, wind direction at the 10-foot level in the center of the clearcut could be simultaneously compared to wind motion to 100 feet along the clearcut edge. An alarm clock was attached to the weather station to allow the wind observations to be related to time.

Yellow phosphorus smoke bombs were activated within the canopy of the adjacent timber in an effort to follow the motion of the wind as it passed over the timbered margin into the clearcut. The resulting dispersal pattern was observed visually and recorded on film. Smoke bombs were also activated at ground level along the ridge line and the dispersal pattern similarly observed.

CHAPTER IV

RESULTS AND DISCUSSION

Seedfall

The 1969 seed crop proved to be a poor one, as the late spring forecast had predicted. As a result, a negligible amount of seed was collected in the traps. This same lack of seed prohibited development of seed dispersal patterns. However, a number of seeds were recovered in the seed collectors, and these were closely related to the weather conditions prevailing at the time of dispersal. More than 83 per cent of the seeds gathered in the collectors were dispersed into an atmosphere of less than 50 per cent relative humidity. Slightly more than 80 per cent were dispersed in atmospheric conditions warmer than 70° F. Low relative humidity (< 50 per cent) and warm temperature (>70° F.) appeared to be common denominators accompanying seed dispersal. Normally, the winds accompanying such a temperature-humidity regime were slope, rather than general in nature. However, there was not sufficient data to justify making any conclusions.

Hindsight suggests it would be wise to check cones for seed sometime in August, even if a late spring check forecasts a good crop. By so doing, harmful effects on the seed crop due to an unseasonable frost or other natural causes could be noted, and the placement of seed traps postponed until a better crop is produced. Installation of seed traps at measured intervals throughout a cutting unit is a major task, and should not be undertaken unless an average or better seed crop is imminent. Furthermore, fewer traps are required to obtain adequate dispersal data in years of average-to-heavy seedfall.

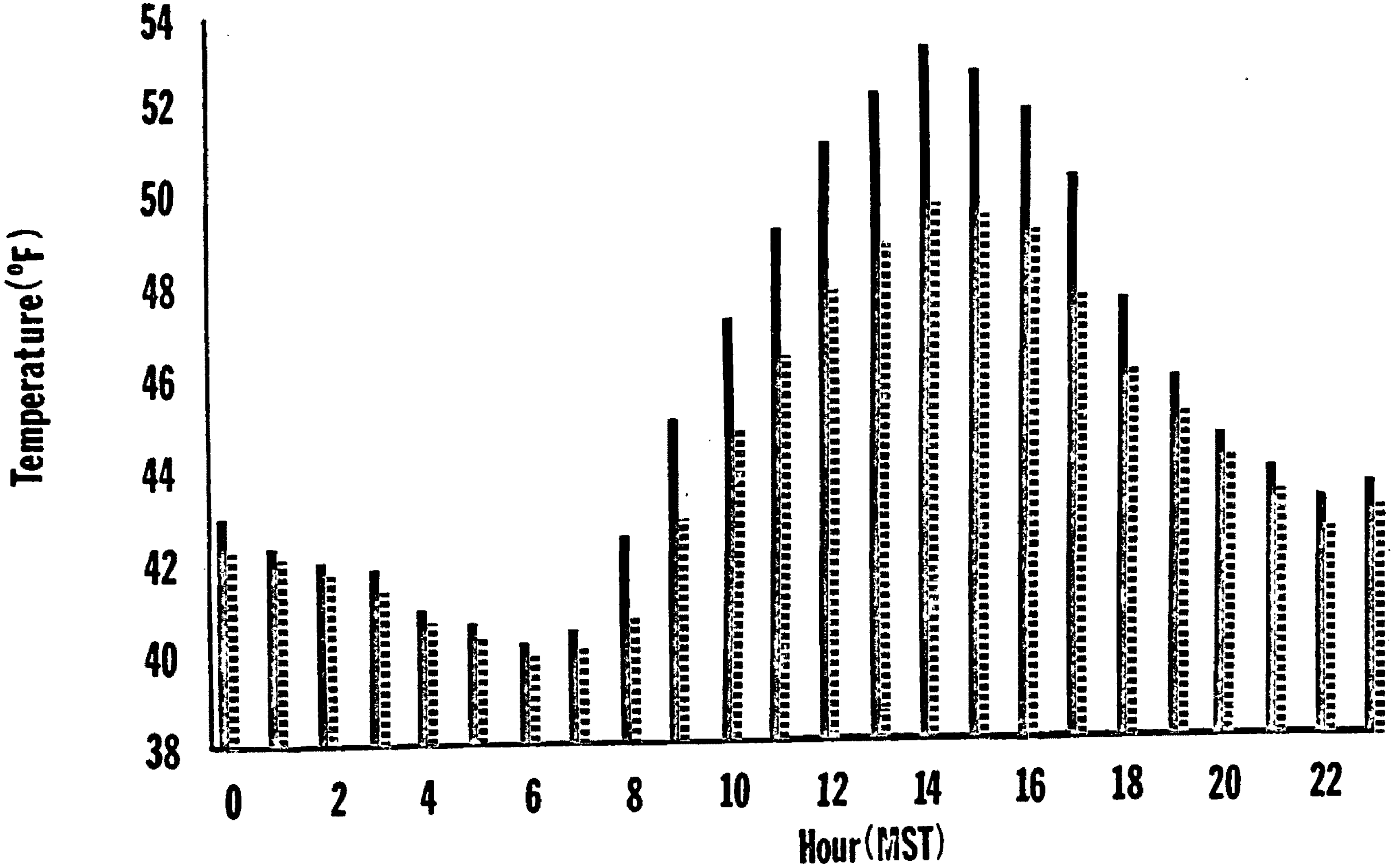
Because of the lack of seed on the study area, wind tunnel modeling of seed dispersal was used as an alternate means of studying dissemination. Results of the wind tunnel tests showed distance of dispersal approaching a plateau at velocities greater than 8 mph. No data were collected for velocities greater than 8 mph, as seed released at greater velocities were dispersed out the exhaust end of the tunnel before coming to rest on the tunnel floor. Direct expansion of results from the wind tunnel drops would indicate a maximum dispersal of about 4 chains for a 100-foot tree. In nature, it is not uncommon for seeds to be dispersed 8-10 chains (Squillace, 1954; Roe, 1967), and occasionally much further. However, Isaac (1930) found that doubling the height of release more than doubled the distance of dissemination. He attributed this relative increase to greater wind velocity at greater heights. Two other factors, turbulence and convection, may also contribute to this disproportionate change in dispersal distance with height. Since the tunnel course was without obstruction, modeled wind flow was essentially laminar. However, in forest openings during daylight hours, turbulence, convection, or both may be operational. Seeds released into strong convective updrafts may be lifted to great heights and consequently be carried long distances before being dropped. This would account for the occurrence of seedlings on plots and seeds in traps several miles from a seed source, as noted by Isaac (1943).

Temperature

Average hourly temperature values were calculated for the period September 11-October 17. On the south aspect, minimum temperature was reached at 6:00 A.M. MST, and the maximum at 2:00 P.M. MST (Figure 4). Maximum and minimum temperatures were reached at the same times, respectively, on the north slope as on the south. Mean hourly temperatures varied 13.1° F. (40.2° F. to 53.3° F.) on the south aspect, and 9.9° F. (39.9° F. to 49.8° F.) on the north. The bulk of the 3.2° F. difference between the temperature spread of the two slopes occurred at the upper end of the range. At night, except for slight differences in radiational cooling, the temperature regimes on the two slopes were essentially equal. This was reflected in the negligible difference (0.3° F.) between temperature minima on the two slopes. In an investigation of temperature characteristics of a mountainous area of Germany, Geiger (1965) provided data on maximum and minimum temperatures for all aspects. He maintained that temperature maxima have essentially the same distribution as global radiation values, which would account for the rather large difference in temperature maxima between the south and north slopes at Newman Ridge. Temperature minima, on the other hand, were viewed as being regulated by the downslope flow of cooled air.

During the hours of sunlight at Newman Ridge, the south aspect received considerable direct radiation at a sharp angle [average of 626 Cal/cm^2/day for

Figure 4. Average hourly temperatures on south and north aspects (Sept. 11-Oct. 17)



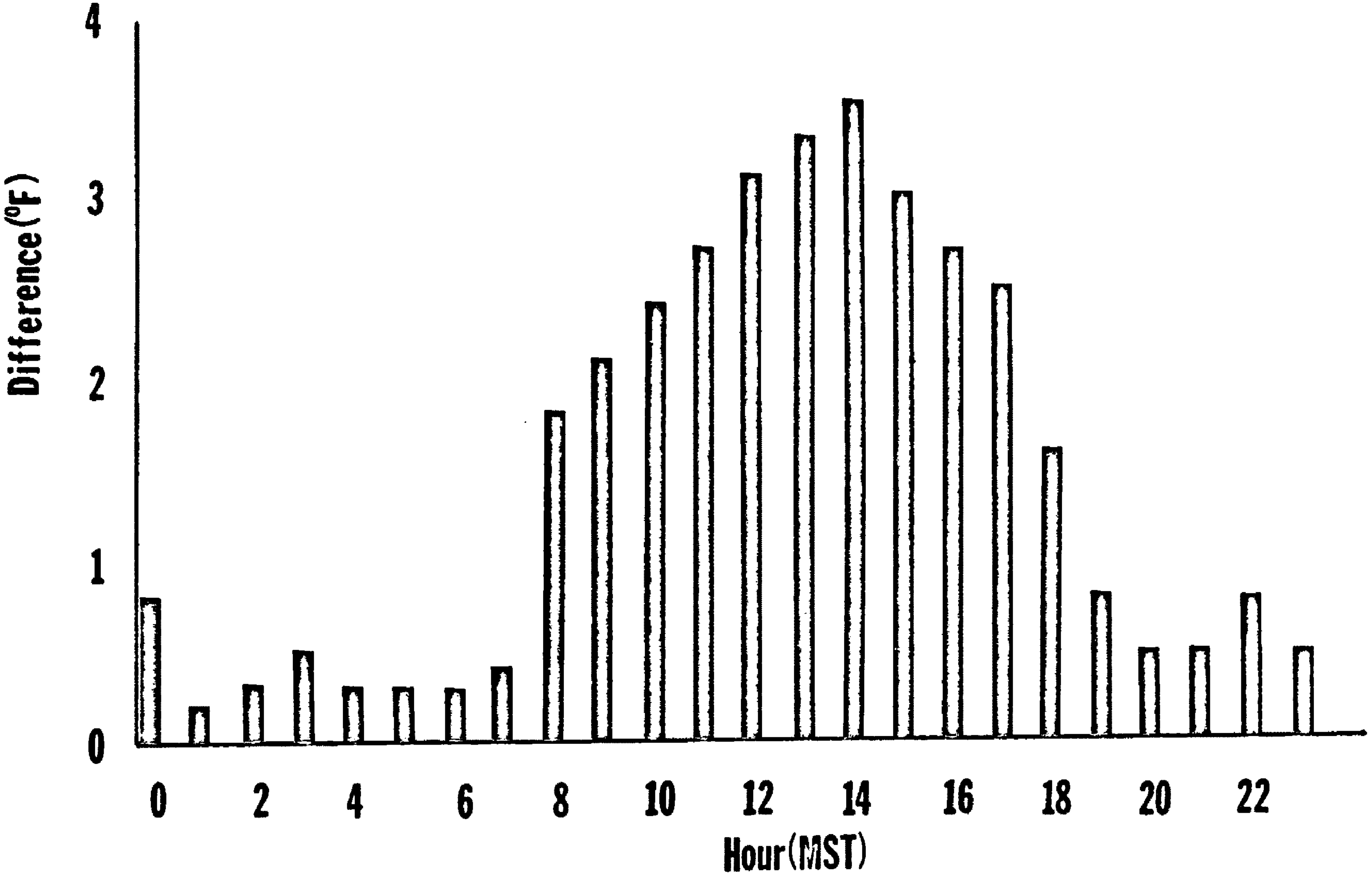
the study period (Buffo, et al., 1972)], whereas the steeper north slope received it for a shorter time and at a much flatter angle (average of 124 Cal/cm^2/day). The effect of this significant difference in radiational input reached a peak at 2:00 P.M., when maximum temperatures on the two slopes differed by 3.5° F. (Figure 5). Thus, over 90 per cent of the difference in mean temperature ranges between the opposing slopes could be attributed to daytime maxima.

Relative Humidity

Relative humidity values were also averaged by hour for the 37-day study period. The maximum relative humidity occurred at 7:00 A.M. MST on the south slope and at 8:00 A.M. MST on the north (Figure 6). However, the minimum average relative humidity occurred at 2:00 P.M. on the south aspect, but not until 4:00 P.M. on the north.

Differences in relative humidity on the two slopes were striking. The smallest difference (10.4 per cent) occurred at 6:00 A.M. and the greatest difference (21.8 per cent) at 11:00 A.M. and 12:00 noon (Figure 7). A difference in relative humidity between the two slopes would be expected, but the magnitude of the difference was not. A part of the maximum difference (21.8 per cent) that occurred at 11:00 A.M. and 12:00 noon can be attributed to the 2.7° F. and 3.1° F. average temperature differences that existed at the same times, respectively, between the two slopes. However, this factor cannot account for the 10.4 per cent difference in relative humidity that existed

Figure 5. Average hourly temperature differences between aspects, south minus north (Sept. 11-Oct. 17)



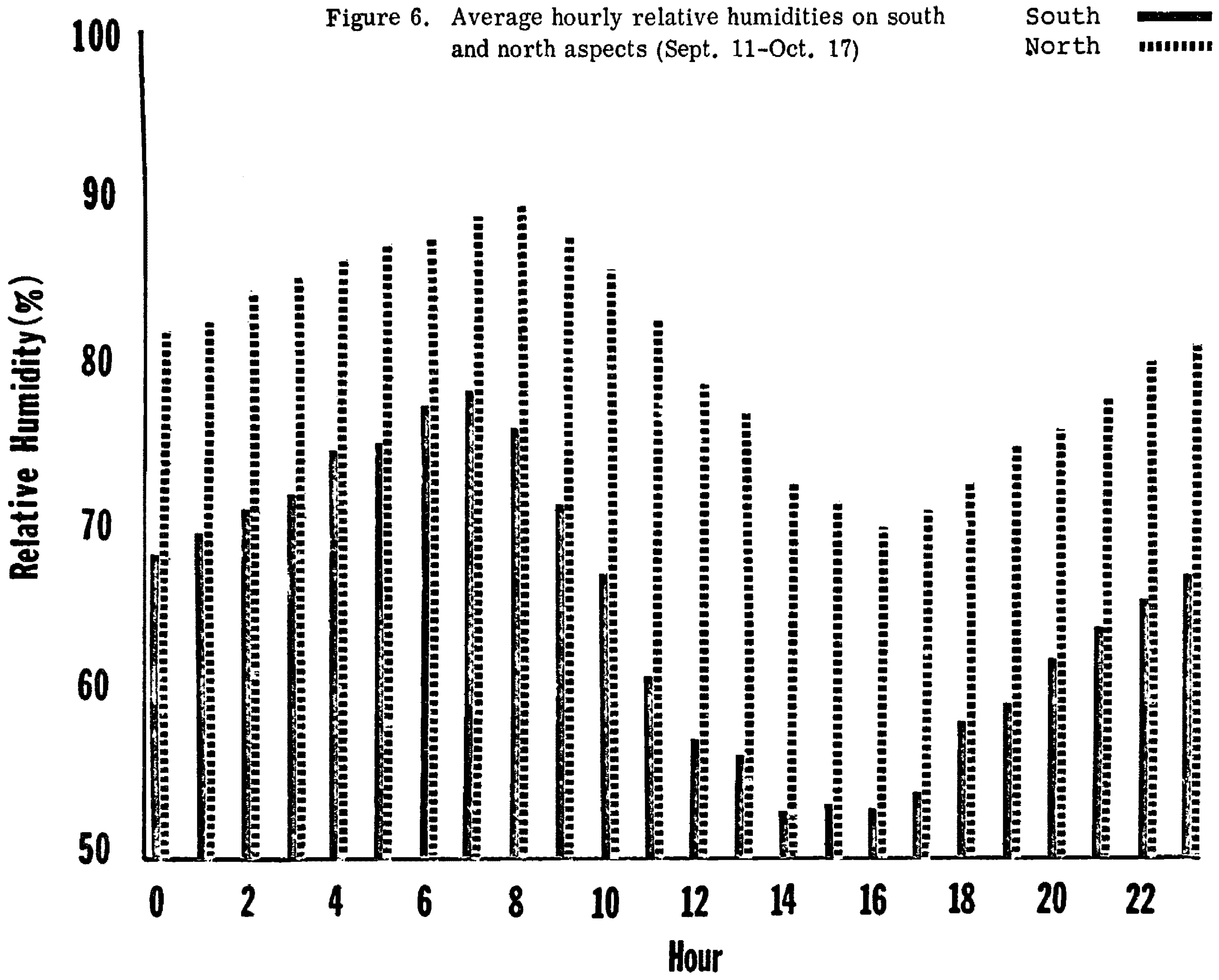
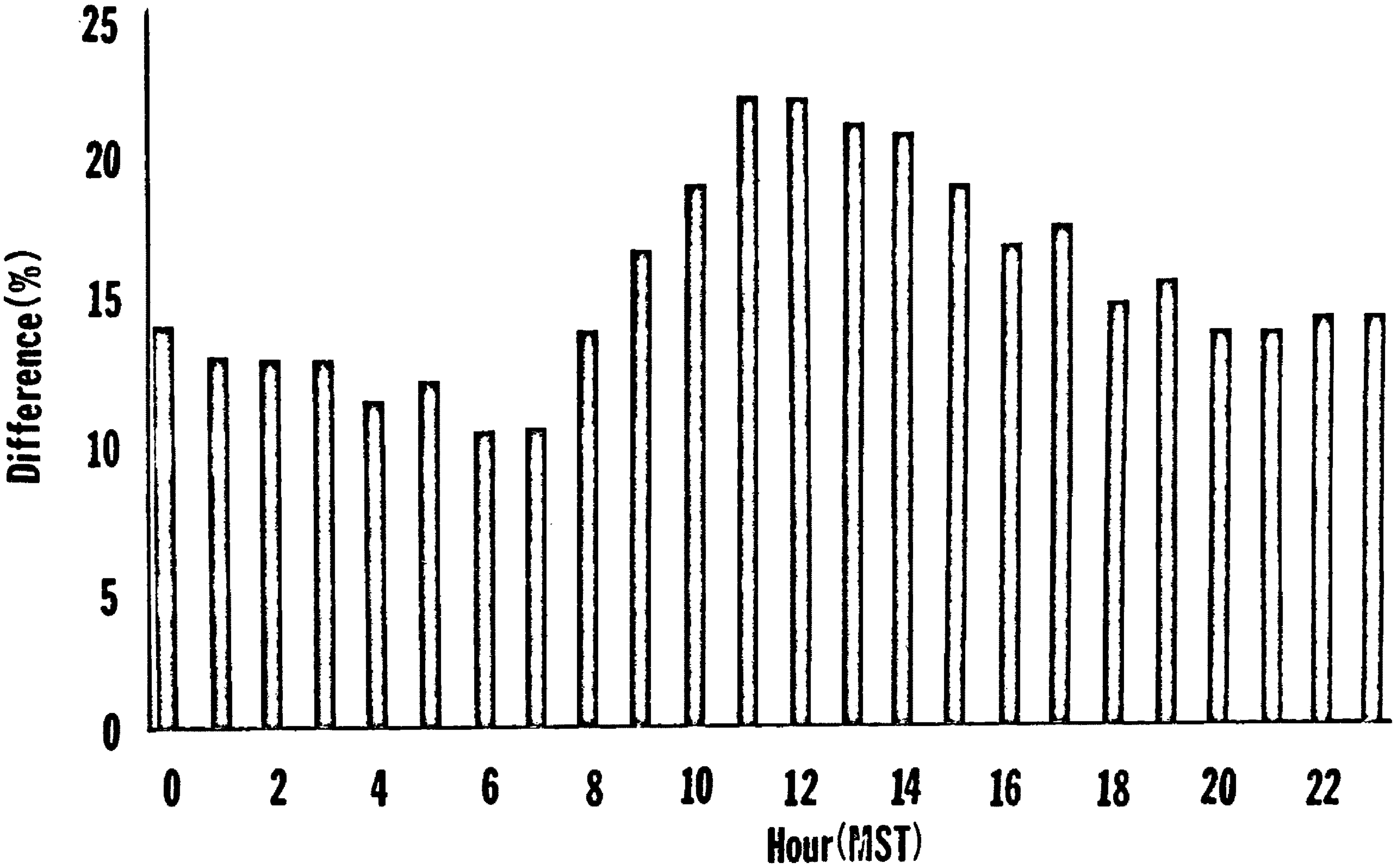


Figure 6. Average hourly relative humidities on south and north aspects (Sept. 11-Oct. 17)

Figure 7. Average hourly relative humidity differences between aspects, north minus south (Sept. 11-Oct. 17)



between the two slopes at 6:00 A.M. with a mere 0.3° F. temperature difference. Therefore, other factors must be looked for to help explain this discrepancy. It is suggested that the bulk of this difference was a result of two factors acting in combination. Soil moisture to four inches is substantially higher on the north aspect than the south (Shearer, 1969). Accompanying this higher soil moisture on the north slope is a lower wind velocity. At night, with radiational cooling, low velocity downslope winds develop. The heavier, cooler air flows downslope as a sheet (laminar flow). However, this is a low velocity movement, with relatively little mixing. In contrast, the south slope has lower soil moisture and higher wind velocity. This results in a lesser amount of evaporated moisture being mixed or diffused in a larger volume of air, i.e., lower humidity. The combination of these two factors probably accounts for most of the difference in humidity between the two slopes.

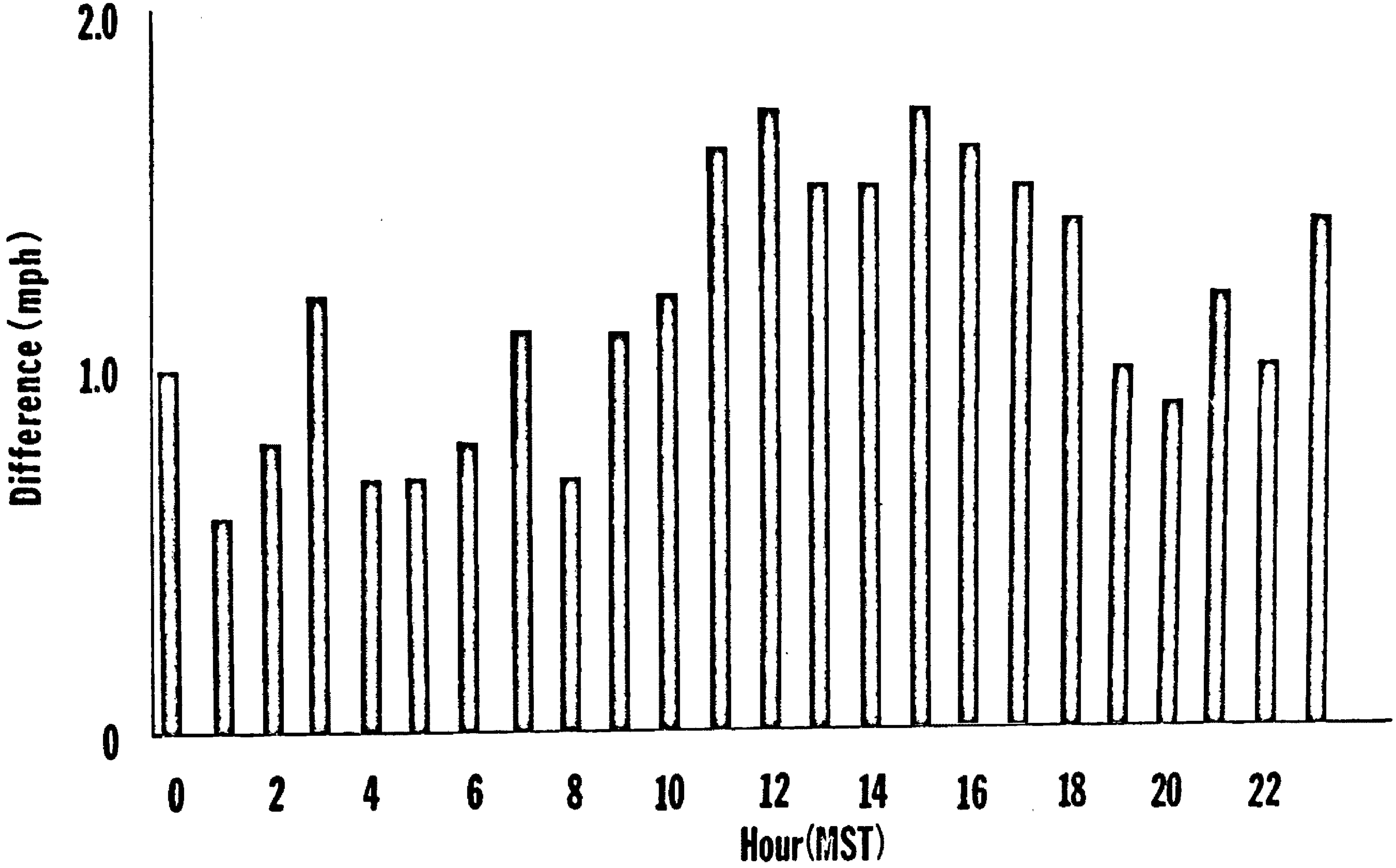
Interestingly, temperature minima and maxima were reached at the same time on the two slopes. However, relative humidity minima and maxima were reached one and two hours later, respectively, on the north slope than the south. Several reasons can be offered for this lag. First, the amount of moisture in the atmosphere at a given time comes from one of two sources, precipitation or evapotranspiration. Discounting precipitation in this discussion, evapotranspiration becomes the sole source of moisture. Relative humidity is a function of both moisture and temperature. In this situation, temperature has both a direct and indirect effect on humidity conditions. The direct effect is that with a given amount of moisture in the atmosphere, the higher the temperature, the lower the relative humidity, and vice versa. The indirect effect is through evapotranspiration, for with increasing temperature, transpiration increases. This has somewhat of a balancing effect, however, as a higher transpiration rate increases moisture in the air, but the increasing temperature that causes it reduces relative humidity. The lag could result from the response time required to increase respiration and, hence, the transpiration rate of the vegetation. That the heating was less direct and slower on the north aspect may account for the even greater humidity lag here than on the south slope.

Part of this lag could also be due to the recording instrument. Relative humidity sensors are one of the least sensitive and weakest of all weather measuring instruments (Steele, 1973). For example, hygrometer hairs can be brushed with water until saturated, yet not reflect a 100 per cent humidity reading for 10 minutes or more. In the less extreme conditions that occur naturally, this delayed response may be even longer. MacHattie (1966) stated that hair hygrographs are relatively inaccurate near saturation, so that differences in readings between the 95 per cent and 100 per cent classes are of questionable significance.

Wind

Diurnal wind velocity trends were similar in development at the two slope stations. Wind velocity was at a minimum at 8:00 A.M. at both stations (Figure 8), increased throughout the morning and early afternoon hours, and

Figure 8. Average hourly wind velocity differences between aspects, south minus north (Sept. 11-Oct. 17)

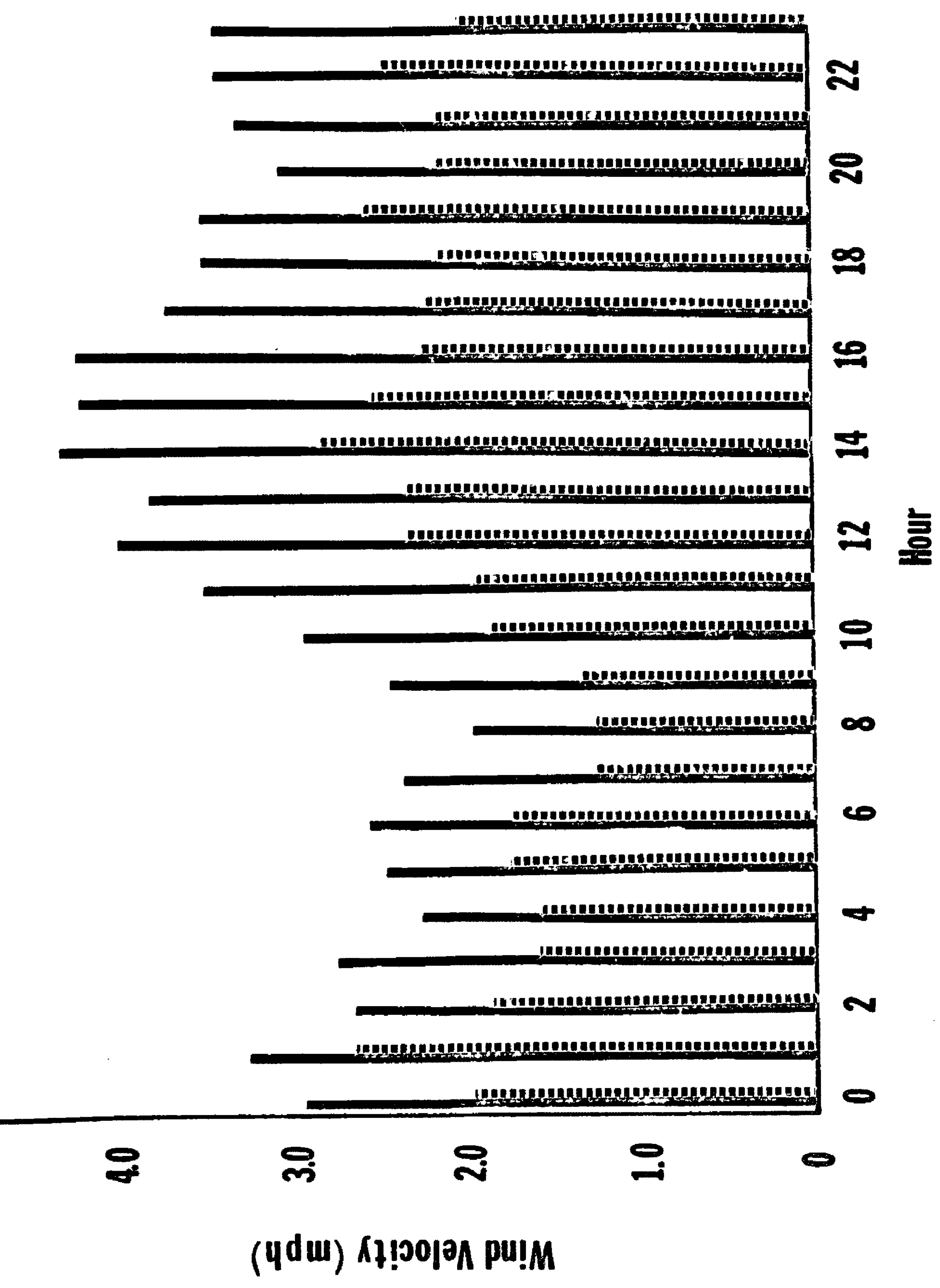


reached a maximum at 2:00 P.M. on both slopes. However, velocity was somewhat greater on the south slope than the north at all hours, day and night.

Whereas the same type of wind appeared to be acting on the south and north aspects, quite a different force seemed to be at work on the ridge. The ridge station shows little relationship to the two slopes, as the minimum wind occurred at 1:00 P.M., and the maximum at 10:00 P.M. Furthermore, the minimum wind velocity on the ridge was greater than the maximum on either the south or north slopes. Several explanations can be offered for these notable differences. The portion of the ridge in question is a shallow saddle between Newman Peak to the west and an unnamed high point to the east. The ridge station appeared to be dominated by synoptic scale general winds, rather than lower velocity local winds. This would reconcile both the effect of topography and general winds on measurements at the ridge station.

South was the dominant wind direction on the ridge every hour of the day and night (Figure 9). After considering winds aloft, as well as the topography, this rather surprising fact becomes easier to understand. The rather low velocity on the ridge from mid-morning to mid-afternoon, with a minimum velocity occurring at 1:00 P.M., may be the result of slope winds ameliorating the effect of the general wind. During mid-day hours of peak insolation, slope winds developed sufficient velocity to form a convection chimney at the ridge. Slope wind development with convective updrafts may be sufficiently strong at this time to prevent the general wind from lowering onto the ridge. During this period, wind velocity and direction on the ridge should reflect the local

Figure 9. Average hourly wind velocities on south and north aspects (Sept. 11-Oct. 17)



wind situation on the dominant slope. Since stronger slope wind development occurred on the south aspect than the north, wind direction should be, and was, similar for the south and ridge stations. The higher velocities recorded at the ridge station, as compared to the S-3 station, were probably due to a slight topographic effect of the saddle re-enforcing the slope wind.

During the evening and early morning hours, downslope winds were low velocity and of little consequence. Thus, some other source must be sought to explain the continued southerly flow of air on the ridge, and at higher velocities than occurred during the late morning and afternoon hours. The general wind has characteristics that could sustain the direction and modify the velocity. A check of 700 millibar synoptic charts for the period September 11-October 17, 1969, showed gradient winds at the 700 mb level to be predominantly southwesterly. However, gradient wind momentum that descends to the surface encounters topographic friction. McIntosh and Thom (1969) estimate that surface winds are, on the average, backed about 30° counterclockwise from the isobars in the Northern Hemisphere. Schroeder and Buck (1970) reported that directional deviation due to friction varies from 25° to 45°, depending on the roughness of the terrain. Considering the roughness of the Newman Ridge terrain, a directional displacement of nearly 45° would be expected. Frictional forces tend to displace the general wind in a counterclockwise direction, so that with the 45° displacement, the resultant directional flow was generally from the south. General winds are of higher velocity than local surface winds, accounting for the increased velocity recorded on the ridge during nighttime hours.

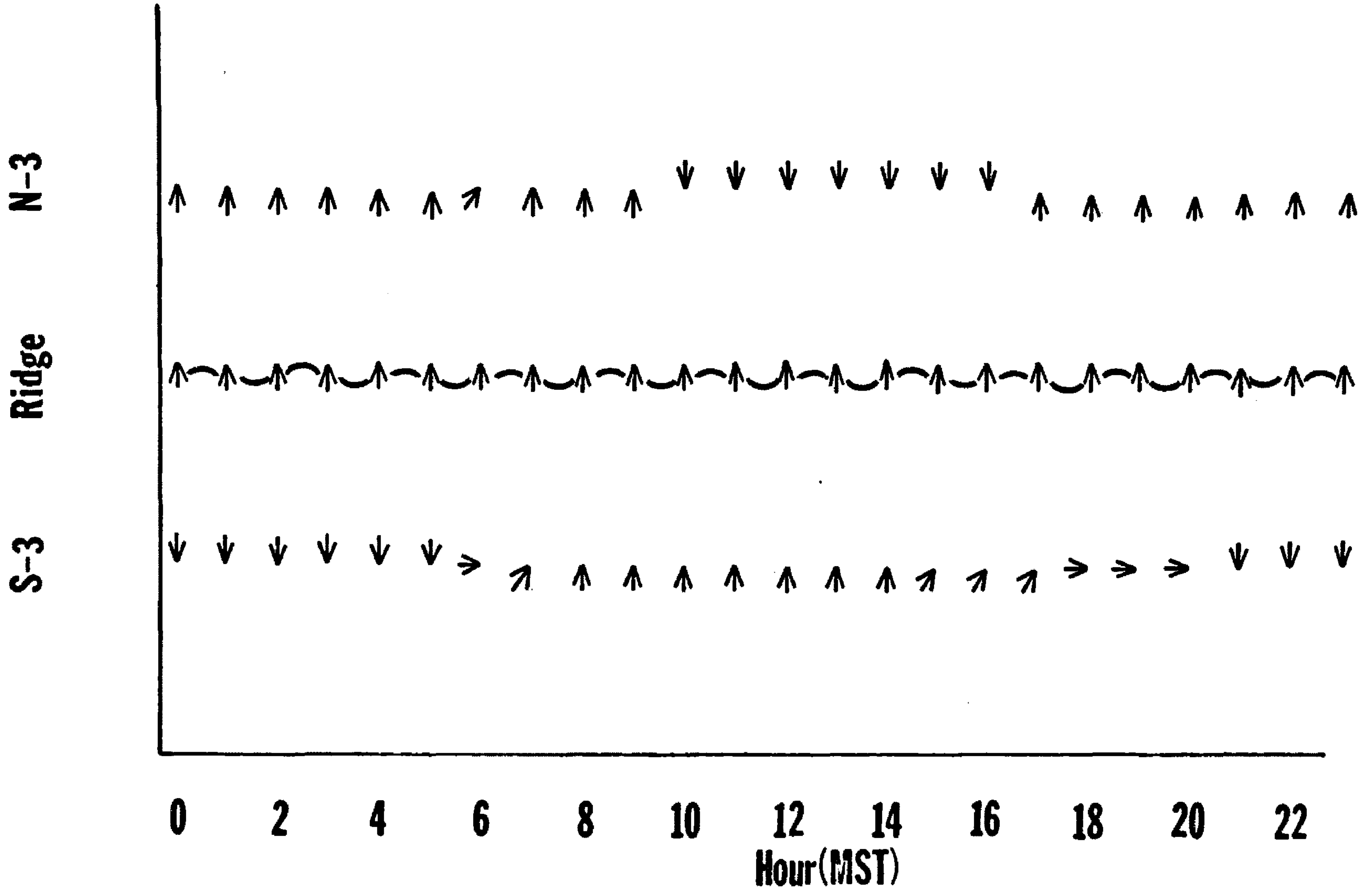
In his study of winds in Alberta, MacHattie (1968) postulated that local wind patterns may be less evident on clear days than on days when solar radiation is somewhat less intense. He reasons that convective activity on days of high radiation allows coupling of the surface wind with the gradient wind. This coupling action brings gradient wind momentum to the surface, obscuring the surface winds. He further suggested that the more intense the incoming radiation, the stronger the coupling. However, MacHattie's proposal does not appear to reflect measured and observed conditions at the ridge station.

Instead, the wind pattern on the ridge appears to follow quite closely the cycle suggested by Shcroeder and Buck (1970). They maintain that mid-day slope winds in mountainous terrain tend to push general winds aloft above ridgetops. The general wind flows over the convective currents rising from ridgetops. Frequently, the daytime upper winds are felt only on the highest peaks. When this condition exists, with the exception of the highest peaks, all surface winds are almost purely convective. Upslope winds combine with up-valley winds to determine wind speeds and directions at the lower elevations. With the weakening of upslope winds in the late afternoon and early evening hours, downslope flow begins, and general winds are again able to lower onto exposed ridges.

Diurnal wind patterns on the south and north aspects were more representative of classical valley-mountain wind theory. Considering a 24-hour cycle on the south slope, and beginning at midnight, downslope winds were prevalent (Figure 10). These winds were, in effect, a shallow layer of air "sliding down the mountain." This was a low-velocity, laminar movement which weakened very gradually until sunrise. Within a two-hour period after sunrise, wind direction had shifted from northerly (downslope) through westerly and southwesterly, to southerly (upslope). Wind velocity for this first hour of upslope motion was the lowest velocity of any hour of the day or night. As incoming radiation increased through the remainder of the morning and into the afternoon, wind velocity also increased, reaching a maximum at 2:00 P.M. In the next hour, the transition from upslope to downslope winds had begun, but in reverse order to what occurred in the morning. Wind direction shifted from southerly, through southwesterly and westerly, to northerly (downslope). This evening transition in direction took place over a six-hour period, whereas the morning shift required only two hours. At 9:00 P.M., the downslope winds were again in effect, and continued until midnight, completing the diurnal cycle.

In deriving slope wind components for a fuel moisture prediction model in California, McCutchan, et al. (1973) made the assumption that daytime upslope winds were a function of solar insolation and slope, with a maximum wind component possible at 20 feet of about 10 mph. Spot checks of wind velocity at the S-3 station on warm, sunny afternoons suggested a maximum slope wind velocity of about 8 mph at 10 feet. Downslope winds, on the other hand, were viewed by McCutchan, et al. as being a function of slope only.

Figure 10. Dominant wind components by hour on S-3, N-3, and the ridge between (Sept. 11-Oct. 17)



A somewhat similar cycle was operational on the north aspect, only here the changes were more abrupt. At midnight, downslope (southerly) winds were in effect. This was a gravity-powered movement, with the sheet of heavier air slowly flowing downhill. This downslope motion decreased in velocity but continued unabated until 10:00 A.M., four hours longer than on the south aspect. At 10:00 A.M., there was an abrupt change to upslope winds, as a result of direct sunlight first becoming incident on a portion of the slope. Velocity of the upslope wind increased reaching a maximum at 2:00 P.M., the same time the maximum was reached on the south slope. A weakening, upward flow of air continued until 5:00 P.M., at which time there was a sudden change to downslope winds. The transition in direction occurred four hours earlier here than on the south slope. Downslope motion held until midnight, with little hourly change in velocity, completing the diurnal cycle.

The use of Pibal weather balloons in conjunction with time lapse photography appeared to have merit as a means of visualizing wind behavior at the timber-clearcut interface. However, wind speeds in excess of 8-10 mph limited the usefulness of this method, as the balloons were either blown to the ground or into the seedwall and destroyed.

Smoke bombs activated in the canopy were effective in showing the wind regime into which a seed is released. At moderate wind velocities, the smoke cloud was observed taking on a definite roll, or eddy motion. The likelihood of such turbulent motion is even greater at higher velocities. But again, as with the balloons, high wind velocities made this method ineffective, as the smoke was dissipated so rapidly as to afford little time for observation.

Wind-Temperature Relationships

During the September-October seedfall period, the tendency for wind velocity to decrease at night and increase during daylight hours was noted. Since maximum and minimum average wind velocities coincided quite closely with maximum and minimum average temperatures, respectively, it seemed probable the two parameters were in some way related. In order to determine what relationship, if any, existed between temperature and wind velocity, linear regression methods were employed. Recorded values of temperature and wind velocity for each hour of the 37-day study period were used in the regression. The temperature element of each pair became the independent variable and the velocity element the dependent variable.

Regressions of wind on temperature were run for all hours, for daylight hours only, and for the hours 12:00 noon to 6:00 P. M. In each case, the coefficient of correlation was very low. It would appear that if wind-temperature relationships do exist, carefully planned sampling techniques would be needed to isolate them. Regular checks of barometric pressure would be required to identify high and low pressure systems and movement of fronts. Similarly, measurements of solar radiation would be necessary to classify daylight hours as being cloudy, partly cloudy, or clear. These measurements, and perhaps others, would be needed to determine whether general or slope winds were the dominant force at a given time. Only when slope winds were determined to be operational would a regression of wind and temperature be computed. Quite probably, however, a linear regression of wind on temperature is too simplistic an approach to describe changes in wind velocity. Instead, multiple regression would probably be a better method of determining relationships between wind and other environmental parameters. Wind velocity would again be the dependent variable, with temperature, solar radiation, barometric pressure, and relative humidity as the independent variables.

CHAPTER V

POSSIBLE MANAGEMENT IMPLICATIONS

After analyzing the data, one must ask what practical information the results may provide for management. Conclusions that can be drawn from the data must be qualified, in that the data are representative only of a given area and slope position. However, further studies could provide similar information for other locations, as well as for lower and midslope positions.

Keeping these limitations in mind, a new term is offered here that would allow at least a degree of objectivity to seedfall considerations. The term is "seed dissemination potential," and would be obtained indirectly from measurements of environmental parameters. Seed dissemination potential (SDP), as distinguished from regeneration potential, is concerned only with the mechanical means of dispersal, and not the physiological processes of germination and growth. Thus, dissemination considerations end when the seed hits the ground; whether the seed ever germinates is of no concern here.

Initially, estimates of SDP would be rough at best, but could be improved empirically with a larger data base. Though based on objective measurements, prediction of SDP would be in subjective terms, such as "poor," "fair," or "good."

In spite of a failure seed crop in 1969, a small number of seeds were collected in traps. Collected seeds were closely related to atmospheric conditions prevailing at the time of release. Of these, 83 per cent were released and dispersed in atmospheric conditions with a relative humidity of less than 50 per cent. For this reason, attention is focused on the period from 12:00 noon to 6:00 P.M., that time of day when relative humidities are lowest and wind velocities highest. This combination of factor levels optimizes chances of seed release and subsequent dispersal. Measurements of these factors would be used as the basis for predicting SDP, and would be taken during the autumn seedfall period.

For example, a location that commonly registers a relative humidity less than 50 per cent during the prime seedfall period from 12:00 noon to 6:00 P.M. would receive one point. If maximum wind velocity consistently occurred between 12:00 noon and 6:00 P.M., another point would be scored. Thus, a score of "zero" would indicate a "poor" SDP, a score of "one" a "fair" SDP, and a score of "two" a "good" SDP.

Taking data from the two aspects under consideration, the SDP can be predicted for each slope. Using the criteria outlined above, the north slope would score a "one" for a "fair" SDP rating, and the south slope a "two" for a "good" rating. The higher rating given the south slope is due both to the low relative humidities ($<$50 per cent) and maximum wind velocities that occur at this location during the prime seed dispersal period.

The value such a rating system may have for management purposes can only be conjectured at this time. One possibility is incorporating SDP estimates with other considerations in planning the size and shape of clearcuts.

One may, for example, be able to clearcut an area twice as large on one aspect as on another. Or, a generally square or circular shape may be the best design for adequate dispersal on one slope, whereas a long, narrow shape may be better on another. Again, looking only from the standpoint of getting suitable coverage by dispersal, a shelterwood or group selection may be advisable on a north aspect, while clearcutting may be acceptable on the south.

One advantage of such a method is that once an SDP is established for an area, parameters used in making the estimate would not have to be remeasured. Measurements used for predicting SDP could also be used in heat and water budget considerations.

CHAPTER VI

SUMMARY

Seed dispersal as related to atmospheric conditions and topography was studied on two Newman Ridge clearcuts. Units S-3 and N-3 were chosen because of their opposing aspect and proximity to each other.

A survey of the 1969 seed crop taken in late spring, 1969, forecast a poor seed crop. This forecast was borne out by the vast majority of empty seed traps following the prime seedfall season. Due to the lack of seed, it was not possible to identify seed dispersal patterns. The misdirected effort in placement of seed traps preceding the 1969 seedfall presents a good example for management. This experience points to the importance of synchronizing site preparation with an average or better seed year. When depending on natural seedfall for regeneration, the importance of good seed production while the site is still receptive cannot be overemphasized.

In spite of the lack of seed, temperature, relative humidity, and wind speed and direction were recorded continuously for the period September 11-October 17. These atmospheric conditions were recorded on an upper slope, south-facing clearcut (S-3), an upper slope, north-facing clearcut (N-3), and the ridge between. The purpose of collecting detailed information on these parameters was to relate seedfall to the weather conditions prevailing at the time of dispersal.

Average hourly temperatures and wind velocities were higher, and relative humidities lower on the south aspect than the north for all hours. Slope winds appear to dominate conditions at the S-3 and N-3 stations both day and night.

At the ridge station, the dominant wind direction was south for all hours, day and night. This suggested that slope winds were prevalent during daylight hours of peak insolation, but that general winds were dominant during the early morning and late afternoon hours, and at night.

Environmental relationships on both aspects indicate that slope winds were prevalent during the prime seedfall hours (12:00 noon to 6:00 P.M.) of low relative humidity and warm temperature. Therefore, with an average or better seedcrop, it is likely most seed disseminated on the Newman Ridge clearcuts would be dispersed by slope winds.

The term "seed dissemination potential" or "SDP" was introduced. SDP would be derived indirectly from measurements of relative humidity and wind velocity, and would be a method of rating the mechanical means of dispersal for an area. Though based on objective measurements, estimates of SDP would be in subjective terms, such as "poor," "fair," or "good." Of the two slopes studied on Newman Ridge, S-3 has a higher seed dissemination potential than N-3. The reasons for this rating were that S-3 has a weather regime of low relative humidity (<50 per cent), and maximum average wind velocity during the prime seed dispersal period (12:00 noon to 6:00 P.M.).

This approach may have management value when used with other considerations in planning the size, shape, and location of clearcuts. For example, solely from the standpoint of seed dispersal, clearcutting may be feasible on one aspect but not on another, or at one slope position but not another.

Detailed information on environmental parameters in relation to topography has many potential applications besides seed dispersal. Among these are uses in the study of windthrow, seedling survival, the spread of certain insects and diseases, and evapotranspiration and energy budget considerations.

If the extensive forests of the Northern Rockies are to receive intensive management in the foreseeable future, more than biological information is necessary. Additionally, establishment of a broad base of topographic and environmental data is needed as well. With continued study, it is hoped that before a treatment is applied to a forest system, it will be based not only on a knowledge of the system itself, but also on a knowledge of the mediums both supporting and surrounding that system.

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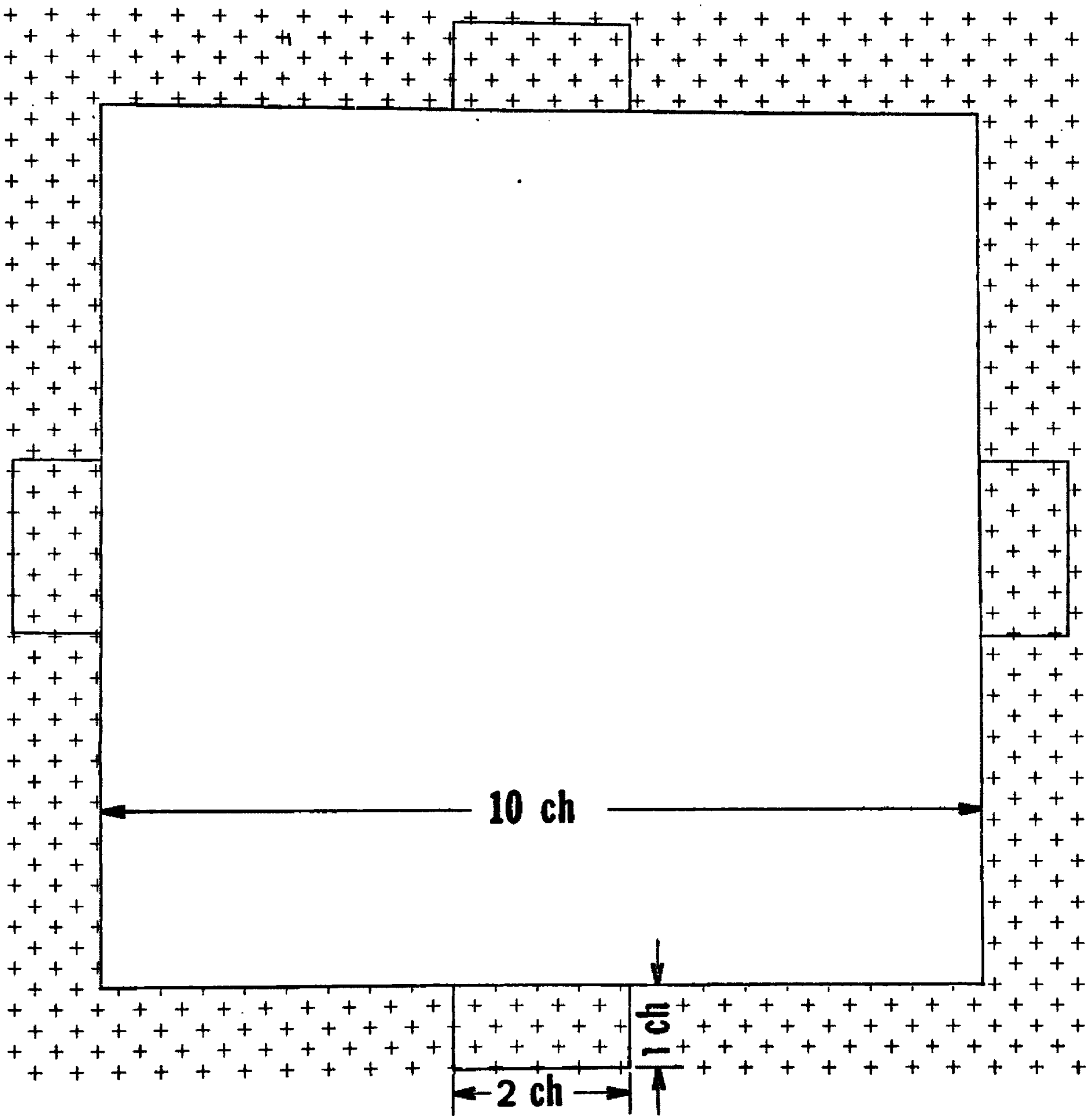
APPENDIX A

APPENDIX A

Sample plot locations within timber surrounding a clearcut.



APPENDIX B

UNIT NUMBER_____ PLOT NUMBER_____

Tree No.		DBH	B.A.	C.C.	Vigor	Total Rings (BH)		Tip Angle	Base Angle	Total Angle	Slope Dist.	Ht. above B.H.	Total Ht.	Crown Leng.
							Cl.Bole + Cr.							
							Cl.Bole							
							Cl.Bole + Cr.							
							Cl.Bole							
							Cl.Bole + Cr.							
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