DISPERSAL AND ESTABLISHMENT OF RED SPRUCE AND FRASER FIR IN THREE BALD AREAS OF THE SOUTHERN APPALACHIANS

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Research/Resources Management Report No. 41

by

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1980

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ABSTRACT

DISPERSAL AND ESTABLISHMENT OF RED SPRUCE AND FRASER FIR IN THREE BALD AREAS OF THE SOUTHERN APPALACHIANS

Three bald areas were selected for study to determine if red spruce and Fraser fir seeds were reaching them and to make general observations on rate of invasion and establishment patterns. The first area was a grassy bald completely surrounded by a spruce-fir forest. The remaining two areas were heath balds that could only receive seeds via long distance dispersal methods. One meter square seed traps using "Tangletrap" to trap seeds were placed in all these areas for one dispersal season. A small number of seeds were collected in the grassy bald, and none were collected in the heath balds. The low number of seed collected was due to a low seed production year in the adjacent spruce-fir forest.

The surrounding spruce-fir forest was aged along the ecotone between it and the grassy bald and found to be about 33 years old. Analysis of permanent plots revealed no negative associations between Fraser fir seedlings and existing species.

The invasion rate of spruce-fir into the grassy bald is quite slow. However, it is believed that the area will eventually be reforested. The two heath balds will remain predominately heath-shrub communities for several decades. The primary invaders into these heath areas will include beech, birch, northern red oak, mountain ash, and hawthorn.

INTRODUCTION

The term "bald" has been loosely applied to several types of treeless areas in the past. Some "balds" are presently covered with forest. For the purpose of this study, Mark's (1958) definition will suffice: "A bald is an area of naturally occurring treeless vegetation located on a well-drained site below the climatic treeline in a predominately forested region." Generally, in the southern Appalachians, two types of balds are considered, the heath balds which are composed primarily of woody ericaceous species, and the grass balds, dominated by the mountain oat grass Danthonia compressa, sedges, and assorted herbs.[1] In addition, many balds share characteristics of both these types.

Balds appear scattered throughout the southern Appalachian mountain region. They range in altitude from approximately 1385m (4500 ft.) to 2030m (6600 ft.). Balds are often surrounded by spruce-fir forests on their upper boundaries with a northern hardwood forest forming their lower border (Mark, 1958). Many balds occur on rounded domes of mountain tops, while others are found on southern or southwestern facing slopes. Historically, balds have been important to humans as lookout posts, campsites, game lures, pastures, and more recently as preserved areas in National Parks and National Forests (Wells, 1956; Lindsay, 1977). Many offer exceptional views and floral displays. As a result, balds, both heath and grassy, have been the subject of considerable study.[2]

[1]Nomenclature generally follows Radford, Ahles, and Bell (1974). Nomenclature for Betula allegheniensis follows Harden (1971).

[2]For a complete review of the earlier studies see Gersmehl's (1970) annotated bibliography.

The purpose of this study was to test the hypothesis that red spruce (*Picea rubens*) and Fraser fir (*Abies fraseri*) seeds are dispersed by wind into some bald areas, but that establishment is being halted or slowed by some unknown environmental factor(s).

Bald Origin

The subject of bald origin has been a matter of some controversy for many years, and numerous theories concerning bald origin have been postulated (Gersmehl, 1970). Two main theories have been presented. Human activity was suggested by Wells (1936a, 1936b, 1937, 1946, 1956) as the cause of bald origin. He suggested origin via clearing and settlement by the Cherokee Indians in prehistoric times for use as summer campsites, lookout points, and game lures.

Natural origins were assumed by Cain (1931), Camp (1936), Brown (1941), Whittaker (1956), Billings and Mark (1957), Mark (1958), Gersmehl (1970), and Lindsay (1977, 1978, 1979). Natural conditions which have been considered as possible causal agents of balds include climatic, edaphic, topographic, biotic, or pyric factors, or some combination of these.

Climatic factors were emphasized by several investigators. Brown (1941) suggested wind-throwing of trees as a possible origin and also (1953) noted some damage to seedlings by winter ice storms. This observation supported Harshberger's (1903) hypothesis that ice storms may have deforested the bald areas.

Cain (1942), Whittaker (1956), Billings and Mark (1957), and Mark (1958), attributed at least some importance to a post-Wisconsin xerothermic period which may have aided in the removal of hardwood and coniferous trees on some mountain summits. Mark (1958), labeled these as "Bald susceptible" zones.

Edaphic factors have been studied by Brown (1941), Cain (1931), Davis (1930), Fink (1931), Gilbert (1954), and Gersmehl (1970). Periods of soil moisture deficiency associated with thinness of soil cover and severe air temperatures have been postulated as factors in bald origin (Gersmehl, 1970).

Balds predominate on rounded summits or southwest slopes (Mark, 1958). Camp (1931) hypothesized that exposure, particularly that from desiccating southwesterly winds, was a major factor in bald origin. Whittaker (1956) believed that extreme exposure resulting in high water loss during dry periods could initiate bald formation.

Biotic factors may also contribute to bald origin. Grazing, browsing, and trampling by native animals, particularly deer, have been suggested as important factors in bald origin (Cain, 1942). Failure of orchard type growth form forests at high elevations to reproduce due to climatic conditions and the thick ground cover of grasses, which prevented seedling establishment, have been suggested by Davis (1930). He further suggested that retrogression from forest to bald would occur as these old trees died out. Also Gates (1941) proposed that twig gall wasps destroyed numberous hardwood trees and thus led to a bald condition.

Clements (1936) is perhaps the only author to propose that balds originated solely by pyric factors. Davis (1930), however, listed fire as a possible causal factor. In addition, several authors, including Cain (1942), Gersmehl (1970), Barden (1978), and Lindsay and Bratton (1980), recognized pyric factors as playing a role in bald maintenance.

The problem of bald origin is quite complex and is unlikely to have a universal answer. It would seem that each bald may trace its origin to a different set of circumstances.

Bald Maintenance

Some balds were in existence before the appearance of European man. Therefore, in addition to the question of origin, the question of bald maintenance must be considered. It is indeed an oddity that the normal processes of plant succession have not resulted in the reforestation of these treeless areas. In keeping with the question of origin, there have been numerous theories postulated in an attempt to explain bald maintenance. The question of maintenance may prove to be as difficult to answer as that of origin. Once again the theories may be grouped into those suggesting natural means of maintenance and those suggesting maintenance by some form of human interference.

One method of natural bald preservation is through competition between spruce and fir and existing species. This has been suggested by some authors. Wells (1936a) indicated that the balds may be maintained through root competition from the mountain oat grass (Danthonia compressa) which survives at an unusual type of subclimax. Some type of inhibition by blackberries (Rubus spp.) has been noted by Korstian (1937), who also suggested that red spruce (Picea rubens) seedlings may be out-grown by various other herb, shrub, and tree species. In addition, some allelopathic interference has been observed in heath balds by Gant (1978), who found several phytotoxins present in Rhododendron spp. canopy drip, leaves, litter, roots, and soil. Plants containing higher amounts of these compounds included Rhododendron maximum and R. catawbiense. Varying degrees of radical reduction were observed in three test species including, Abies fraseri, Betula lenta, and Tsuga canadensis.

Another possible explanation is that of the severity of the bald environment relative to that of the nearby forested areas (Gersmehl, 1970).

Gersmehl mentioned this possibility in his discussion of the "exposure hypothesis" for bald origin and maintenance, citing studies by Evan (1963), Zeigler and Grosscup (1883), Harshberger (1903), Davis (1930), Camp (1936), Brown (1941), and Whittaker (1956).

Several authors have also suggested that man has played at least an indirect part in the maintenance of balds through the grazing of his sheep and cattle in these high elevation natural pastures. That these areas were used as pastureland, before most were included in National Parks, National Forests, or other preserved and protected areas, has been well documented by Lindsay (1977) and others. Some of the authors who propose that balds may have been maintained at least in part by grazing or browsing include: Cain (1942), Camp (1942), Billings and Mark (1957), Gersmehl (1970), and Lindsay (1977, 1978, 1979).

On the other hand, it has been shown by Brown (1941) that transplanted red spruce and Fraser fir seedlings can indeed become established and be maintained in balds. It has been postulated (Billings and Mark, 1957; Mark, 1958; Gersmehl, 1970) that availability of a seed source and an adequate seed supply may be lacking. The problem of dispersal of seeds may depend on several factors which include: (1) availability of an adequate seed source, (2) distance of the seed source from the bald, (3) direction and velocity of prevailing winds and frequency of intense cyclonic disturbances, and (4) dispersal by agencies other than wind.

The lack of an available seed source may, in fact, lead to the maintenance of some balds. On the other hand, others may receive sufficient seed yet be maintained as balds by competition, severity of environment, other biotic factors such as grazing and browsing, fire, human interference, or a combination of these factors.

Bald Reforestation

In order to become reforested, the balds must have an adequate seed source or supply, must exhibit conditions suitable for germination of viable seeds, and must allow the seedlings to become established, grow, and reproduce.

Lindsay and Bratton (1980) have shown that reforestation is occurring on some balds. They have indicated that certain hardwood tree species will grow well within the bald environment. Working at Gregory and Andrews Balds (both in the Great Smoky Mountains National Park), they predicted that these balds were likely to be completely reforested by the years 2007 and 2042, respectively. Serviceberry (*Amelanchier arborea* var. *laevis*) was found to be the most abundant invading species on Andrews Bald, followed by Fraser fir. Hawthorn (*Crataegus flabellata*) and serviceberry were the most abundant in open areas of Gregory Bald, followed by northern red oak (*Quercus rubra* var. *borealis*), which grew well once established.

Reforestation has been linked with the cessation of grazing in these areas (Cersmehl, 1970; Lindsay, 1978, 1979). Grazing of domestic animals has been stopped on all but a few isolated cases where balds are still privately owned. Gersmehl (1970) suggested that this grazing played a part in opening up of shrubby areas and thus establishing a dominant grassy cover by suppressing woody generation. Bruhn (1964), Gersmehl (1970), Kring (1965), Lindsay (1977, 1978, 1979), Lindsay and Bratton (1980), Smathers (1979), and others have noted that considerable reforestation has occurred following the cessation of clearing, logging, and fires by man (Gersmehl, 1970).

On the other hand, some balds do not seem to be undergoing a similar rapid or marked reforestation. The complexity of the bald environment once again becomes apparent. Factors which may lead to the reforestation of one bald yet allow another to remain are not yet fully understood. Man's use of balds is important in this respect. Lindsay and Bratton (1980) have suggested that succession in bald areas is slower than in areas at lower elevations. They also noted that bald succession is faster in fire-scar areas. Barden (1978) concluded that fire was needed at least every five to eight years to retard reforestation. Smathers (1979) has noted that, since the cessation of livestock grazing in the Craggy Mountains, invasion of beech, birch, and mountain ash is replacing the heath-grassland areas.

The process of reforestation in balds must be examined with respect to each individual area. Factors such as historic origin, topography, climate, soil conditions, present vegetation (both within and surrounding the bald), as well as previous and present usage by man must all be considered.

This study will attempt to answer the following specific questions in regard to the individual areas studied:

(1) Do some balds receive a conifer seed supply while others do not?

(2) What are potential seed sources?

(3) How are red spruce and Fraser fir invading these areas?

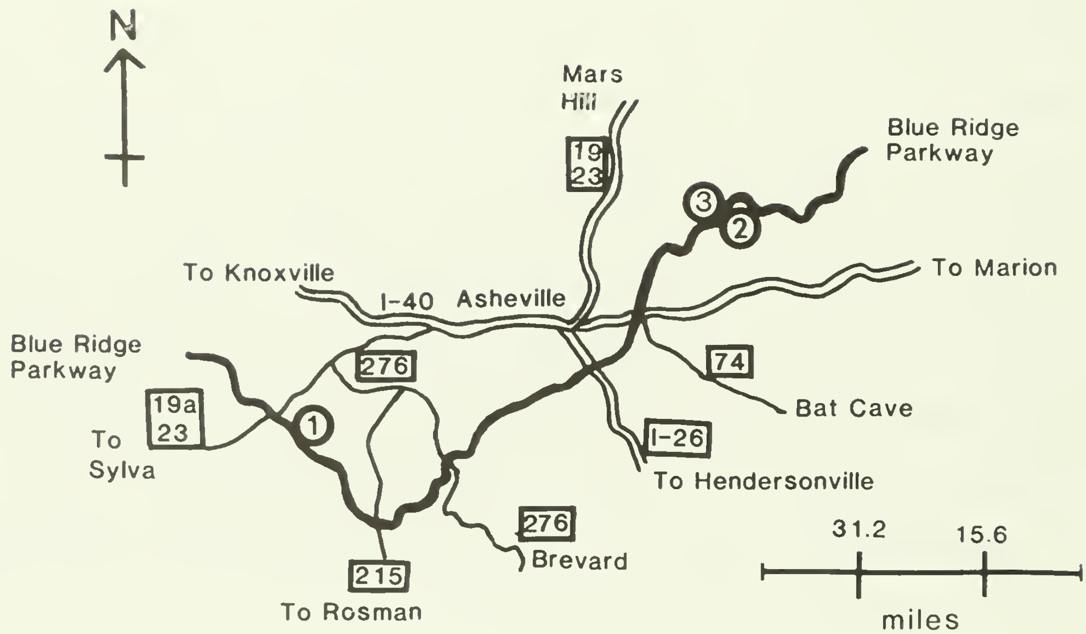
(4) Are seedlings becoming established in any particular positive or negative association with preexisting species?

(5) Are long-term growth and establishment taking place?

(6) What, if any, long-term vegetational patterns may be predicted for the areas studied?

Study Sites

Three areas were selected as study sites. All three are located along the Blue Ridge Parkway in the Blue Ridge Province of the Southern Appalachian Mountains (Fig. 1).



1. The Judaculla Fields, Blue Ridge Parkway mi. 432.
2. The Craggy Dome, Blue Ridge Parkway mi. 364.
3. The Craggy Flats, Blue Ridge Parkway mi. 365.

Figure 1

Location of Study Sites

The Judaculla Fields are two quadrangular treeless areas of about one-half and one hectare each. The fields are located at latitude N 35°22' and longitude W 82°59' at an elevation of 1856-1908 m (6000-6200 ft.). There is a potential spruce and fir seed source surrounding the entire area (Fig. 2). Thus, the area is suitable for a seed dispersal study. The upper Judaculla Field was used because it was somewhat more isolated or obscure from potential visitors, and therefore, less likely to be tampered with. This area is also easily accessible from the Blue Ridge Parkway.

The upper field or plot of the Judaculla Fields is surrounded by a spruce-fir forest as described by Gersmehl (1970), with fir being the dominant species. The transitional area between the bald and the forest consists of ecotonal areas ranging from about two to ten meters. There is a projection of large trees which enters the bald from the east. This divides the eastern half of the bald into an upper and a lower section for about 45 m. A grassy corridor about 10 m wide separates this section of large trees from the main forest.

Within the bald proper there are three adult trees present. These include a red spruce, a Fraser fir, and a hawthorn (Crataegus punctata). The remaining woody vegetation is composed predominately of patches of blackberries (Rubus canadensis) and of the low-bush blueberry (Vaccinium vacillans). The predominant herbaceous and grassy vegetation includes Danthonia compressa, D. spicata, and Solidago spp. These grassy herbaceous areas are most often located in the northern areas of the bald.

The second site, Craggy Dome, consists of a heath bald. The Dome is located at latitude N 35°42' and longitude W 82°22' at an elevation of 1870 m (6080 ft.). There is no immediate seed source for this area (Fig. 3). However, there are a few established red spruce and Fraser firs on the southern

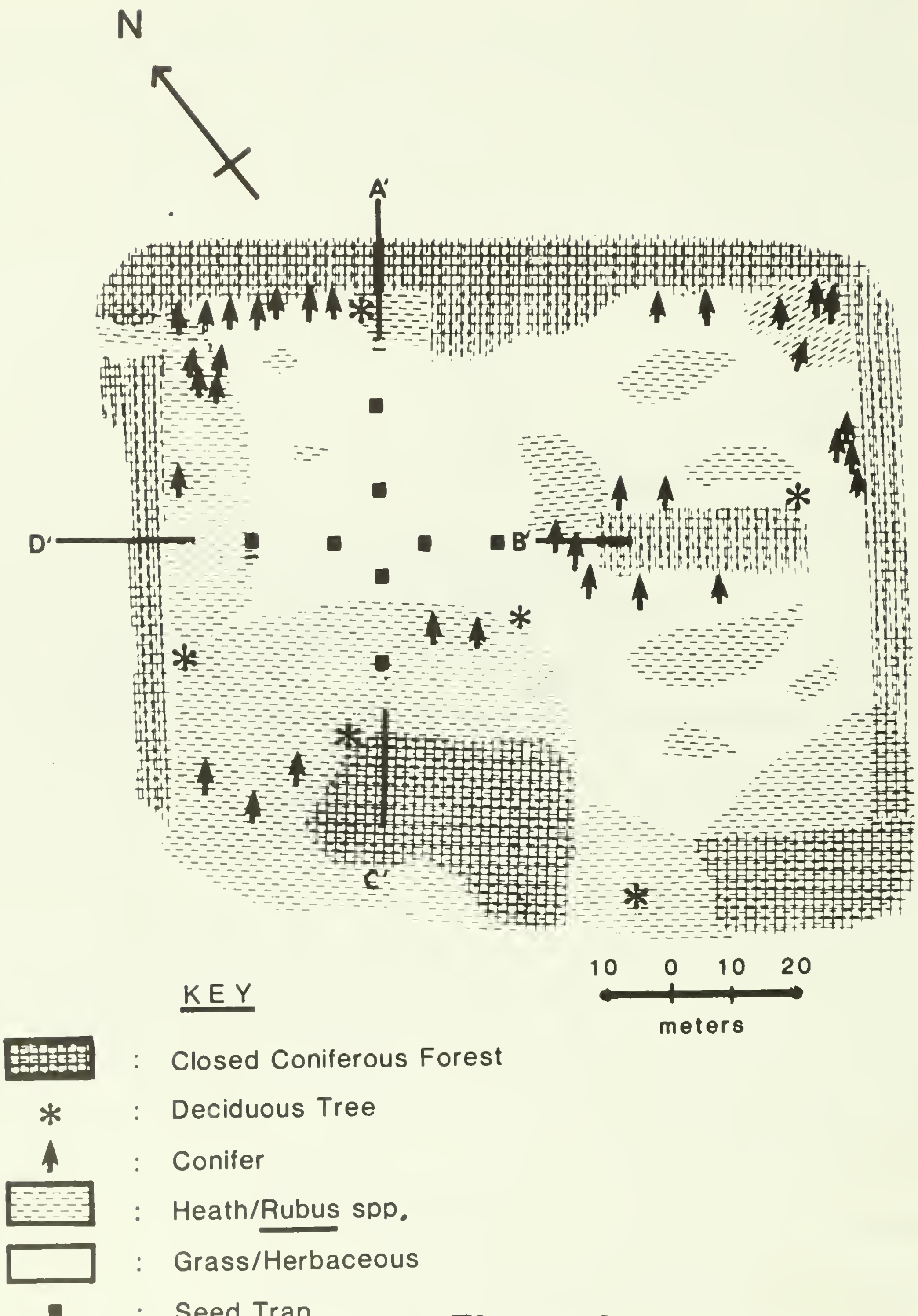


Figure 2

The Upper Judaculla Field

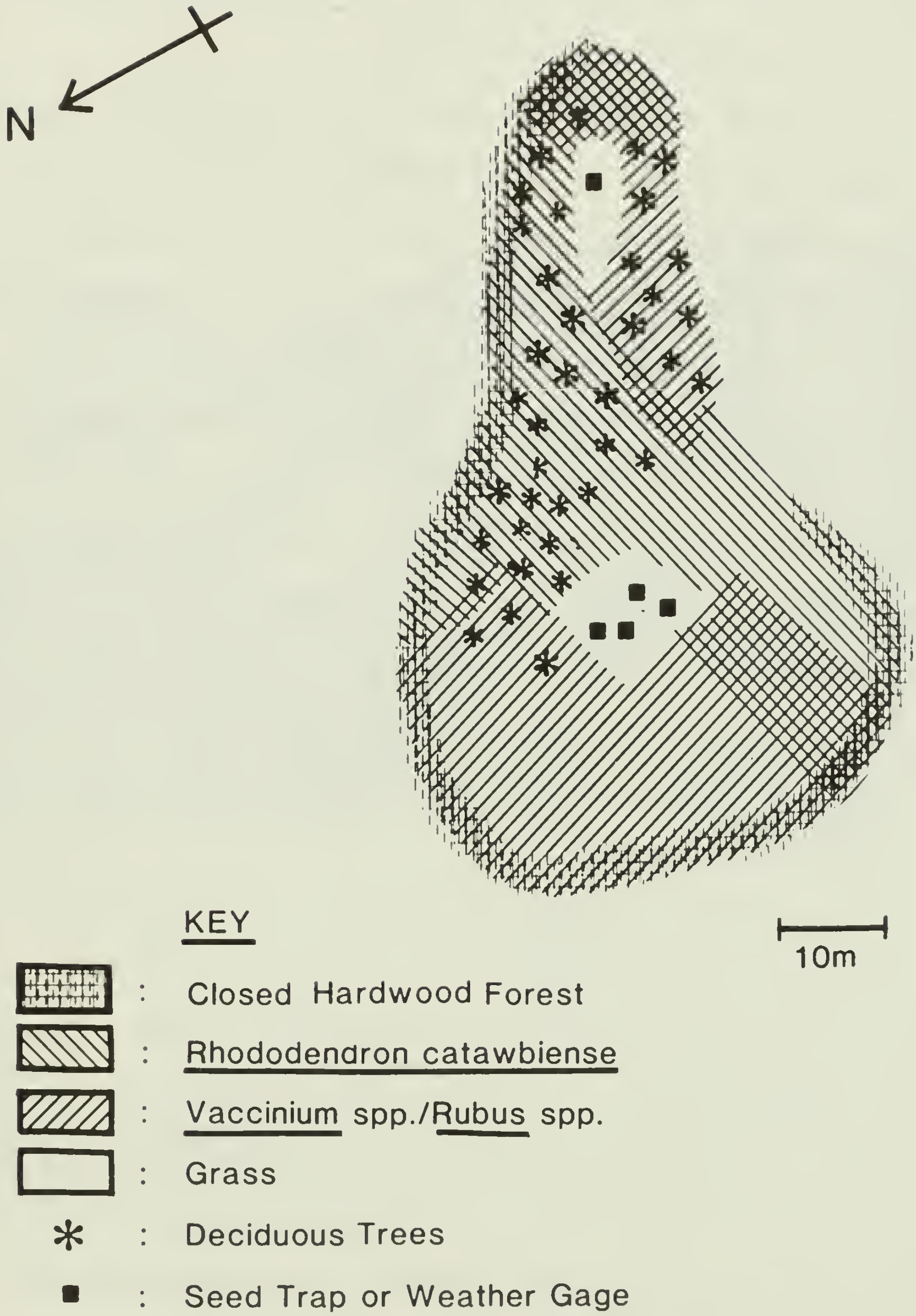


Figure 3

The Craggy Dome

and eastern slopes. These trees are scattered at around 1630 m (5400 ft.) and 1754 m (5700 ft.) and are of reproductive age.

In addition, at least one spruce seedling and several hemlocks (Tsuga canadensis and Tsuga caroliniana) are established on the near-bv Craggy Pinnacle (Smathers, 1979). Potential seed sources for the Craggy Dome and Pinnacle are the Black Mountains about 5.5 km away and two spruce plantations on Bullhead mountain about 1.2 km away, both to the north.

The dominant species on Craggy Dome is Rhododendron catawbiense. The immediate adjacent areas are also dominated by R. catawbiense with numerous high-bush blueberries (Vaccinium constablaei). Several beeches (Fagus grandifolia) are also present. The forest surrounding the dome consists of a typical high elevation beech-birch forest. The beeches and yellow birches (Betula allegheniensis), which dominate this forest, are characteristically gnarled and twisted with greatly reduced apical dominance due to the severe environmental factors affecting them.

The third area, Craggy Flats, is located about 1.5 km southwest of Craggy Dome and consists of a heath-grassland bald (Fig. 4). Located at latitude N 35°41' and longitude W 83°23' at an elevation of 1784 m (5800 ft.). There are no established spruce or fir trees present. The previously mentioned Black Mountains and the spruce plantations on Bullhead Mountain may serve as a seed source for this site. In addition, a plantation at Bee Tree Gap may serve as a potential seed source. This plantation lies to the southwest and is approximately 1.5 km away.

The Craggy Flats area is composed predominately of Rhododendron catawbiense, Rubus canadensis, Vaccinium constablaei, and V. vacillans. Scattered tree species include hawthorn (Crataegus spp.), beech, and northern red oak

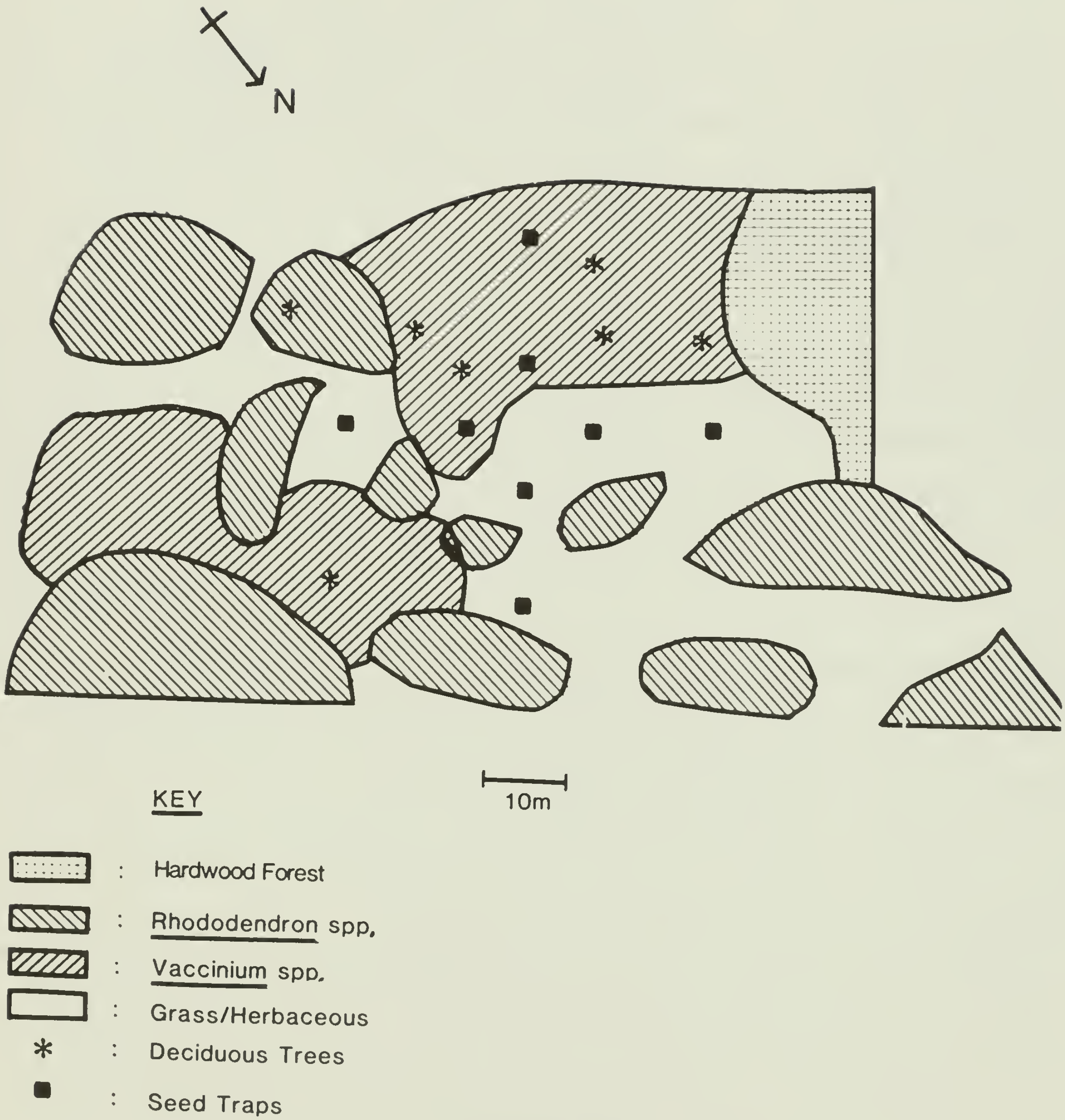


Figure 4

The Craggy Flats

(_Quercus rubra_ var. _borealis_). Interspersed in the clumps of heath are patches of grassland. The predominant herbaceous species is the mountain oat grass with some sedges (_Carex_ spp.) and goldenrods (_Solidago_ spp.) also present. Forests surrounding the area are very similar to those described for the Dome area with the addition of more northern red oaks and yellow buckeyes (_Aesculus octandra_).

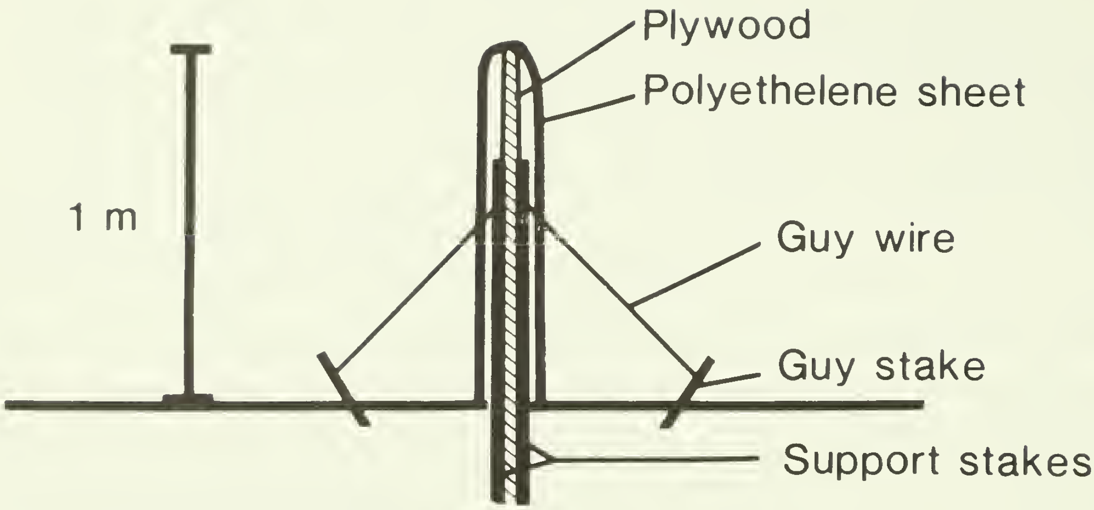
METHODS AND MATERIALS

The establishment of red spruce and Fraser fir forests in heath or grass balds hinges on three important steps: (1) A sufficient number of viable seeds must be dispersed into the area. (2) These seeds must germinate and grow into seedlings. (3) The seedlings must then develop into mature adults capable of reproduction. These three stages in bald reforestation were studied by three techniques: (1) seed trappings, (2) increment corings, and (3) vegetation analysis. In order to determine whether spruce and fir seeds reach certain bald areas, three such areas (Judaculla Fields, a grassy bald; Craggy Dome, a heath bald; and Craggy Flats, a heath-grassland bald) were selected for seed trapping studies.

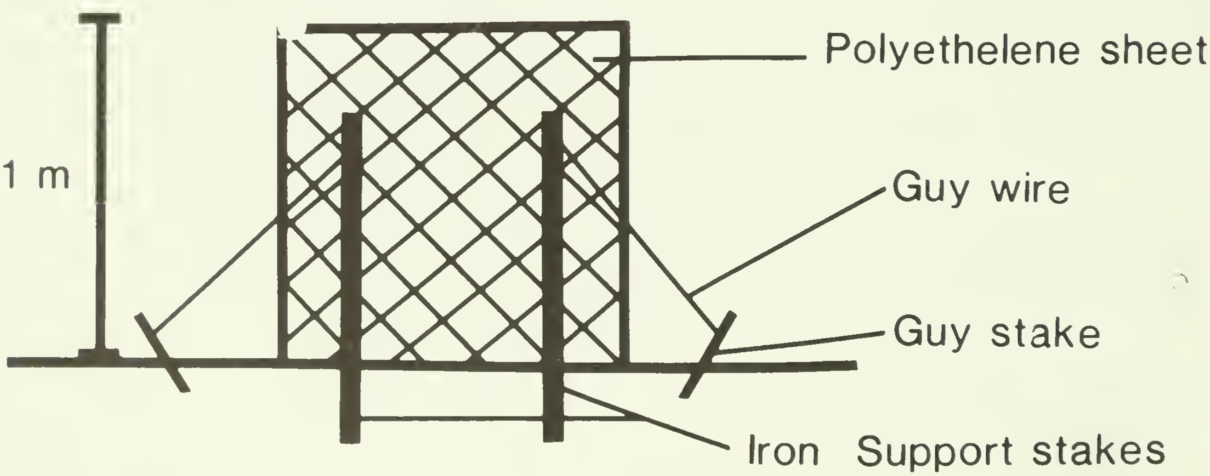
Seed Traps

Seed traps were placed at each of the areas mentioned. The trappings in this study were designed to (1) show the quality of seeds which reach these areas, and (2) indicate the direction and distance of seed dispersal.

The seed traps used in this study consisted of 1 m^2 sheets of 0.6 cm AC exterior plywood covered with sheets of 0.6 mm thick polyethylene coated with "Tangletrap," a sticky substance used for trapping insects. Tangletrap is insoluble in water and will not lose its effectiveness even under extremely wet conditions. The traps were secured to the ground vertically by 1.2 cm diameter concrete reinforcement bars driven approximately 61 cm into the ground where possible. Some traps required guy lines to support them in the areas with shallow soil. Guy lines secured the traps at ground level to avoid destruction by high winds, and offered a vertical trapping surface (Fig.5). The front and back sides of the traps were coated with a



A. Side View



B. Facial View

Fig. 5
Seed Traps

thin layer of Tangletrap to give a total trapping area of 2 m^2 for each trap. The vertical position and surface orientation of the traps made it possible to determine the direction of seed dispersal.

Eight traps were placed in the Judaculla Fields and eight in Craggy Flats. Two traps were placed on Craggy Dome. Placement of traps at Judaculla Fields and Craggy Flats included four facing southwest-northeast and four facing southeast-northwest, giving a total of 4 m^2 collecting areas to each quandrant. The traps were placed in two transects of four traps each, which intersected each other as a cross (Fig. 6). At Craggy Dome two traps were placed at right angles to the direction of potential seed sources (the Black Mountains and lower Craggy Dome).

Traps were checked at two-week intervals and the polyethylene replaced as needed. The plastic sheets were then checked for their content. Collections were made from September through March to coincide with the time of dispersal (Radford, Ahles, and Bell, 1974; Fowells, 1965) and to observe any late dispersal in winter.

Increment Corings and Bisects

The seed source stand at Judaculla Fields was aged by increment boring. Trees that were either observed or judged to be of reproductive age were cored, and the diameter at breast height (dbh) was taken. Only those trees that directly faced the bald with no other trees obstructing potential seed dispersal from the major side and upper branches were considered. Some seeds may have been blown in from more distant sources by convention and/or severe wind conditions, or carried in by other vectors such a birds or rodents. However, it is believed that the percentage of seeds reaching the bald by these means

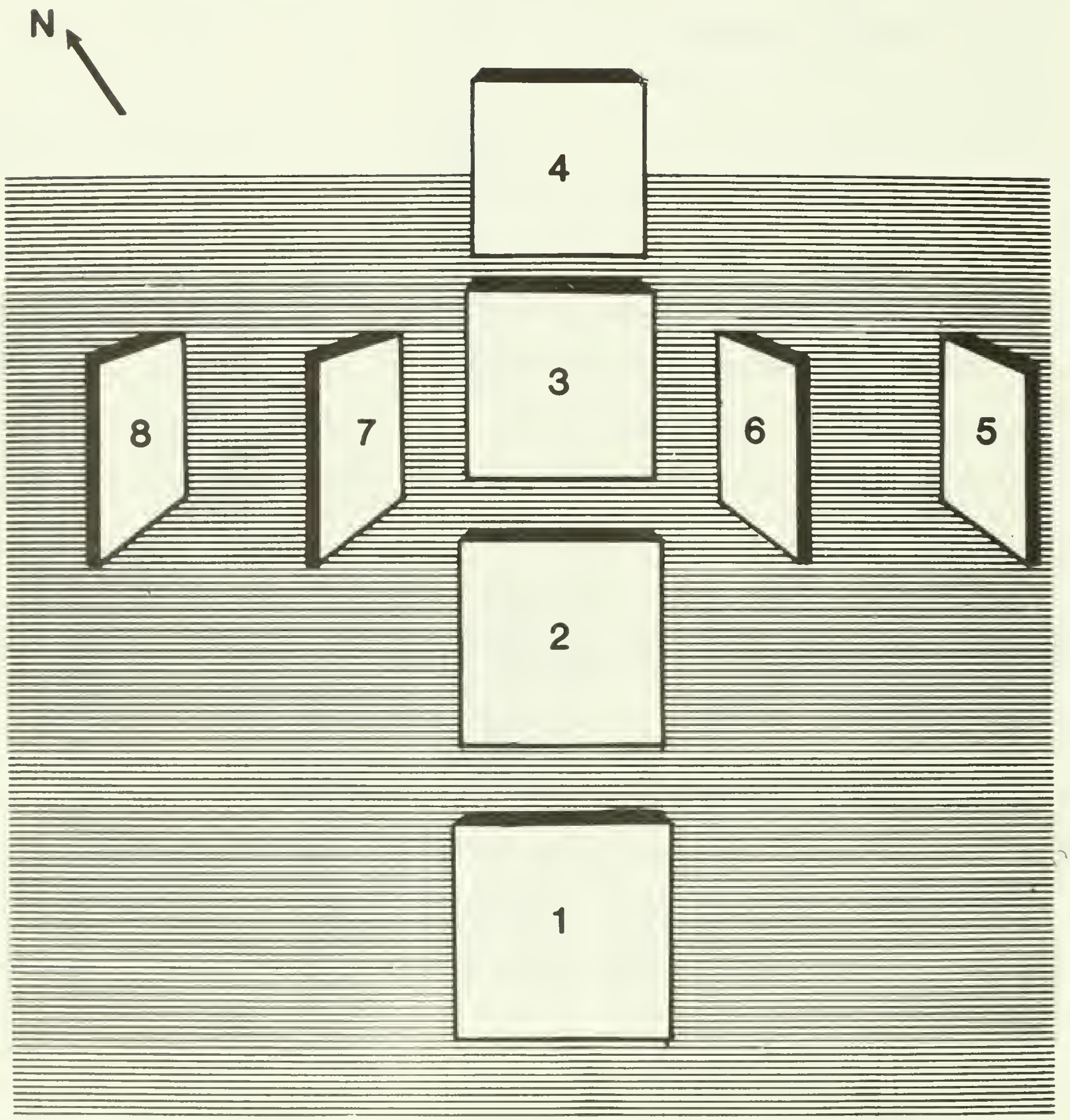


Figure 6
Trap Placement, Number, and Orientation
at Judaculla Fields.

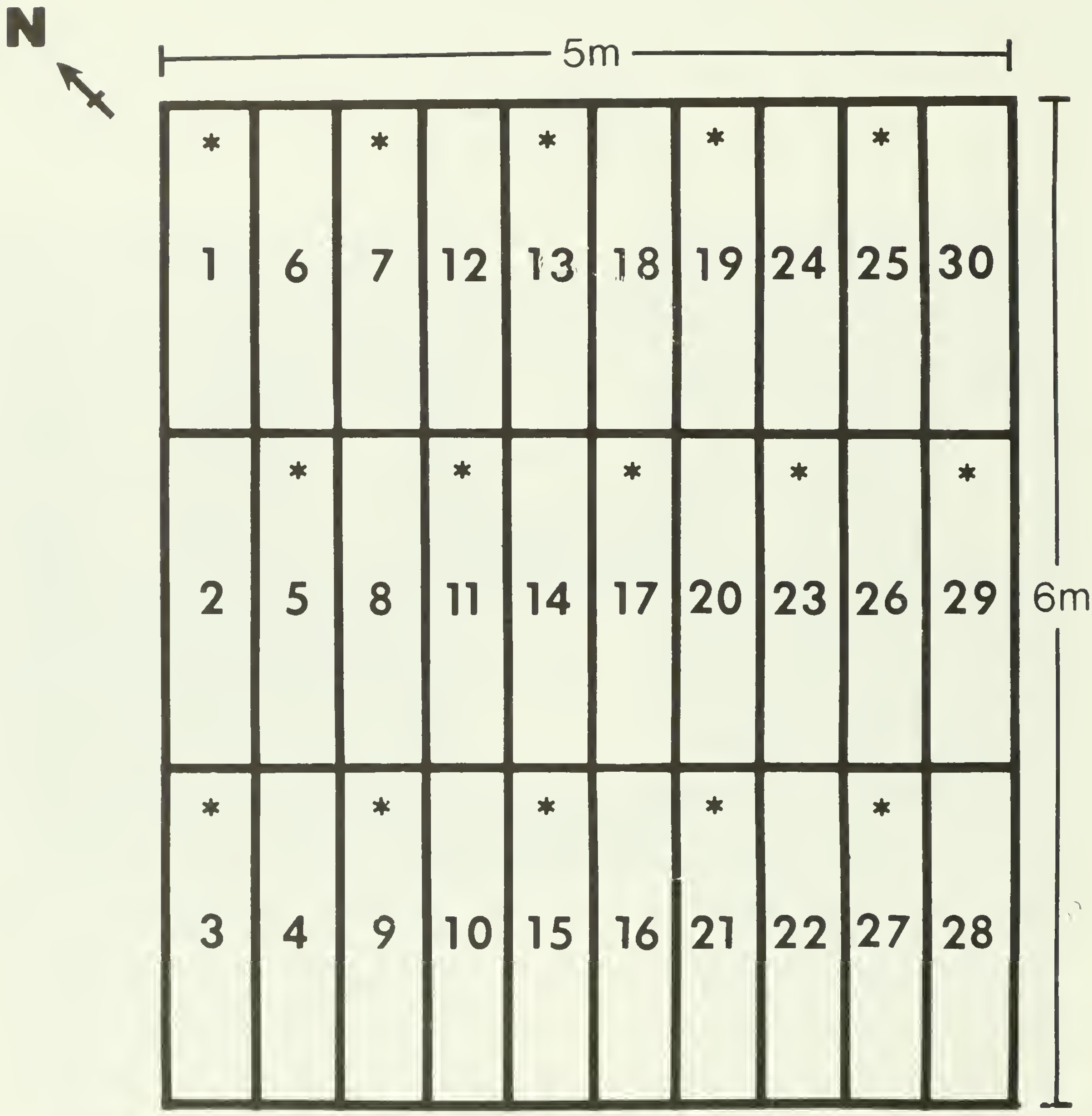
was so low as to be insignificant for the purpose of this study. These corings helped show how long the area had received seeds.

To evaluate further the invasion into the bald, bisects were prepared in accordance with Oosting (1958), and profile diagrams drawn as in Beard (1944). Four such bisects were prepared, one beyond each seed trapping transect.

Vegetation Analysis

Some seedlings are becoming established within the Judaculla Fields. However, it has been suggested (Cain, 1931; Korstian, 1937; Gant, 1978) that some form of competition, either physical or chemical, may result in the failure of many seedlings to become established. Therefore, plots were sampled within the Judaculla Fields to determine if any positive or negative associations were apparent between the fir seedlings and the dominant species present. Geographic location and species list of sample plots are given in Appendix A and B.

Permanent plots containing seedlings were selected for sampling. Plots in which no seedlings were found were designated as non-seedling areas to be compared with seedling areas. Four plots 5 m wide by 6 m long were subjectively selected to include areas with and without seedlings present. Within each plot subplots were established. They were one-half by two meters long. Cover in the subplots was estimated by the relevé system of Mueller-Dombois and Ellenberg (1974). Subplots were numbered in lengthwise progression proceeding up and down the rows (Fig. 7). Odd numbered subplots were sampled in order to avoid duplicate or overlapping samples. Four permanent plots were sampled; fifteen subplots were sampled for each permanent plot. Relative coverage and frequency estimates were determined according to Pittillo and Smathers (1979).



* Indicates Subplots Actually Sampled.

Figure 7
Permanent Plots

All plots were reexamined in the spring of 1980 to observe conditions of the spruce and fir seedlings following winter.

Contingency tables were used to determine whether any associations existed between the occurrence of Fraser fir and any other existing species. Two by two contingency tables were set up and Chi Square tests were performed to determine if differences between observed and expected numbers of simultaneous occurrences were due to chance alone. Yates' correction factor for continuity was made due to the small sample size, and the conventional level of five percent probability was used to indicate a significant difference in observed and expected values.

Finally, due to limitations, the third question, that of long term growth and establishment, was only considered in a general way based on observations of existing conditions. This included a general assessment of the number and conditions of existing established seedlings or young adult trees. Additionally, observations pertaining to potential reforestation capabilities of these areas were suggested.

RESULTS

The results are presented in three sections: (1) Seed Trappings, (2) Increment Corings, and (3) Vegetation Data.

Seed Trappings

Eight conifer seeds were trapped. These seeds included three of Fraser fir and five of red spruce (Table I). All seeds were collected in the Judaculla Fields.

Two fir seeds were collected from the northeast and one from the southeast. One spruce seed was collected from the southeast and four were collected from the northwest. No seeds were collected from the southwest.

Three general observations are apparent from the above results. (1) Seeds were collected on five of the eight traps. (2) Six of the eight seeds were collected from the northeast or northwest. (3) Five of the eight seeds or 62.5% were spruce despite the observed dominance of Fraser fir in the surrounding forest.

Other materials collected by the traps included numerous flies and other insects, spiders, bits of leaves and grasses, and a variety of herbaceous (mainly Asteraceae) seeds which were not identified.

Although no seeds were collected at Craggy Flats or Craggy Dome, these traps appeared equally effective in catching the above materials.

Traps of all sites collected the insect and vegetative materials in relatively equal quantities.

Traps at both the Craggy Dome and the Craggy Flats attested to the severe winds prevalent on such high elevation unprotected areas.

TABLE I

Results of Seed Trapping Experiment

Trap #	Trap Side	Direction	Species	Location	Date
					1979
7	*D	NW	Spruce	Judaculla	10/ 9
3	B	NE	Fir	Judaculla	10/16
5	C	SE	Spruce	Judaculla	10/16
6	D	NW	Spruce	Judaculla	10/16
2	B	NE	Fir	Judaculla	10/31
6	D	NW	Spruce	Judaculla	10/31
7	C	SE	Fir	Judaculla	10/31
6	D	NW	Spruce	Judaculla	11/13

*Refers to trap orientation. A = southwest; B = northeast; C = southeast; D = northwest

Due to severe winds at Craggy Dome and Craggy Flats, traps were subject to being blown over as well as to tears and rips in the polyethylene cover. These tears results in traps being stripped of their plastic covering and thus rendering the traps ineffective for trapping seeds. Traps at these areas required more repairs than did the traps at the Judaculla Fields.

Increment Corings and Bisects

A total of 86 trees were cored to determine the approximate age and composition of the forest ecotone surrounding the upper Judaculla Field. The forest ecotone is primarily a fir forest with spruce being the only other canopy species present. Fraser fir accounted for 71% of the trees cored (Table II). The average age of the ecotone forest was 32.6 years. Predictions pertaining to previous seed supply to the bald was based on these ages. Fraser fir tended to grow slightly faster than did the red spruce (0.89 cm/yr vs. 0.86 cm/yr).

The oldest trees cored were a 65-year-old red spruce and a 62-year-old fraser fir. Trees ranged in size from 12.9 to 64.1 cm. In addition, several other large fir trees were observed but not cored. These large trees were dead, apparently due to the balsam woolly aphid (*Adelges piceae*) infestation. Also several other trees were found with aphid infestation. The forest height was estimated to be between 18.4 and 20 m (60-65 ft.).

The bisects (Figs. 8-11) revealed that the bald-forest transition zone ranged from approximately two to ten meters in width. Position of the ecotone bisects is shown in Figure 2.

Plot Analysis

Of the 60 subplots sampled, 28 (47%) contained fir seedlings. Only one plot, however, contained spruce seedlings. The fir seedlings accounted for

TABLE II

Age, Size, and Species of Trees Cored

Species	Number	%	Age Range (avg. age yrs.)	Range of dbh (avg. in cm.)	Average Growth Rate (cm/yr.)
Abies faseri	61	71	*15-62+ (30.2)	17.9-64.1 (26.75)	.89
Picea rubens	25	29	17-65 (38.5)	16.3-52.1 (33.14)	.86
Total	86	100	15-65 (32.6)	12.9-64.1 (28.61)	.88

See Appendix C for complete field data.

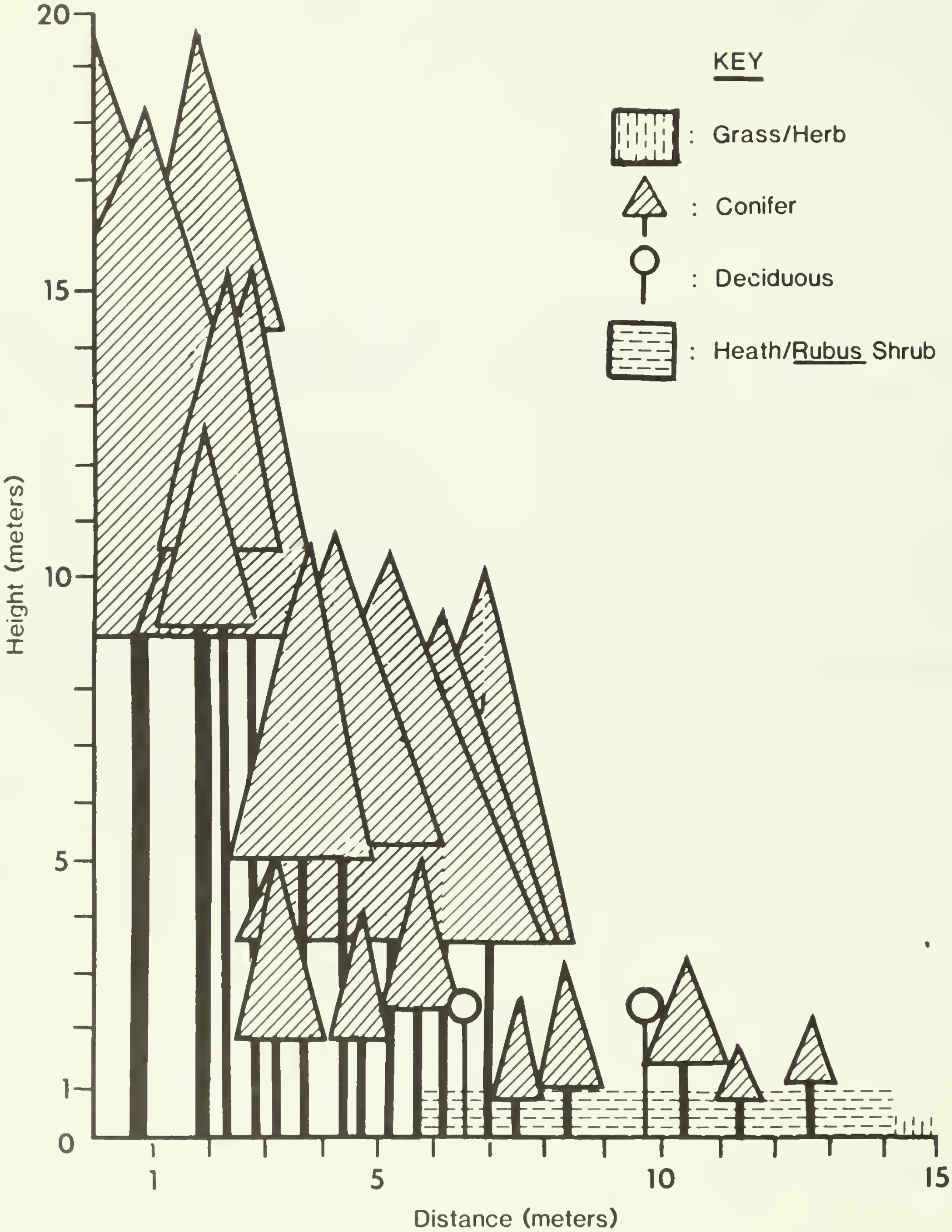


Figure 8

Profile Diagram (Bisect) of Northeast Ecotone-A'

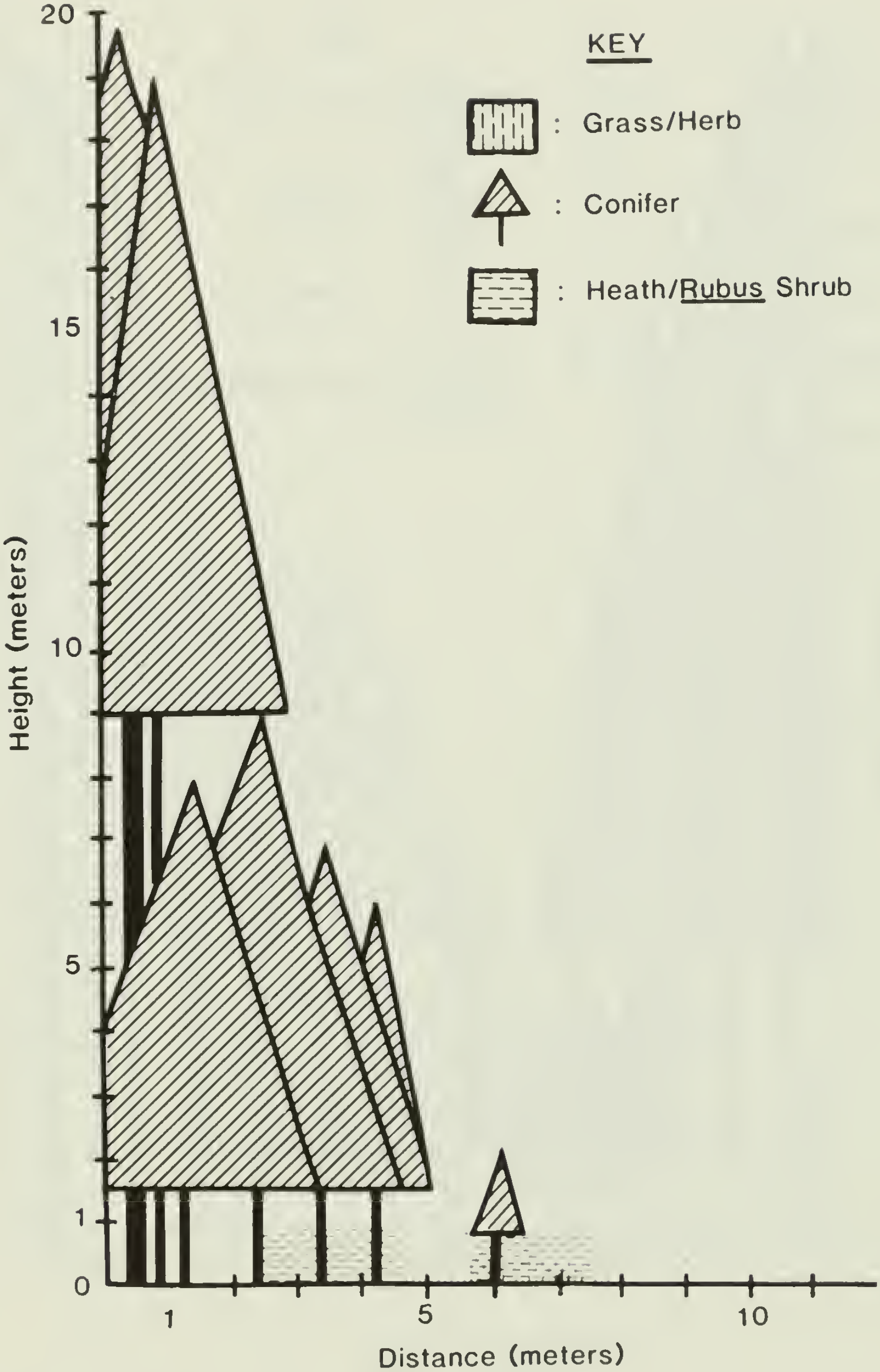


Figure 9

Profile Diagram (Bisect) of Southeast Ecotone -B'

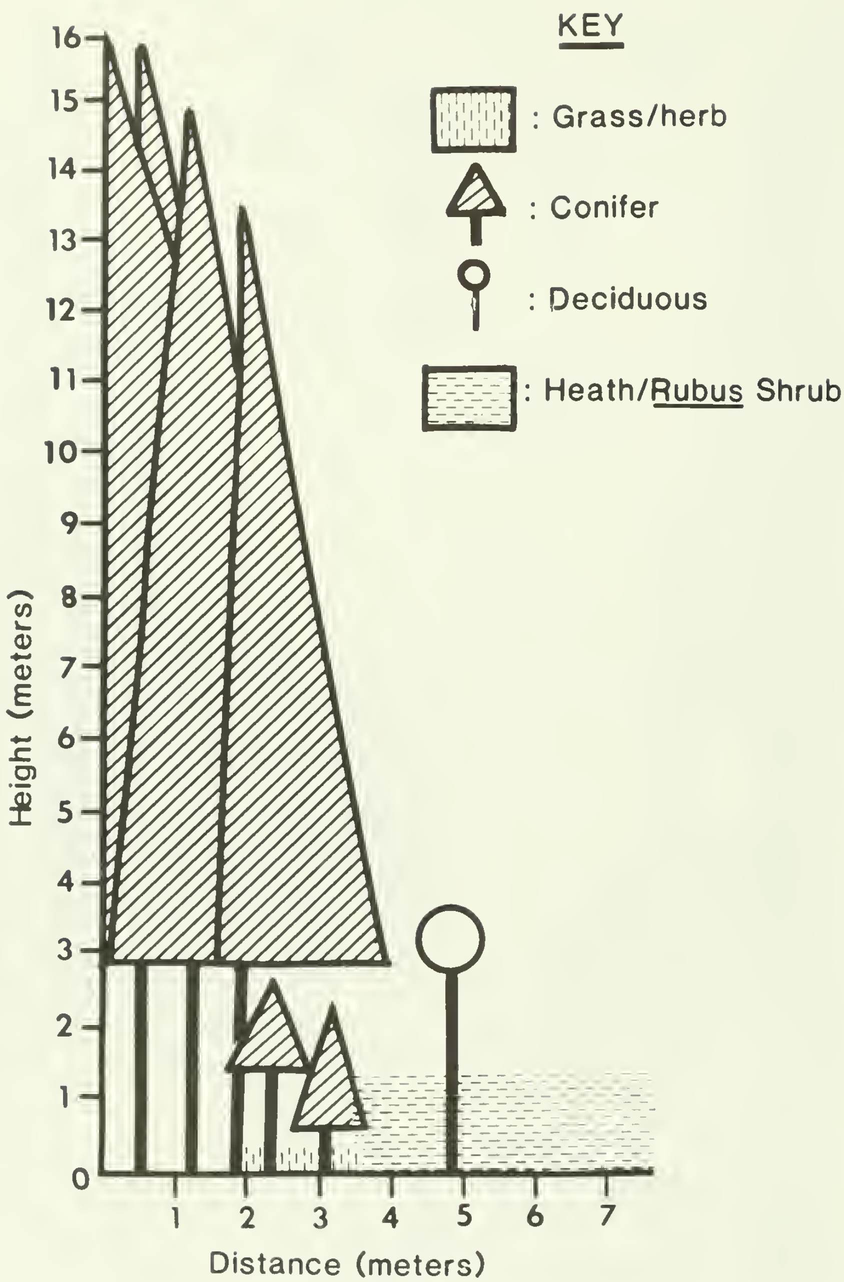


Figure 10

Profile Diagram (Bisect)

of Southwest Ecotone -C'

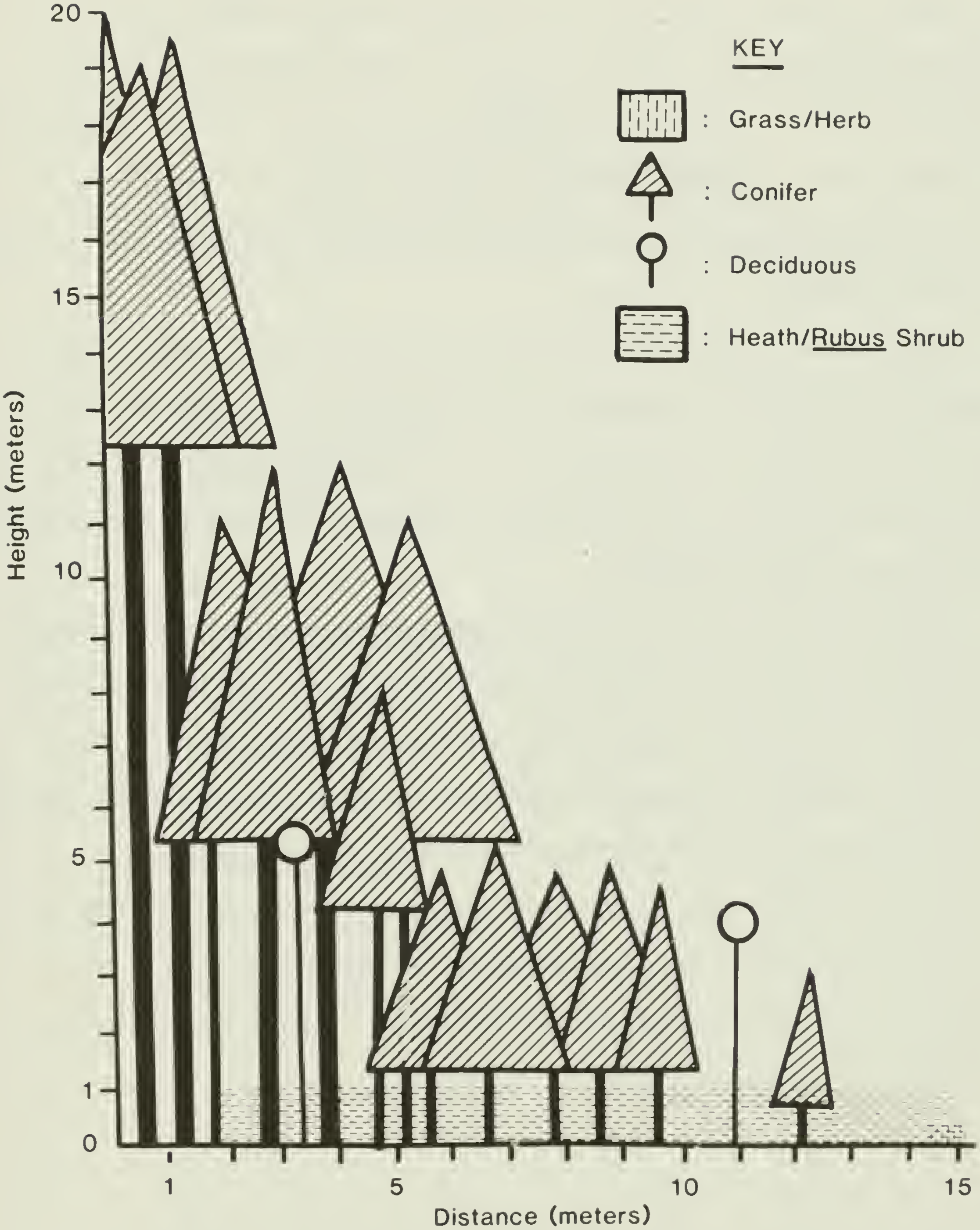


Figure 11

Profile Diagram (Bisect) of Northwest Ecotone-D'

only a small portion, 1.39%, of the relative coverage (Table III). Danthonia compressa, by contrast, had the largest coverage value with 33.09% of the area. Houstonia serphyllifolia had the greatest frequency with 87%. This species, however, had a low coverage value of only 4.81%. The top 15 species accounted for 93.21% of the estimated total relative coverage of the area sampled.

Contingency tables constructed for each of the top 15 species indicated that there were no negative associations apparent between the presence of Fraser fir and the presence or absence of other species (Table IV). Only one slightly positive association was noted. That was between Fraser fir and the moss Polytrichum sp.

The second sampling of the area during early June of 1980, revealed that many fir seedlings are not able to overwinter successfully in these open areas. During the relatively mild winter of 1980, twenty of the sixty-five seedlings observed (or 30%) were damaged. These damaged seedlings showed significant observed drying and browning of the needles.

Only one winter month, February, was significantly cooler than the previous average (Table V). Precipitation for the period of June 1979 through May 1980 approximated the normal amount for that period (2195 mm mean average vs. 2274 mm for the study period).

TABLE III

Relative Coverage and Frequency Values for Major Species Encountered

Species	% Relative Coverage	Frequency %
Danthonia compressa	33.09	82
Danthonia spicata	19.59	85
Vaccinium vacillans	6.35	70
Carex spp.	6.05	82
Houstonia serpyllifolia	4.81	87
Solidago roanensis	4.17	83
Deschampsia flexuosa	3.22	45
Lichen (foliose)	3.08	30
Solidago glomerata	2.78	28
Lycopodium flabelliforme	2.78	13
Rubus canadensis	2.08	28
Abies fraseri	1.39	47
Potentilla canadensis	1.34	45
Polytrichum spp.	1.29	27
Bare	1.24	16
Total	93.21	768
$\overline{X}$	6.21	51.2

TABLE IV

Results of Contingency Tables

Species	Both present *0	**E	Abies alone 0	E	Other sp. alone 0	E	Neither 0	E	X^2	P
Danthonia compressa	16	18.7	12	9.3	24	21.3	8	10.7	1.4152	.25-.30
D. spicata	25	23.8	3	4.2	26	27.2	6	4.8	0.2573	.55-.60
Vaccinium vacillans	21	19.6	7	8.4	21	22.4	11	9.6	0.2583	.55-.60
Carex spp.	21	22.9	7	5.1	28	26.1	4	5.9	0.8353	.40-.45
Houstonia serpyllifolia	24	24.3	4	3.7	28	27.7	4	4.3	0.0316	.70
Solidago roanensis	23	23.3	5	4.7	27	26.7	5	5.3	0.0134	.70
Deschampsia flexuosa	12	12.6	16	15.4	15	14.4	17	17.6	0.0027	.70
Lichen (foliose)	11	8.4	17	19.6	7	9.6	25	22.4	1.4063	.25-.30
Solidago glomerate	10	7.9	18	20.1	7	9.1	25	22.9	0.8094	.35-.40
Lycopodium flabelliforme	5	3.7	23	24.3	3	4.3	29	27.7	0.3406	.50-.55
Rubus canadensis	9	7.9	19	20.1	8	9.1	24	22.9	0.1060	.70
Potentilla canadensis	9	12.6	19	15.4	18	4.4	14	17.6	2.6001	.15-.20
Polytrichum spp.	12	7.5	16	20.5	4	8.5	28	23.5	5.5706	.03***
Bare	7	4.7	21	23.6	3	5.3	29	26.7	1.6205	.25-.30

*Observed values
**Expected values
***Indicates a positive association with _Abies fraseri_

TABLE V

Mean Monthly Temperature for Richland Balsam Mountain (°C)

	*1931-1956	**1979-1980
June	14.2	11.6
July	15.4	13.2
August	15.0	14.2
September	17.7	4.2
October	8.1	7.8
November	1.8	3.6
December	-0.8	1.6
January	-1.8	-0.6
February	-2.3	-6.0
March	0.2	1.7
April	5.1	3.3
May	10.1	7.3
$\overline{X}$	6.5	5.0

*Data extrapolated from Mt. Mitchell Station data in Pittillo and Smathers (1979).

**Unpublished data provided by Garrett A. Smathers National Park Service, Cooperative Studies Unit, Western Carolina University.

DISCUSSION

Seed Dispersal Patterns

Dispersal of conifer seeds and the ensuing natural spruce-fir reforestation of balds depends on factors stated in the previous section on bald reforestation. Each of these factors must be considered. The availability of an adequate seed source within dispersal distance is the first criterion to be met. The results and observations indicate that the Judaculla Fields have an adequate seed source surrounding them, while neither of the Craggy sites have such a near-by seed source.

The distance which spruce and fir may disperse their seeds is a matter of some controversy. As mentioned previously, some authors (Mark, 1958; Gersmehl, 1970) have indicated that these species are only capable of short distance dispersal of seeds. On the other hand, Siggins (1933) and Korstian (1937) have indicated that both species were capable of long distance seed dispersal. Korstian concludes that both species may disperse their seeds more than 250m.

Both direction and velocity of prevailing winds must be considered. A potential seed source must be oriented in the proper direction to allow seeds to reach a designated area. Finally, dispersal means other than wind should be appraised. Rodents may be important in conifer seed dispersal in some areas. However, Mark (1958) concluded that dispersal by these animals was not sufficient in bald areas.

The Judaculla Fields ideally meet these requirements for seed dispersal. The potential seed sources from all directions and at varying distances provide suitable dispersal-measuring corridors.

Seed trapping results in the Judaculla Fields offer some interesting observations, despite the limited number of seeds collected. The traps, however, proved very capable of catching seeds and practically anything else that came in contact with the sticky surface.

Several other types of seed traps have been used in the past. Mark (1958) worked with metal funnels 25.6 cm in diameter, set at ground level. He studied coniferous and hardwood dispersal at Round Bald and collected no seeds during the first season, despite a reported heavy seed crop that year. However, the following season he collected seven spruce seeds at a distance of six meters from the source and one fir at a distance of 35 meters. He then concluded that both species have a very limited dispersal range (Mark, 1958).

Tagawa (1966) used wooden boxes filled with cotton wool to trap seeds. His trappings took place on the lava flow area in southwest Japan.

Plastic vessels which contained water to trap seeds were used by Ryvarden (1971). He set these traps at ground level and collected seeds for two consecutive months, late July through early September, for three years.

None of the above trapping methods were judged to be adequate for this study. First, any method of seed trapping which places the traps directly on the ground would not indicate the direction from which the seeds were dispersed. Thus, neither Ryvarden's nor Mark's method would be applicable. Second, due to high winds and precipitation expected on bald summits (Shanks, 1954), a wind sock or cotton filled box, such as that used by Tagawa, may not have withstood these adverse conditions. And last, it was observed earlier this past year (1979), that the seed crop was small. Both species are characterized by cyclic years of low and high seed production. The red spruce generally has good seed years at intervals of three to eight years (Fowells, 1965) while Fraser fir has good years alternating with poor ones (Speers, 1968). Therefore, these small traps were judged to be too small to catch seeds effectively.

The low number of seeds collected can be explained in part due to the poor year for seed production. Speers (1967) indicated that both seed yield and quality diminished during poor seed production years. The infestation by the balsam wooly aphid has also hampered seed production by the Fraser fir. Fedde (1973) has shown the trees infested with these aphids produced both shorter cones and lighter, smaller seeds than do healthy trees. This infestation may explain, at least in part, why only three fir seeds were collected. Since the surrounding forest at Judaculla Fields was dominated by fir, a larger proportion of fir seeds was expected. However, more spruce seeds were collected.

At the Judaculla Fields seeds were collected from three of the four directions. No seeds were collected from the southwest. Four of the eight seeds came from the northwest. This corresponds with prevailing wind patterns. Also this involved dispersal either down or across the slope which is more common than upslope.

The two Craggy areas studied offer a contrast to the Judaculla area. The aforementioned criteria for seed dispersal into an area can explain the absence of seeds. These areas do not meet any of these criteria. The potential seed sources lie to the west and the northeast. Therefore, prevailing wind patterns would not favor dispersal into the area. In addition, these seed sources are at distances which exceed one kilometer. Thus, it seems unlikely that enough seeds would reach either area to be collected by these trapping methods.

The seed trapping data lead to the following conclusions: (1) Some seeds are reaching the Judaculla Fields but seldom reaching the other two areas. This supports the original hypothesis. (2) The data suggest that some other mechanisms must be in operation to halt or slow reforestation at the Judaculla Fields. The approximate trapping area there was 16 m^2 or 0.51% of the 56 m by 56 m (3136 m^2) total area traversed by the traps. Since the eight traps were placed at right angles to the ground, their total vertical-catching surfaces (16 m^2) cannot be used as an exact parameter to compute the percent of ground surface receiving seed. However, these crude calculations suggest that approximately 1568 seeds fell in this area, or an average of one seed per two-meter square. This figure implies that more establishment should be taking place. (3) The data are not sufficient to draw any positive conclusions about dispersal capabilities of spruce or fir.

Tree Ages in Ecotonal Zones

Korstian (1937) believed that seedling bearing ages for spruce and fir may vary according to environmental factors such as soil depth, light, moisture, competition, and other factors. He added that trees grown under open conditions may bear seeds at 15-20 years of age. Fowells (1965), on the other hand, indicated that spruce would produce very few seeds before 30 years of age.

The forest surrounding the Judaculla Fields was logged most recently in the 1940's. This reduction in standing large trees may have led to perpetuation of the bald through a reduction of the seed source. Reforestation, however, may begin to take place at a faster rate now that sufficient seeds are being produced in the area.

Of note also is the forest's advancing into the bald. These ecotonal areas which Gersmehl (1970) observed to be generally less than three meters wide are becoming wider. In the ten years since Gersmehl's observations, the ecotone is estimated to be between two and ten meters wide and at several areas within the bald, woody vegetation is becoming established. The invasion of spruce and fir into the bald is uneven, occurring primarily from the north or northeast. Apparently some environmental modifications occur at the forest edge favoring germination and establishment of seedlings.

Seedling Establishment

The plots sampled revealed that fir seedlings were much more abundant than spruce seedlings. This contrasts with the relative number of seed collected. This apparent contradiction is primarily due to the previously stated balsam woolly aphid infestation (will be discussed later) and to the generally low production year.

Danthonia compressa and D. spicata accounted for more than one-half of the estimated coverage (52.68%) of the plots sampled. Despite the thick mats formed by these species no negative associations were observed between them or any species tested and the fir seedlings. However, it must be pointed out that only primarily herbaceous communities were sampled and different results might be obtained if sampling were conducted in the shrubby areas.

A positive association was noted between the fir seedlings and the moss Polytrichum sp. This association was minimal (P = .03) and merely suggests that some factors other than chance may be involved. In addition, due to chance alone, it is likely that at least one species tested would show some association.

Of greater importance and interest are the data obtained during the second sampling of these areas. As stated previously, 30% of the seedlings examined were found to have a minimum of one-half of their needles browned; others were completely browned and dead. This suggests that some seasonal factors served to reduce seedling number. These factors may simply involve extreme cold or drought. However, as stated, the past winter (1979-80) was neither exceptionally cold nor dry. Therefore, cold and drought alone do not provide a suitable answer to explain this occurrence.

The age and size of the seedlings affected is of some importance. Only one seedling over 25 cm tall was damaged. Therefore, it seems logical to assume that these factors may be most critical during the first few years of establishment. Apparently, seedlings which survive these first several years have a greater likelihood of reaching reproductive age.

These seedling deaths are playing a large role in the maintenance of this bald. However, they may not result in permanent bald maintenance but serve only to slow reforestation efforts.

Invasion Patterns

The Judaculla Fields are in a successional state. They are not simply grassy areas in a climax state or "disclimax" as Cain (1931) termed it.

Continuing invasion by blueberries, blackberries, and tree species will cause this bald to shrink. Reforestation of the bald will occur. In order, however, to predict a possible time-scale for this, more data is needed. The composition of the new forest will be spruce-fir. The balsam woolly aphid infestation will result in at least a temporarily spruce dominated forest. Young fir trees, nonetheless, do not seem to be suffering the extensive damage as that of the older trees, and may yet survive and assist in the reforestation of the area.

In contrast with the Judaculla Fields, the Craggy areas will probably not experience such drastic changes. The Craggy Dome is likely to remain much as it is for some time. Due to the lack of seed supply this area has little likelihood of becoming spruce-fir forest for at least the next century. However, it does have the potential for spruce-fir forest (Smathers 1979). While it will remain heath dominated for the next several decades, invasion by beech and yellow birch may eventually result in their dominance of the Craggy Dome. However, invasion is extremely slow at this elevation and little hardwood regeneration has been observed there.

The Craggy Flats are not likely to become spruce-fir forests due to the same lack of seed source and supply. This area has not recently been covered by spruce-fir forest. The region, however, will probably lose most of its grassland areas due to heath invasion. Eventually Craggy flats may take on much the same complexion of the surrounding forest. Primary invaders and reforesting species will include beech, birch, hawthorn, and northern red oak.

This study has shown that conifer seeds are reaching the Judaculla Fields in appreciable number to be trapped, but not the Craggy areas, due to lack of near-by seed source. Establishment of Judaculla Fields is, however, being slowed by one or more ecological factors. This does not appear to be due to any direct species-species competition but rather to some stress factor on one or two year seedlings. Notwithstanding, it is believed that these fields will eventually be reforested.

Suggestions for further research are given in Appendix D.

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APPENDIX A

Location of Plots Sampled[1]

Jackson County, North Carolina
Blue Ridge Parkway Mi. 432
Southwest facing slope of Richland Balsam Mountain - Judaculla Fields

All Distances from North Corner Stake

1. 58° southwest from peak of High Knob.
   59° southwest, 7' 10" from large flat rock near forest margin.
   Plot located in grassy corridor on east side of upper field.

2. 20° southwest from peak of Double Top Mountain.
   45° southwest from flat rock in center of field, 51'11".
   Plot located in upper field near forest margin at upper northeast center of field.

3. 29° southeast from 1 m^2 round lichen covered rock, 6'5".
   15° southwest from same peak as in #1 above.
   Plot located in lower field in washed area on west side of established spruce and fir trees in center of field, trees 12 yrs.

4. 86° southwest from single large fir tree (7 m) near washed area 70'2".
   17° southwest from same peak as in above.
   Plot located in grassy area of lower field, near forest margin at upper center boundary of field.

[1]Original data deposited in Archives of Western Carolina University. See under J. Dan Pittillo.

APPENDIX B

Species List from Plots Sampled

Species	% Relative Cover	Frequency %
Danthonia compressa	33.09	82
Danthonia spicata	19.59	85
Vaccinium vacillans	6.35	70
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Houstonia serphyllifolia	4.81	87
Solidago roanensis	4.17	83
Deschampsia flexuosa	3.22	45
Lichen foliose	3.08	30
Solidago glomerata	2.78	28
Lycopodium flabelliforme	2.78	13
Rubus canadensis	2.03	28
Abies fraseri	1.39	47
Potentilla canadensis	1.34	45
Polytrichum spp.	1.29	27
Bare	1.24	16
Solidago erecta	1.09	37
Rumex acetosella	1.04	35
Moss	0.84	20
Aster patens	0.79	28
Solidago bicolor	0.69	23
Caryophyllaceae	0.60	20
Prunella vulgaris	0.45	15
Gentiana quinquefolia	0.30	10
Picea rubens	0.30	2
Coreopsis pubescens	0.15	5
Dennstaedtia punctilobula	0.10	3
Rudbeckia laciniata	0.10	3
Angelica triquinata	0.05	2
Lichen fruticose (red)	0.05	2
Lichen fruticose (gray)	0.05	2

APPENDIX C

Tree Ages and Diameter at Breast Height

Tree Number	Species	Age (yrs)	DBH (cm)
1	*Picea rubens*	34	22.5
2	*Picea rubens*	45	41.6
3	*Picea rubens*	26	22.4
4	*Abies fraseri*	34	33.4
5	*Abies fraseri*	34	16.2
6	*Picea rubens*	52+	39.5
7	*Abies fraseri*	38	37.7
8	*Picea rubens*	26	31.0
9	*Abies fraseri*	40	27.5
10	*Picea rubens*	44	20.0
11	*Picea rubens*	30	27.6
12	*Abies fraseri*	18	16.5
13	*Abies fraseri*	19	12.9
14	*Picea rubens*	65	48.0
15	*Abies fraseri*	38	24.1
16	*Abies fraseri*	22	29.4
17	*Abies fraseri*	25	26.3
18	*Picea rubens*	60	48.1
19	*Abies fraseri*	20	24.2
20	*Abies fraseri*	28	21.5
21	*Abies fraseri*	41	43.7
22	*Abies fraseri*	17	15.4
23	*Picea rubens*	29	18.7
24	*Picea rubens*	32	22.0
25	*Abies fraseri*	22	18.2
26	*Abies fraseri*	35	29.7
27	*Abies fraseri*	35	31.3
28	*Abies fraseri*	43	27.9
29	*Abies fraseri*	42	24.2
30	*Abies fraseri*	40	33.6
31	*Abies fraseri*	26	25.3
32	*Abies fraseri*	27	26.3
33	*Picea rubens*	49	37.0
34	*Picea rubens*	30	24.1
35	*Abies fraseri*	18	16.1
36	*Abies fraseri*	44	50.3
37	*Abies fraseri*	30	21.4
38	*Abies fraseri*	28	18.8
39	*Abies fraseri*	15	14.5
40	*Abies fraseri*	32	47.3
41	*Abies fraseri*	17	15.9

Tree Number	Species	Age (yrs)	DBH (cm)
42	Picea rubens	17	16.3
43	Abies fraseri	34	27.0
44	Picea rubens	31	34.2
45	Abies fraseri	19	20.1
46	Abies fraseri	26	20.9
47	Picea rubens	40	44.2
48	Abies fraseri	26	21.7
49	Abies fraseri	19	18.0
50	Abies fraseri	52	45.5
51	Abies fraseri	42	64.1
52	Picea rubens	32	19.1
53	Picea rubens	39	45.1
54	Abies fraseri	25	18.9
55	Abies fraseri	29	26.5
56	Abies fraseri	19	15.8
57	Abies fraseri	16	14.8
58	Abies fraseri	18	16.0
59	Abies fraseri	20	15.8
60	Abies fraseri	44	46.9
61	Abies fraseri	19	15.5
62	Abies fraseri	20	16.8
63	Picea rubens	56	52.1
64	Picea rubens	31	35.9
65	Abies fraseri	16	17.0
66	Abies fraseri	18	18.3
67	Abies fraseri	15	14.8
68	Abies fraseri	33	29.2
69	Abies fraseri	44	33.5
70	Abies fraseri	42	28.7
71	Abies fraseri	49	40.5
72	Picea rubens	30	26.0
73	Abies fraseri	33	29.4
74	Abies fraseri	38	40.5
75	Abies fraseri	57+	72.4
76	Abies fraseri	53+	72.4
77	Picea rubens	38	29.3
78	Picea rubens	48	30.8
79	Picea rubens	42	39.9
80	Abies fraseri	21	19.3
81	Abies fraseri	21	18.3
82	Abies fraseri	62+	56.0
83	Abies fraseri	30	26.8
84	Abies fraseri	40	34.6
85	Picea rubens	36	33.1
86	Abies fraseri	26	18.5

APPENDIX D

Suggestions for Further Research

1. Additional seed trapping experiments are needed. Trap sizes may be reduced for convenience along with an increase in number of traps to make the trapping more comprehensive. In addition, trapping should be done during a high seed production year for comparison.

2. Further studies regarding the seedling deaths should be conducted. These could consist of field and/or greenhouse experiments to explore possibilities of physical competition as well as allelopathic interference.

3. Experiments on both spruce and fir seed viability and germination rates should be expanded through field and greenhouse work.

4. Additional studies are in order at the Judaculla Fields to observe the rate of invasion by both shrub and tree species.

5. Long-term observation in the Craggy area may assist in a more comprehensive management plan in regard to bald maintenance/bald reforestation relationships.

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering the wisest use of our land and water resources, protecting our fish and wildlife, preserving the environment and cultural value of our national parks and historical places, and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to assure that their development is in the best interests of all our people. The Department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.