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Remeasurement of Permanent Vegetation Plots in the Great Smoky Mountains National Park, Tennessee, USA, and the Implications of Climatic Changes on Vegetation

Rudolf W. Becking
Jerry S. Olson

ENVIRONMENTAL SCIENCES DIVISION
Publication No. 1111

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REMEASUREMENT OF PERMANENT VEGETATION PLOTS IN THE GREAT SMOKY MOUNTAINS NATIONAL PARK, TENNESSEE, USA, AND THE IMPLICATIONS OF CLIMATIC CHANGES ON VEGETATION

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FOREWORD

The UNESCO intergovernmental program on Man and the Biosphere (MAB) includes a Global Environmental Monitoring System (GEMS), and assessments of trends in man's ecosystem and technologies. Among nongovernmental international organizations, the Scientific Committee on Problems of the Environment (SCOPE, of the International Council of Scientific Unions, ICSU) has provided expert guidance on the needs and meaning of environmental monitoring.

The United States of America contributes to these Biosphere activities in Environmental Monitoring and Assessment of the Biosphere. The U.S. Department of Interior (DOI) and/or the Energy Research and Development Administration (ERDA) provide the leadership and cooperation with the U.S. Department of Agriculture (especially the Forest Service), TVA, other agencies, universities, and individuals.

This report deals with the establishment and inventory of permanent vegetation plots within the Great Smoky Mountains National Park. The information collected represents the accurate description of current vegetation conditions. They will form the beginning of a series of benchmark studies to monitor changes in the vegetation and the environment. This effort seeks to coordinate continuing studies of a Southern Appalachian Biosphere Reserve Cluster linking the fully protected conservation reserves like those of the Great Smoky Mountains National Park benchmark sites with other experimental reserves and reserch staffs. This project may contribute baseline information towards the MAB project 8 (Biosphere Reserves), project 2 (Temperate and Mediterranean Forests) and other projects of international significance.

The present report represents field work of the summers of 1976 and 1977 by Dr. Rudolf W. Becking under a subcontract with the Oak Ridge National Laboratory (ORNL) to relocate, reinventory and permanently mark the well publicized vegetation plots of Dr. Robert H. Whittaker and Rudolf W. Becking. Dr. Jerry S. Olson ORNL coordinated these research efforts. The permanent plots are well suited for biological monitoring and early assessment of any environmental changes

in the forest environment of the Smoky Mountains. Of special interest will be the early assessment of the hypothesis that the high-elevation relic spruce-fir forest communities and/or some of its rare or endemic species might be threatened with extinction when climate warming takes place. It is anticipated that within the next century climate-warming may occur as a byproduct of the continued increase in atmospheric CO_2 from accelerated burning of fossil fuels. The evidence and implications of such increase of global CO_2 and temperature have been reviewed recently by Baes et al. (1976). These assessments are part of a project on The Global Carbon Cycle and Climatic Risks, supported by the ERDA Divisions of Environmental Research and Technology Overview.

PREFACE AND CONCLUSIONS

If the accelerating burning of fossil fuels produces enough increase in atmospheric carbon dioxide to raise the mean surface temperature of the earth several degrees, very important ecological and social consequences are anticipated (Baes et al. 1977). Vegetation and animal life depend upon certain narrowly defined environments or niches to succeed and grow to full maturity and complete their life cycles. Studies and climatic monitoring throughout the low elevational areas of the United States will focus upon shifts in crop zones and agricultural risks. Shifts of storm tracks and even temporary heating or chilling can upset many environmental adaptations rather suddenly.

The present pilot study concentrated on a complementary aspect of concern, namely the slow but drastic shifting of forest zones, especially in mountainous regions. The high-altitudinal forest ecosystems of the Great Smoky Mountains, in particular the spruce-fir forests, have been much-studied and admired as relic forests (Cain 1935, 1943; Whittaker 1956) (Fig. 1). The purpose of this study is to estimate and eventually measure the magnitude of potential vegetational shifts in undisturbed natural vegetation in the absence of the many other complicating impacts of man.

Results from two summers (1976 and 1977) suggest that even comparatively small temperature increases of 1°C (1.8°F) could indeed lead to botanically significant changes in the spruce-fir forest communities of the southern Appalachian mountains. These forests are famous for many plant species endemic to these summits - species of limited ranges and only narrow niches. Increased temperature (or variability) of total climate would increase the probability of extinction, or of narrowing relics to very isolated spots. If increases of 3° to 5°C or more should occur as predicted, changes may eliminate the Fraser fir forests first and then red spruce, or at least change the spruce-fir forest from a locally dominant ecosystem to a "relic." Successional adjustments would be expected to a substitution of certain hardwoods and/or hemlock for the now predominantly spruce-fir coniferous forests of the crest of the

Fig. 1. Virgin Red Fraser spruce-fir forest (here with understory of striped maple and rhododendron, on the Bullhead Trail to Mt. LeConte) provides unique scientific and aesthetic character to the Great Smoky Mountains National Park (September 2, 1976, R. W. Becking).

Great Smoky Mountains National Park and similar areas along the Blue Ridge Parkway. With or without a potential climatic warming, the Fraser fir forests are already prone to attack by the balsam wooly aphids (see below). This attack may eventually eliminate the Fraser fir at a more rapid rate than otherwise if projected climatic warming indeed occurs (Fig. 2). The 20 permanent bench mark plots established in 1976 and 1977 and evaluated in this report should help to document regional and global changes in the human environment.

Hypotheses of mountain landscape changes are based mainly on the existing altitudinal distribution and stand characteristics of the forests, documented on a relatively small number of vegetation plots measured first in 1959. In most plots, the stand changes by 1976-1977 did not yet suggest that a distinct altitudinal (temperature) shift in life zones has started. However, there have been weather-related disturbances, most notably blowdown by wind near the Mount LeConte Lodge and shelter. At this high elevation ($\sim$ 1900 m) total spruce-fir stand destruction has been followed by dense regenrations of 1 to 2 m fir, with no aphid encroachment yet visible. Local observations between Mt. LeConte and Brushy Mountain (1500-1700 m) indicated conspicuous dying of Fraser fir near its lower altitudinal limit, possibly related to the unusual drought in late summer 1976.

Observations (including those of Ronald Hay) in the Park do indicate rapid spread of the balsam woody aphid since 1959. Mortality is actually caused by a fungus introduced by the aphid. Around Mt. Mitchell, northeast of Asheville, N.C., aphid infestation had already started in 1959 and has since eliminated many of the older fir forests below 1600 m. Mt. Mitchell fir forests above 1600 m have not yet suffered so severely despite the local proximity of infestation sources. This suggests that climatic warming changes might reinforce the damage from pest infestation, in addition to creating unfavorable shifts of the physiological and ecological adjustments of several high-altitude trees and herbs. The general increase in temperature would be accompanied by increased evapotranspiration. This may well become further

(A)

(B)

Fig. 2. Spruce-fir survives in relatively isolated Appalachian peaks, already isolated by warming climates of postglacial time. A. Clingman's Dome (September 16, 1976). B. Mt. LeConte, Myrtle Point overlook and heath bald (September 3, 1976, R. W. Becking).

aggravated by less precipitation (or less reliability of rain and snow) and/or more frequent wind destruction. A weakened condition of the high-altitudinal vegetation would make it more prone to insect attacks and diseases. Its regeneration potential may be drastically impaired. Therefore, the combined impact of climatic changes could be substantially more drastic and sudden than might be guessed from a mere altitudinal shift of the existing climatic zones.

ABSTRACT

BECKING, R. W., and J. S. OLSON. 1977. Remeasurement of permanent vegetation plots in the Great Smoky Mountains National Park, Tennessee, USA, and the implications of climatic changes on vegetation. ORNL/TM-6083. Oak Ridge National Laboratory, Oak Ridge, Tennessee. 118 pp.

This report summarizes field work over two summers (1976 and 1977) to relocate, monument and reinventory permanent vegetation plots in the Great Smoky Mountains National Park. These plots were first established by the senior author and R. H. Whittaker in 1959-62. The inventory results are discussed in terms of vegetation changes in high-altitudinal forest ecosystems, in particular the spruce-fir forests, and the factors, climate shift and biotic and abiotic agents, bringing about vegetation change. A second aspect of the report summarizes experience and offers recommendations for establishment of permanent vegetation plots for the purpose of providing a monitoring tool with which to measure long-term ecological change.

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1. INTRODUCTION

The objectives of a 1976-77 experiment in biological monitoring were:

(1) To measure and summarize changes in certain southern high altitude (spruce-fir and beech) forests since earlier studies in the Great Smoky Mountains by R. W. Becking.

(2) To project vegetational impacts to be anticipated from climatic change (including 1° to 5°C warming over the next century).

(3) To advise ORNL and cooperating organizations on feasible ways to predict and monitor ecosystem changes in forests (suitable for Biosphere Reserves like the Great Smoky Mountains National Park).

In 1959, R. W. Becking and Robert H. Whittaker conducted intensive studies estimating the biomass and productivity of the major plant communities of the Great Smoky Mountains. In the summer of 1962, Becking expanded the vegetation sampling of the spruce-fir forest communities to include site variations and successional stages of forest vegetation. The principal task of the 1976-77 field work was to use a reinventory of a few high elevation vegetation plots as a test of relatively intensive plot procedure for monitoring biospheric changes. Change is predicted from shifts in global climate or more local weather-related disturbances of ecosystems (Baes et al. 1976). These efforts were coordinated as much as possible with ongoing research work noted below, as background for using the Great Smoky Mountains as a Biosphere Reserve (see Series Forword).

1.1 REPORT CONTENT

The following work covered the main objectives of Becking's subcontract from Oak Ridge National Laboratory and reflects joint ERDA/Interior Department interest in a Southern Appalachian Biosphere Reserve cluster (Johnson et al. 1977).

(1) Permanent monumentation of the 1959-1962 Whittaker-Becking plots of high altitude ecosystems within the Great Smoky Mountains National Park and a inventory of trees and vegetation, as a baseline for monitoring of future change.

(2) Reporting of vegetational or environmental changes in the reinventoried plots or surroundings since 1959.

(3) Using climatic gradients with altitude in the Smoky Mountains for estimating the potential impact upon the spruce-fir forest communities from a plausible global warming of regional or global climate (e.g., related to CO_2 burned from fossil fuels).

(4) Recommendations for permanent monumentation and monitoring of mountainous forest ecosystems for the Southern Appalachian Reserve cluster in which the Great Smoky Mountains and the Oak Ridge Reservation are complementary parts.

(5) Use of NASA remote sensing of ERTS (LANDSAT) Satellite imagery for the detection and extended mapping of forest communities and for the monitoring of vegetational changes of the spruce-fir and other forests of the Smoky Mountains.

(6) Tests of the FORET computer program (Mielke et al. 1977) for stand growth projections of the spruce-fir forest communities of the Smoky Mountains in a modified form to predict drastic population changes due to climate and/or infestation of fir forest by balsam woolly aphids.

Tests on (1) and (6) reiterate the importance of coupling the empirical monitoring of ecosystems and of climate with the latest advances in computer analysis of environmental patterns in space and trends in time.

2. PERMANENT PLOT ESTABLISHMENT AND OBSERVATIONS

In 1948 Whittaker established composite transects and site samples for a frequency count of trees by diameter classes and species. These transects were selected to provide for elevation and/or moisture gradients. The frequency data of the stands were collected by tallying about 100 trees at stations regularly spaced at 50 to 150 m apart along the transect. These stations were not permanently marked nor were trees tallied within a measured area. The purpose of these tree inventories was to determine relative densities and the distribution of tree species along the selected environmental gradients.

The 1959-1961 vegetation plots were definitive in size, 20 x 50 m (0.1 ha) in area. A 100% tree inventory per one-inch DBH classes was done to provide mensurational data as to stand structure and density, basal area, and preliminary estimates of tree volumes and biomass. Because these plots were not permanently and precisely marked in the field initially it was impossible to duplicate these inventories exactly in 1976 and 1977. Therefore, a permanent plot properly monumented allows for future precise relocation of plot boundaries and inventories. These inventories of 1959 and 1976/77 will be analyzed in this report.

The field work of 1959-1961 by Whittaker and Becking and 1962 by Becking resulted in the inventory of some 184 plots of varying intensity. Species lists (relevees) are distributed over the main forest types as follows:

Spruce-fir forests	82 plots of which 14 plots have soil profile information and 23 plots have stand inventory data
Oaks and Oak Heath	21 plots of which 8 plots have soil profile information and 2 plots have stand inventory data
Heaths and Pine	27 plots of which 7 plots have soil profile information and 1 plot has a stand inventory
Cove Hardwoods and Hemlock Forests	27 plots of which 6 plots have soil profile information and 4 plots have stand inventory data
Beech Gaps and Beech Forests	27 plots of which 5 plots have soil profile information and 5 plots have stand inventory data

In the course of 1976-77 field work 20 plots were monumented, 7 plots were of the spruce-fir forest type, 3 were high-elevation beech gap forests, 5 were cove hardwoods-hemlock forests, one was an Oak-Heath forest, two were pine heaths and two were open heath plots. All these vegetation plots were approximate reinventories of previously established vegetation plots. The phytosociological reinventories and soil profile information will be summarized in a separate report.

The monumentation procedures have been judged practical and satisfactory to serve as a model or example for forest ecosystems in mountainous Biosphere Reserves. On the average it requires some 8 man hours for a 3-person crew to monument, reinventory the stand, reinventory the floristic composition, and describe the soil profile in the field. An additional three hours are needed to compute basal areas and stand densities and to analyze the soil for color and pH per soil horizon. Vegetation plots with soil profile and basal area (BA/hectare) determinations require approximately four hours for a 3-person crew, while vegetation plots with only a floristic inventory can be executed within a 2-hr period by a trained phytosociologist.

Most forest relevees showed a remarkable stability in species and cover estimates to date. Effects of destructive biomass sampling have become totally unnoticeable. Mortality has increased slightly in some stands but there is very little change in tree structure and floristic composition for most. However, certain exceptions have been noted in 2.4 for Mt. LeConte.

2.1 INVENTORY PROCEDURES

The inventory procedures used have the primary objective to mark and record permanently the present forest stand and to make a future remeasurement of the identical forest stand possible. There was little to no flexibility in plot location since the main purpose was to remeasure the formerly established research plots. These plot locations are plotted on USGS 7.5 minute quadrangle sheets to facilitate their relocation. In addition, each plot is surveyed to a nearby permanent landmark to facilitate their precise location on the ground. These land

markers have been included in the plot location sketch map. The line survey was executed with staff compass and is an open-ended uncorrected survey line with no permanently marked stations. The survey is in the metric system.

The adopted size of the inventory plot is 20 x 50 m. The plot dimensions and the bearing of the center line are surveyed. For convenience, the inventory plot is subdivided into ten 10 x 10 m quadrants and steel pipes are planted at each of the corners. All the trees are individually tagged with aluminum numbers and an aluminum nail at DBH level or at 1.30 m above the ground. Their diameter was recorded by measurement with a diameter tape just above the nail and recorded to the nearest 0.1 inch for the 1976 inventories and to the nearest 0.1 centimeter for the 1977 inventories. In addition, approximate tree locations are mapped per 10 x 10 m quadrant and upcoming young tree regeneration is also mapped.

A limited amount of sample trees are carefully selected to represent each species by diameter range. These selected trees are cored for their past 20-year DBH increment and for their age, and the total tree height is measured with a tape and a clinometer in meters. Periodic remeasurement of these sample trees can indicate growth relationships between trees and their environment. All inventory information has been deposited for future reference.

2.2 INDIVIDUAL PLOT DISCUSSION

Each individual plot will be discussed and observations will be made as to location, plot inventory information and inventory and/or vegetation changes since the initial establishment in 1959-1962. Plot data are summarized in Tables 1 through 4.

2.21 SPRUCE-FIR FOREST COMMUNITIES

The Spruce-fir forest communities are limited to elevations above 1400 m (4200 Feet) and reach their most southerly limit around Clingman's Dome. Within their elevation zonation they are interspersed with heath balds and beech gaps.

PLOT H1 590607 & 760807 Mingus Lead South Slope

Plot Location and Site

This plot is surveyed from the Indian Gap parking lot and is close to forest edge. The Appalachian Trail (AT) touches this plot on its lower and upper boundary. Human impact in the form of small shortcut trails, illegal fire pits and camping are also evident. Although the xeric conditions are more or less uniform the lower part of this plot is distinctly more moist than the upper part. Because of the proximity of the forest edge, the gap effect and the human impact this plot is not representative for a south exposure spruce-fir forest community.

Vegetation Composition

A relative recent invasion has taken place by such plant species like Amelanchier laevis, Sorbus americana, Viburnum alnifolium, Ilex montana, and Rubus canadensis. Greater light intensities are reflected by the presence of such species as Eupatorium rugosum, Angelica triquinatum, and Dennstaedtia punctiloba. There have been no major changes yet in the moss composition.

This plot is not typical for the south slope spruce-fir communities because it lacks a dominance of herbs or mosses. In fact, the plot area (has always been) relatively bare in 1959 and now in 1976 there is more evidence of heavy foot traffic and illegal campfires. It is located just above the Appalachian trail in the first S-curve and often hikers will make shortcuts towards the parking lot through the plot area. In addition, this plot has several species of the cove forest environment which are quite unusual for the typical spruce-fir forest communities. Plants which have persisted from 1959 till 1976 in the stand are Mitchella repens, Smilax herbacea, and Rhododendron maximum.

Stand Inventory

As expected with the normal stand development free density declined with approaching maturity while the basal area stocking increased. The only significant tree mortality observed is among the smallest diameter

classes with especially a sharp increase in mortality of Abies. There is an increase in diameter growth of the larger and dominant trees as expected for mature spruce-fir stands approaching greater maturity. Generally Picea may live at least twice as long as the Abies under normal natural conditions. With the advance of the woolly aphid the spruce may be even the only surviving tree species. This plot has a heavy woolly aphid infestation and free roll among the mature forest trees.

PLOT H2 590609 & 760910 Mingus Lead East

Plot Location and Site

This plot is located on a spur ridge with an East slope along the trail between Indian Gap parking lot and Newfound Gap. The plot is on the first ridge where a sharp curve bends the trail towards the north into the first small beech gap. It is surveyed from a large spruce tree. The plot is uphill from this tree and above the trail. It is a typical spruce-fir forest for a south exposure or more xeric conditions.

Vegetation Composition

This stand has demonstrated a considerable breakdown in the Abies tree layer (Fig. 3A). There is evidence of a heavy woolly aphid attack dating back as far as five years ago on most of the mature Abies trees. This stand may be the first and the oldest aphid attack at this location and at this elevation within the Park section.

Over the past five years a very dense reproduction of young Abies has developed into a dense shrub understory which has become almost impenetrable (Fig. 3B). In the large openings created by the death of the mature fir, additional shrub species have invaded the plot area: Vaccinium erythrocarpum, Rubus canadensis, Betula alleghaniensis, and Sorbus americana. This dense shrub understory has drastically decreased the herb cover due to intense shade. Therefore, there is a significant reduction in cover and abundance of Dryopteris campyloptera/intermedia and Senecio rugellii, and an increase in the herb layer of Vaccinium

(A)

(B)

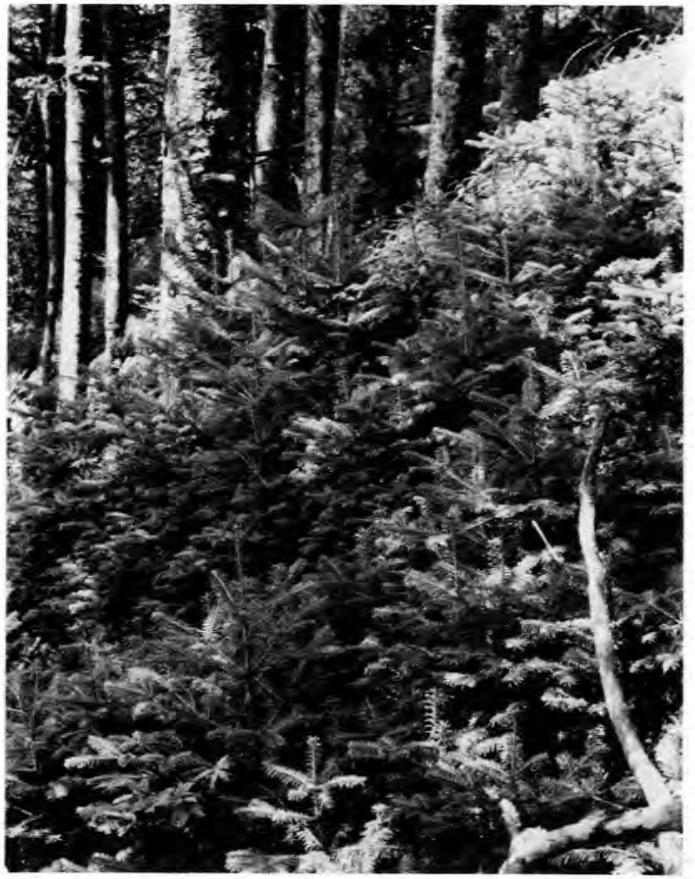

Fig. 3. Recent balsam wooly aphid infestation on plot H2 (760910, September 13, 1976, R. W. Becking). A. Killed fir trees breaking down. B. Regeneration in canopy openings.

erythrocarpum, Lycopodium lucidulum, and Oxalis acetosella. In the moss layer Brotherella recurvans, Thuidium delicatulum, Bazzania trilobata, and Lepidozia reptans increased in cover.

Stand Inventory

This stand illustrates typically the establishment of a second age-class of young Abies under a mature and older age Picea canopy (Table 1). There is a considerable increase in stand density of fir in the smallest diameter classes while the spruce overstory remained about the same. Due to heavy mortality among the largest Abies trees there has been a reduction in basal area stocking since 1959 although there has been considerable basal area growth among the remaining spruce trees due to the elimination of the competition of the mature firs (Table 2).

Plot H4 590611 & 760704 & 760801 Mt. Collins NE slope

Plot Location and Site

This plot is located off the nature trail on Mt. Collins. The exact location of this plot could not be definitely verified but the established plot is reasonably close. Already in 1959, this plot was not homogeneous in site conditions since within the plot area at least one minor drainage was crossed creating variable moisture conditions. The plot is within the older-age part of the present stand.

Vegetation Composition

This plot has practically not changed in species composition from the 1959 inventory. One large overmature Abies tree has fallen due to old age with no evidence of any woolly aphid attack. Because of this canopy opening there is some increase in Viburnum alnifolium, Rubus canadensis, Betula alleghaniensis, Drypoteris campyloptera/intermedia, Senecio rugellii, and Aster acuminatus (Fig. 4). This plot is in a generally moist site with the corresponding increase in Rhytidiadelphus triquetrus, Hylocomium umbratum, Hylocomium splendens, Lophozia incisa,

(A)

(B)

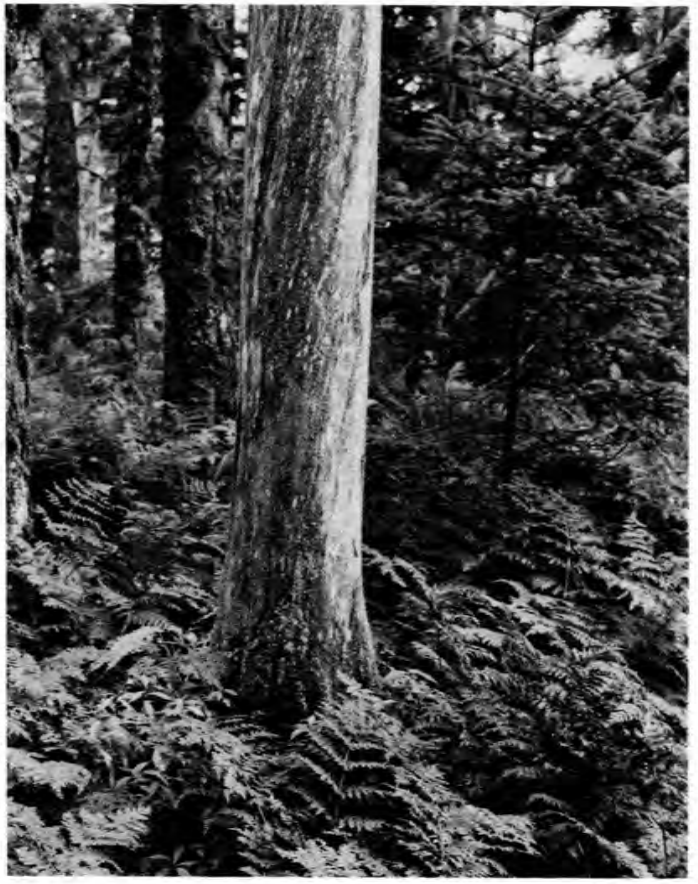

Fig. 4. Fraser fir (Abies fraseri) naturally regenerates itself in some high summit plots that are practically unchanged between 1959 and 1976. A. Smooth trees on south slope of Clingman's Dome, near radio tower (Plot 760806, August 26, 1976). B. Ferns thriving in moist opening around dead tree on Mt. Collins (Plot H_4, Plot 760704, August 25, 1976, R. W. Becking).

Jungermania lanceolata, Blepharostoma trichophylla, and Bazzania trilobata in the moss layer.

Stand Inventory

Tree density increased in the lowest diameter classes in the spruce, while the stocking of fir and yellow birch remains almost the same. Significant mortality occurred in the two lowest diameter classes among the fir.

PLOT RWB #20 590614 & 760802, 760803, 760804 Mt. Collins

Plot Location and Site

This plot was established to represent a young and thrifty spruce-fir stand with a predominance of Abies. It has been surveyed from the intersection of the Nature Trail with the Appalachian Trail. The 1959 vegetation survey was homogeneous but no tree inventory was made at that time. However, in 1976 it was impossible to fit the young spruce-fir stand within a homogenous 20 x 50 m inventory plot size. Therefore, the most southerly part of this plot is in an older stand with mature spruce and there are different drainage and more moist site conditions in that part of the stand. For the stand inventory and vegetation composition these diverse conditions have been recognized in the records.

Vegetation Composition

Due to the relatively young age of the main fir stand there is practically no shrub cover. The herb layer is dominated by Dryopteris campyloptera/intermedia and Senecio rugellii and a complete moss layer. There is very little vegetation change in this plot since 1959.

Stand Inventory

This is a young stand predominantly of fir with some spruce mixed in. It is relatively even-aged, and probably originated some 50 years ago following a windthrow. Part of the older spruce stand is still

remnant in the southerly portion of this inventory plot. There is one large dead Abies due to a lightning strike. There is no evidence yet of a woolly aphid attack.

Plot #RWB 21 590618 & 760806 Clingmans Dome SE Slope

Plot Location and Site

This plot was established near the radio tower on Clingmans Dome but no 1959 stand inventory is available. It is characteristic for the high elevation spruce-fir forest communities and is on a gentle SE slope next to the radio tower. There is no evidence of site disturbance within the plot area caused by the construction of the radiotower. There are several windthrows below and outside the plot area. In the resurvey of the 20 x 50 m plot area size its northern boundary practically touches the instrument building of the radio tower.

Vegetation Composition

This plot shows practically no change in species composition. It is characteristic for the unusual predominance of Athyrium asplenoides over Dryopteris campyloptera/intermedia. Since 1959, there is some decrease in cover of Clintonia borealis and Senecio rugellii. This plot is also dominated by Abies and is probably typical for a high elevation south slope spruce-fir stand.

Stand Inventory

This stand is of a relatively young age and exhibits a good rate of diameter growth. (Fig. 3A). There is no evidence of a woolly aphid attack upon the fir within this stand, although below it along the parking lot and the parkway road firs have been dying from a woolly aphid attack for the last two years.

PLOT RWB #22 590617 & 760805 Clingmans Dome North Slope

Plot Location and Site

This plot has been surveyed in from the observation tower on top of Clingmans Dome and is situated just off the AT on the north slope. The plot area follows a mior spur ridge and ends just above rock ledges that create the summit area.

Vegetation Composition

The dominance of *Abies* on this exposed north slope position has been severely affected by windthrow and/or old age of the overmature trees. This has resulted in a corresponding increase in *Viburnum alnifolium* and *Rubus canadensis* in the shrub layer. This plot is more moist than others by the presence of *Chelone lyonii*. The runoff of the paved area around the observation tower is drained into this plot. Mosses that increased in cover are *Brotherella recurvans* but *Hylocomium splendens*. For the remainder there is remarkably little vegetational change.

PLOT RWB #23 590619 & 760907 Clingmans Dome Parkway East Slope

Plot Location and Site

This plot is located below the parkway on a spur ridge west of the Nolan Divide on an East slope. It is located within the mature spruce stand with a windthrow just below and east of it. The plot was not inventoried in 1959. The plot area is laid out parallel to the ridge line and ends at the windthrow.

Vegetation Composition

The vegetation has changed by an increase in the shrub cover due to the increases in light from the nearby windthrow areas. The old and overmature *Abies* have died creating small openings in the stand. Similar increases in herb and shrub cover have occurred in *Vaccinium erythrocarpum* and *Abies fraseri*, *Picea rubens*, and *Betula*

alleghanieniensis. Due to the increase in shrub cover there is a decreasing herb cover. Most notably affected was Senecio rugellii and Hylocomium splendens. In the moss layer, Brotherella recurvans, Thuidium delicatulum and Plagiothecium elegans increased.

Stand Inventory

This stand is characterized by the predominance of the large and overmature spruce trees. The incoming wave of new spruce and fir regeneration will eventually compete with this spruce overstory.

2.211 DYNAMICS IN SPRUCE-FIR STAND STRUCTURES

The stability of the vegetation and stand composition of the sampled spruce fir communities is remarkable for the period of 1959 to 1977. The only observed mortalities were from natural causes like old age and massive windthrows or lightning strikes. In 1976 there was only one incidence of the woolly aphid infestation in Plot H_2 causing changes in stand structure. So far, the woolly aphid has attacked only the Fraser Fir (Abies fraseri), although the same woolly aphid species has been known to attack Norway spruce in Europe.

The stand dynamics further reveal that the successional status of the fir is short-lived when compared to spruce. Therefore, often two or even three generations of the Fraser fir may recycle themselves under one generation of the spruce. Natural regeneration will readily establish itself even under partial canopy cover and there seems to be an abundance of seed. The fir regeneration seems to prefer the more open areas, often forming dense impenetrable thickets. There is a great mortality in the lowest diameter classes.

Yellow birch also favors the more open areas of windthrow while spruce regeneration becomes more competitive in the more shaded areas. Under full canopy closure most tree regeneration will remain stunted for decades. Following any opening of the dense tree canopy there are corresponding increases in shrub and herb cover and a shift in species dominance.

2.212 WOOLLY APHID INFESTATION

The currently known expansion pattern of woolly aphid infestation follows ridges upward from the eastern North Carolina side of the Great Smoky Mountain range. By 1976 only one of the monumented plots was affected significantly by the balsam woolly aphid (Adelges piceae). The damaged trees indicated that the woolly aphid attack was not older than five years. Observations on Mt. Mitchell suggest that the balsam woolly aphid will eventually kill all young to mature fir trees at elevations of less than 1500 m (∿ 5000 ft), while fir regeneration of less than 1 m and larger trees above 1700 m elevation remain free from attack. It is very likely that the stands on Clingman's Dome (Fig. 3), Mt. Collins, and Mt. Mingus will be most affected. More changes in tree species composition will then take place other than those caused by windthrow. The present monumentation and inventories may well document such environmental catastrophes.

No woolly aphid attacks have yet been observed high on Mt. LeConte (Fig. 4). Yet Fraser firs were seen dying, apparently with a fungal disease, at lower altitudes [e.g., along the Trillium Gap - Mt. LeConte trail around 1500 to 1600 m (4800 - 5300 ft) elevation]. There in mixed spruce-fir-yellow birch stands many of the smaller and mature fir trees had been killed recently, still holding dead redbrown needles.

Prolonged 1976 summer drought may have hastened death of fir trees at these low elevations. A future climatic warming could further enhance such risk of warming, desiccation, and susceptibility to pest attack. These changes in species composition and stand structure can be monitored by these permanently marked plots. However, sampling should be expanded into the Mt. Guyot and Mt. Sterling areas to represent better the spruce-fir forest communities within the Park.

2.213 CATASTROPHIC DESTRUCTION IN SPRUCE-FIR FORESTS

The most spectacular exceptions to the general stability of the spruce-fir forest communities were the plots visited in September of 1976 on Mt. LeConte. These illustrated the essentially complete destruction of former stands (Fig. 5A and 5B). Apparently, high winds

(A)

(B)

Fig. 5. Catastrophic destruction of fir forests north of Mt. LeConte Lodge is related to natural weather disturbance plus human disturbance. A. Total blowdown of fir stand along Trillium Gap Trail by 1968-1969 winds, followed by new fir seedling establishment. B. Water erosion from torrential rains, aggravated by water channeled along paths of Trail and salvage logging after the blowdown (September 3, 1976, R. W. Becking).

in the winter of 1968-1969 caused massive blowdown of trees. Since that winter this blowdown pattern has expanded itself within or adjacent to vegetation plots established in the summer of 1959.

The vegetation composition has drastically changed in such windblown areas because the entire tree canopy has been suddenly eliminated. Succession increases fire cherry (Prunus pennsylvanicum) within windblown areas. Mountain ash (Sorbus americana) resprouts from the damaged trunks and tends to be locally dominant. A few remaining suppressed spruce and firs persist, but a new wave of spruce and fir regeneration is actually the predominant invader of the area.

Because of abundant light and the faster growth rates of the fir, the young firs tend to predominate the area struggling with hardwoods like fire cherry, mountain ash and yellow birch. Fraser fir regeneration and reestablishmnet by even-aged waves following windthrows may be the common pattern of cyclic regeneration within the spruce-fir zone of the Smoky Mountains. This pattern is also discernible in the younger stands inventoried in 1959 and 1976-77 where the fir trees tend to be represented only within a narrow range of diameter and age classes. The oldest and largest trees are red spruce [(Picea rubens)]. Furthermore due to deeper and more widespreading root systems, red spruce tends to resist windblow. Individual old spruce trees are probably residuals from older stands. These spruces survived windblows and have grown to larger sizes as compared to their accompanying fir populations.

2.214 EROSION HAZARDS IN SPRUCE-FIR FORESTS

Observations of the soils within windthrown areas have indicated locally severe sheet and gully erosion, coupled with the total removal of surface organic matter (Fig. 5B). Apparently, removal of the forest canopy resulted in greater surface runoff and movement of soil materials. Relatively unweathered bedrock was exposed, creating difficulties for the reestablishment of new trees. Where surface runoff from camp sites and trails has been diverted into such windthrow areas, severe erosion has created new gullies, approaching 1 m deep (Fig. 5B). The main conclusion from the observed stand changes is that high-elevation

fir forests are vulnerable to windthrow and other impacts of weather. This is particularly true for fir forest above 1800 m elevation, especially where such forests are adjacent to or situated in gaps in the mountain chain. The presence of beech forests in such gaps below 1800 m has been attributed to severe wind and ice storms (Russell 1953).

On Mt. LeConte the vegetation plots are potentially subject to other human impact. Until recently dead trees have been actively logged for lumber and fire wood for the heating needs of the LeConte lodge. Spruce wood was preferred for stove wood over yellow birch and fir. Because of its workability fir was used for lumber in the construction of cabins. The logging impact is very significant in that logs were skidded downhill over the forest floor by horse, helping to start gullies that deepened through subsequent recent erosion (Fig. 5B). Some plots could be useful to document environmental changes due to traffic, including visitor activities, while other plots should be free of such added complications.

2.22 BEECH GAP FOREST COMMUNITIES

The beech gap forests occupy a specific environmental niche at the same elevations as the spruce-fir forest communities. The stand structure and species composition provide for one of the most drastic and striking contrast among spruce and beech forests and type boundaries are very abrupt. Generally, the forested gaps are dominated by beech and buckeye.

PLOT L3 590904 & 590907 & 760911 Newfound Gap South Slope.

Plot Location and Site

This plot is surveyed in from the Newfound Gap parking lot along the Appalachian Trail northward. It is situated between the ridge crest and the trail and is parallel to the AT for its entire length. It is readily accessible from the AT as well as from a minor trail along the ridge crest. Several shortcut trails have developed into the plot area and trail erosion is evident. The site is typical for a high

elevation southern exposure of a beech gap forest. Because of frequent and intense human traffic there is no evidence of any pig or hog damage in the area.

Vegetation Composition

There has been practically no change in species composition nor in species cover. This plot is in a relatively dry well-drained site typified by the predominance of Carex eastivalis. Slight increases in species cover were noted for Aster macrophyllus, Angelica triquinata, Eupatorium rugosum, Solidago caesia, and Athyrium asplenoides. Mosses on the soil substrate are quite uncommon while the epiphytic tree lichen cover is prominent. Towards its western part there are older and larger beech trees.

Stand Inventory

This is a relatively young beech gap forest as indicated by the increase in stand density, with only minor changes in basal area stocking. It appears that the stand is stagnated in its growth.

Plot L4 590901 & 590902 & 760912 Newfound Gap North Slope

Plot Location and Site

This plot has been laid out parallel to the ridge on the north slope opposite L_3 to illustrate the striking vegetation differences between the different exposures. The plot is surveyed in from the L_3 plot corssing the ridge. Within its 20 x 50 m extent the L_4 plot area is not homogenous because there is a more moist area in its western portion which can be distinguished by vegetation analysis. Generally, the downhill side of the plot is more moist than the uphill side. There has been evidence of minor human impact in the form of illegal camping within the area.

Vegetation Composition

This plot is in the drier part of the North slope beech gap forest. There is very little vegetation change from 1959 to 1976. A

few species like Disporum lanuginosum, Epifagus virginianus, and Euonymus obovatus were not observed in the 1976 inventory.

Stand Inventory

Due to the limited extent of the beech gap its eastern part encroaches into the spruce-fir forest communities as indicated by the presence of many suppressed spruce trees in this section of the plot. There has been a notable increase of spruce in the smallest diameter class. Beech exhibited good diameter growth in the middle diameter classes as does the buckeye (Aesculus octandra). Acer pennsylvanicum and Sorbus americana showed up for the first time in the 1976 tree inventory. Other woody plants remained practically unchanged.

PLOT L5 590903 & 760913 Newfound Gap North Slope, lower slope

Plot Location and Site

The exact location of the 1959 plot could not be exactly relocated. The presently marked L_5 is some 40 m downhill and parallel to the L_4. It reflects the more moist site conditions. Drainages have definitely become more distinct with gullies soil removal and erosion.

Vegetation Composition

The more moist and sheltered site is reflected in the increase of Acer saccharum and Aesculus octandra. In the shrub layer hemlock (Tsuga canadensis) is occurring and at this plot location it may have reahed its highest known elevation of occurance (1615 m or (5300 feet), within the Park. Vegetation remained practically unchanged from the 1959 inventory.

Stand Inventory

There have been sharp reductions in stand density in most of the tree species like beech and spruce while Acer saccharum increased. Correspondingly the basal area stocking increased in the 10 - 19 inch

diameter classes due to normal stand development. For the remainder this plot, inventory remained practically unchanged.

2.221 DYNAMICS OF THE BEECH GAP FORESTS

Very little is known about the dynamics of the beech gap forests and their successional patterns. Towards lower elevations these beech gaps gradually merge with cove forest types predominantly composed of beech, yellow birch and sugar maple with a heavy admicture of hemlocks. The inventoried plots are all located in the Newfound Gap area and definitely beech gaps of other areas should be inventoried and monitored for a better understanding of the dynamics.

In the southern part of the Park around Spence Field and Mineral Gap, north slope beech gap forests have been heavily impacted by hogs (*Sus scrofa*) originally introduced from Europe for hunting purposes in the lowlands (Figs. 6A and 6B). Since about 1959 the wild boar has been invading high elevation beech gap forests in the Cades Cove area. The almost complete destruction of the vernal beech gap flora has changed vegetation patterns drastically (Fig. 6A). Also in the winter time, low elevation cove forests and yellow pine ridges are heavily affected by the uprooting by the wild boar. The current beech gap plots do not yet show signs of hog damage (Fig. 6B). How hog damage will affect the natural processes in these forests is yet uncertain. Current preliminary studies indicate that within pig enclosures in a damaged beech gap, the normal natural vegetation tends to restore itself inside the enclosure.

2.23 THE COVE FOREST COMMUNITIES

These forest types are often widely divergent in species composition and dominance and mixture is the common rule rather than the exception. They all have in common that they are limited in their extent to valley floors and steep sheltered slopes. They cover a wide range of elevation. The current plot series has been established in the Greenbriar area and therefore, cannot be representative for the entire Park.

(A)

(B)

Fig. 6. Recent damage to ground cover is caused by rooting of European wild boar (Sus scrofa) in beech gaps. A. Mt. Mingus (September 12, 1976). B. Newfound Gap plot L4 (September 12, 1976) shows essentially uniform appearance of beech overstory and numerous root sprouts of beech (Fagus grandifolia).

The sites characteristic for the cove forests are a concave topography, abundant subsoil moisture or often even flowing creeks, a sheltered and often a shaded position, colluvial or alluvial soils with a great amount of boulders and rocks. Especially, the cove hardwood forests are very rich in species composition.

PLOT B1 590701 & 770706 Porter Creek Flat

Plot Location and Site

The exact location and some remnant flagging was found on this plot enabling the relocation of the plot center line within an accuracy of one meter. The plot was surveyed in from the Porter Creek footbridge crossing. The plot parallels the trail to the primitive camping area above the first hairpin curve of the trail and is on a gentle slope with scattered rock outcroppings. The area is typical for a mature virgin hardwood cove forest with an extremely diverse vegetation and many seasonal species.

Vegetation Composition

Vegetation patterns have been intensively studied by Bratton (1976) and cove hardwood forests have been described from vegetation analysis of this particular plot. The vegetation composition has remained remarkably constant from 1959 to 1977. There are some increases in species cover for *Halesia caroliniana* and *Tilia heterophylla* but these changes are insignificant. There has been no pig damage in this plot yet, although adjacent cove forests already show signs of pig activity. Many of the early spring floral components cannot be listed in the summer inventories.

Stand Inventory

The stand inventory remained surprisingly unchanged although certain trees have increased well in their diameter growth. Mortality was limited to the lowest diameter classes.

PLOT E1 770721 Trillium Gap Trail

Plot Location and Site

This plot was established by Whittaker on July 4, 1960 to represent the hemlock-rhododendron cove forest. The plot is surveyed in from the main creek crossing of the Trillium Gap Fork and the trail at the 3800 ft elevation. The trail crosses first a side creek and parallels the main Trillium Gap Fork for some 250 meters before crossing it. This crossing is marked with a 5 meter wide creek bed, with large rock boulders in it. Upstream from the crossing several large tree trunks are parallel with the current in the creek bed. The plot is located up the trail some 80 meters and incorporates a very large oldgrowth hemlock tree with a DBH of 157.5 cm. The exact former plot location could not be determined.

Vegetation Composition

The tree layer is dominated by old growth hemlock (*Tsuga canadensis*) with a reasonable admixture of *Magnolia fraseri* and *Betula alleghaniensis*. In the south part of the plot several large hemlock trees have fallen because of rot and old age. The plot area is dominated by *Rhododendron maximum* with a very scattered herb layer.

Stand Inventory

The stand is characterized by mature and overmature hemlock with no new incoming hemlock regeneration under the dense rhododendron shrub layers. Rhododendrons up to 10 cm DBH are not infrequent but the larger rhododendrons are layering on the ground.

PLOT E2 70710 Surrey Fork Area

Plot Location and Site

This plot was established in July of 1960 at about 2800 feet elevation along the Nature Motor Route back of Gatlinburg. The original plot description called for a north slope on Surrey Fork but field reconnaissance eliminated this location. One piece of organ

flagging was finally located on an unnamed side creek. The survey starts at a wooden bridge crossing of a creek 0.7 miles from the Grotto Falls Parking lot towards Gatlinburg or about 0.8 miles above Ephraim Bales Place. The USGS Quad sheet is in error by placing the creek beyond the bridge crossing towards the west of the paved road while actually the main creek parallels the road towards the east. From the flagged Rhododendron it was impossible to develop the 20 x 50 m plot uphill on the north slope before hitting the oak heath forest. A much closer approximation of the original inventory was obtained by orienting the plot eastwards along the creek in the gentle sloping valley rather than on the steep north slope. The 1960 inventory records also indicate problems in the reinventory because Liriodendron trees could not be relocated. The presently marked plot is the best possible compromise for the 1960 inventory.

Vegetation Composition

This plot is typical for a riparian hemlock-rhododendron cove forest with an admixture of beech (Fagus grandifolia), Magnolia fraseri, Betula alleghaniensis, Betula lenta, Halesia caroliniana, Tilia heterophylla and Acer saccharum. The floristic composition is characteristically poor. Heavy mortality exists among the larger overmature Tsuga, Acer saccharum and Fagus grandifolia. This mortality even surpasses in basal area that of the live trees. There are seepage or spring areas within the plot, while its SW corner is in the creekbed. There is a lack of incoming tree regeneration due to the massive and dominant shrub layer of Rhododendron maximum.

PLOT M2 770801 Upper hardwood Cove Forest Trillium Gap

Plot location and Site

This plot is located in the best of the small hardwood coves at the 4300 feet level along the Trillium Gap trail. The trail develops a very sharp hairpin by climbing on the ridge and the slope for the final approach to Trillium Gap. Beyond that hairpin one climbs uphill and

passes first through a small hardwood cove with many large boulders and then again through dense hemlock-rhododendron forests. At about 10-15 minutes climb from the former hairpin curve one comes to a trail portion with steep bare rock cliff walls before entering the M_2 cove. The plot is downhill from the trail and is surveyed to large specimen trees along the trail. The exact location of M_2 was ascertained by discovering remnants of plastic collecting bags left behind in 1960 at the base of the plot. The area is typical for such high elevation cove forests.

Vegetation Composition

The hardwood cove characterized by boulders and rock slides in drainage patterns are characteristically very rich in species composition. Its vegetation has affinities with the high elevation beech gap forests and there was no pig damage within the plot area. A large record specimen tree of Prunus serotina was adjacent to the plot and several large sized buckeyes dominate locally. On both sides of the plot, intermittent small creeks flow in minor drainages after a heavy show. Normally there is no perennial flow within the plot area. In more open areas Acer spicatum predominates the shrub layer together with some large Cornus alternifolia.

Stand Inventory

This stand represents a mature hardwood cove forest with large trees of Aesculus octandra, Tilia heterophylla and smaller trees of Acer saccharum, Acer pennsylvanicum, Acer spicatum, Fraxinus americana and a sprinkling of small hemlocks (Tsuga canadensis). The absence of regeneration of Aesculus octandra is noteworthy. No Fagus grandifolia was observed.

PLOT P1 770806 Liriodendron Cove Forest Trillium Gap

Plant Location and Site

This plot was established by Whittaker in July of 1960 at about 2400 feet elevation above the Hiking Club cabin on the Trillium Gap

trail. The exact plot location could not be ascertained because prominent landmarks like stone walls were missing or not observed in 1960. The best possible compromise for the 1960 inventory was found in a former agricultural field on a small spur ridge between two minor drainages. The plot has been surveyed to the junction of the Hiking Club Cabin trail with the main Trillium Gap trail. It is representative of the successional stages of lower elevation cove forests dominated by Liriodendron tulipifera.

Vegetation Composition

The tree layer reflects affinities with cove forests but its dominance by Liriodendron and Acer rubrum is characteristic. Also characteristic are the abundance of climbers and vines like Parthenocissus quinquefolia and Vitis species. A tree understory develops of small Halesia caroliniana, Tsuga canadensis, Cornus florida trees with an occassional Robinia pseudo-acacia and even Juglans regia. The herb layer is an admixture of weedy species and forest inhabitants. There was considerable pig damage in the herb layer at the time of the vegetation inventory (Aug. 5, 1977). There were practically no mosses on the ground except on large boulders and there was hardly any epiphytic lichen. Liriodendron exhibited the fastest growth rates.

Stand Inventory

The stands exhibits fast initial growth rates of Liriodendron but many of the larger Liriodendron trees have bole deformities, forked boles, broken tops and often climbers to the top of their crowns. Due to the fast growth and dominance of Liriodendron there is heavy mortality among the smallest diameter classes of Acer ruburm and Halesia caroliniana while many Robinia pseudo-acacia are beginning to die. This is the first forest growth following the abandonment of agricultural practices. The herb layer is prevented from full development by the continuous uprooting by pigs.

2.231 DYNAMICS OF THE COVE FORESTS

The middle and low elevation cove forests are representative of vegetation plots within the Greenbrier valley. It is very difficult to generalize dynamic patterns from monitoring these plots. They represent a reasonable crosssection of existing forest types within that drainage basin but they have not been sufficiently duplicated to make them representative. Generally, the predominant forest type is the hemlock-rhododendron forest type covering most of the steep canyon walls as well as the alluvial rocky flood plains of the many small creeks. Their successional patterns are not clear but they tend to reproduce rhododendron thickets with Tsuga overstory. Hardwoods will only establish themselves following fires, land slides or other catastrophic disturbances.

Rocky alluvial or colluvial sites with very limited top soil tend to produce hardwood forests with a rich vegetation. The successional patterns are not clear but generally the more tolerant hardwoods tend to dominate eventually, especially Acer saccharum, Fagus grandifolia and Betula alleghaneiensis or Betula lenta. Some form of disturbance seems to be necessary to regenerate cove forests.

2.24 MIXED OAK PINE HEATH FOREST COMMUNITIES

These Mixed Oak and Pine Heath Forests represent a large group of middle and low elevation forest types in xerix to mesic sites. Usually these forests occupy exposed ridges, rocky south exposures and shallow rocky sites. Many are transitional in nature and often heavily disturbed in the recent past.

PLOT F2 770701 Virginia Pine-White Pine Transitional Forest
Cades Cove

Plot Location and Site

This plot has been surveyed from the Henry Whitehead Cabin on the Large Poplar Road in Cades Cove. It is situated on the SE slope from about the ridge crest towards the base of the slope. There are

distinct moisture differences from the ridge top to the base of the slope. The hemlock and white pine components as well as the understory of Kalmia latifolia and Rhododendron maximum gradually increases from ridgetop to base of the slope. There is no way to separate site differences properly with this plot orientation. Plots parallel to the ridge and the base of the slope are needed but these have not been executed.

Vegetation Composition

Pinus virginiana and Pinus echinata dominate on the more xerix ridge portions of the plot while Pinus strobus and Quercus alba dominate the more moist sites at the base of the slope. The Kalmia heath understory is almost absent on top of the ridge and heavily mixed with Rhododendron maximum at the base of the slope. Vaccinium species are most abundant in the herb layer.

Stand Inventory

This is a young stand with limited mortality and predominantly of small-sized trees. Most of the mortality is in the Pinus virginiana trees due to competition. The stand is relatively even-aged.

PLOT J2 590707 & 770819 Table Mt. Pine Heath Trillium Gap

Plot Location and Site

This plot is located on an exposed pine heath ridge on a south slope at the 1200 m (3600 feet) level on the Trillium Gap trail. The plot is surveyed from a rock outcrop which the trail crosses at around 1200 m elevation. This rock outcrop provides a panormaic view across Cannon Creek towards The Boulevard and the crest with the Appalachian Trail. The plot is located above the second major rock outcrop along the trail on a very steep south slope. The exact boundaries of the 1959 plot could not be located within the dense Kalmia heath. The present marked plot contains more Quercus prinus than the original 1959 tree inventory but definitely represents the average stand conditions

of the Pinus pungens heath forest type better. Adjacent and more eastward a more uniform Pinus pungens stand has been largely killed by bark beetle infestations but the mortality of Pinus pungens within the plot is limited.

Vegetation Composition

The predominance of Kalmia latifolia in the shrub and herb layers is characteristic for these Table Mt. pine heaths. The most predominant small tree is Nyssa sylvatica with Acer rubrum. There is a surprising amount of live spruting chestnut (Castanea dentata) within the stand. The current mortality is mostly Pinus pungens in the lower diameter classes due to bark beetle infestation and competition. This plot had the largest number of trees tagged, well over 450 trees! There is very little change in species composition.

Stand Inventory

The Pinus pungens overstory is fully mature and partly dying. It is gradually being replaced by a hardwood understory mainly of Nyssa sylvatica and Acer rubrum. There are scattered Quercus prinus and Quercus coccinea trees in the moister draws. Most of the tall Kalmia heath is also dying probably due to overmaturity. Otherwise, there has been little change in the tree overstory since 1959.

PLOT C3 770805 Chestnut-Chestnut Oak Forest Trillium Gap

Plot Location and Site

This plot was established by Whittaker in 1960 but his description of landmarks like a giant Quercus prinus tree on the left side of the trail, a cairn of stones and the elevation could not be verified. The only possibility is an open Quercus prinus ridge parallelling the trail at 2425 feet elevation in which stand blazed trees of the center line could be found as well as the large dead Castanea snag. This plot is surveyed from the last creek crossing in the Trillium Gap trail prior to the trail curving southward and westward up the hill. This plot

location could also be identified from the lone small hemlock tree in the middle of the trail and from the cut-off old chestnut logs alongside the trail. This ridge is the second and last ridge with a predominant Gaylusackia ursina herb layer and the only ridge where this Gaylusackia herb layer appears west of the trail.

Vegetation Composition

The vegetation is relatively poor in species composition probably because of past site disturbances like fires and logging. The predominance of Gaylusackia ursina is striking indicating mesic conditions but the stand is relatively open. There are several very large specimen trees of Quercus prinus and Quercus borealis in the area. The plot is located on a small spur ridge with a creek running westerly of it. The vegetation is typical for the local Quercus prinus heath forests.

Stand Inventory

This is a young stand with remnant mature Quercus prinus but no new Quercus prinus regeneration. The understory trees are predominantly Acer ruburm, Oxydendron arboreum and a fair amount of Castanea sprouts. Successional patterns tend to favor hardwoods typical for more mesic sites.

2.241 DYNAMICS OF THE MIXED OAK PINE HEATH FORESTS

Very little is known about the dynamics of the mixed oaks and the pine heath forests. Various admixtures of oaks do occur and successional stages introduce pines into the oak forests. The xeric pine heaths are more stable forest communities on extreme and exposed sites. The current evidence is that past disturbances like forest fires, land clearing and/or logging has created the present species combinations. No virgin oak forest remains at lower elevations within the Park to study successional and regeneration patterns. The currently established Becking - Whittaker vegetation plots are totally inadequate to gain an insight into this complex. Many additional samples at lower elevations must be collected. Even the pine heath forests may need

catastrophic disturbances like lightning fires to propagate naturally the Pinus pungens forests with their serotinous cones.

2.25 HEATH COMMUNITIES

On extreme sites, exposed ridges at high elevation heath species dominate and several endemic heath species are known for the Smoky Mountains. In general, the sites have extreme xeric conditions, a very shallow soil mantle and extreme exposure to the elements. Forest trees rarely persist under these conditions and a shrubby dense heath developed. Occasionally, grassy balds develop but without grazing and fires they tend to develop into heath balds or the forest regains the areas.

For the heath plots the sampling size was reduced to 20 x 25 m. Special procedures have been developed to inventory heath species by 2 x 2 m quadrants and for the dense balds by 1 x 1 m quadrants. These quadrants are placed at the edge or borders of the plot. Every shrub species and tree seedling is tagged with an aluminum tag individually. The main stem is generally tagged and its diameter is measured at ground level to the nearest 0.1 centimeter in diameter. For the sprout clump a tally by one-centimeter diameter classes is maintained separated into live and dead stems. For very small seedlings the tag is wrapped around the main stem for identification. In addition, a map of the quadrant is drawn with the approximate location of each tagged shrub or seedling or clump. In general, these so-called heath plots are spaced at 10 m intervals along the borders of the plot with none of the plots along the center line. Damage to the heath plots is avoided as much as possible in gaining access to the inventory site.

PLOT W7 590703 & 770709 Brushy Mt. Summit

Plot Location and Site

This plot is surveyed from markers at the top of Brushy Mountain. Its location is within the approximately level summit area of Brushy Mountain with a very low heath. The plot area has been repeatedly

sampled and several minor foot trails go through the plot area. The open and bare spots within this heath are places where in the past the total vegetation plus soil has been removed for research.

Vegetation Composition

The vegetation composition has been remarkably constant from 1959 to 1976. Vegetation changes are exceedingly slow and by consequence recuperation or regeneration of the heath is very slow too. The area should be protected from further destructive sampling because of its limited extent.

Stand Inventory

There were no measurable trees within the 20 x 25 m plot size although there is regeneration of tree species, mostly Acer ruburm and Aronia melanocarpa.

PLOT W8 590704 & 770712 Brushy Mt. summit

Plot Location and Site

This plot is surveyed from land marks on the Brushy Mountain summit and its survey is connected with that of Plot W_7. The plot is located on the south exposure below the summit downhill. There is a definite gradient of increasing size of heath shrubs further downhill towards the more mesic site conditions. In general, the shrub cover varies from about 1 to 3 meters in height uphill downhill.

Vegetation Composition

The current plot demarcation includes the lone small Pinus rigida at the summit while the 1959 plot apparently just missed that tree. There is reasonable tree regeneration within the plot, mostly of Acer rubrum, Aronia melanocarpa, Amelanchier laevis, and Viburnum cassinoides. The upper part of the plot has a dominance of Kalmia latifolia and Rhododendron catawbiense while in the more mesic lowest part of the plot Rhododendron maximum and Ilex montana begin to appear.

For the remainder the vegetation composition of this plot has been remarkably stable since 1959.

Stand Inventory

There are very few tree individuals of Acer rubrum, Aronia melanocarpa, Amelanchier laevis and Viburnum cassinoides present.

2.251 DYNAMICS OF THE HEATH BALDS

From all the evidence it seems that heath vegetation does not change and that regenerative processes are exceedingly slow. It is unlikely that the trees will eventually take over due to the extreme site conditions.

3. PREDICTING ECOSYSTEM CHANGES FROM CLIMATIC CHANGE

The example of Fraser fir illustrates a species that may either be eliminated or else become severely narrowed in its distribution, due to climatic change, pest attack, or more likely a combination of both--each factor enhancing the impact of the other. Until work on the carbon cycle and climatic prediction is further developed and combined, we cannot state the probabilities of the climatic change being reflected in certain increase (or decrease) of mean temperature or of other climatic parameters. In the meantime, however, we can outline a set of plausible outcomes for which a conditional probability may eventually be estimated (i.e., if warming equals or exceeds a certain increment, then certain life zone shifts have increased odds of occurring).

First we review studies of the previous climatic measurements in the Great Smokies National Park. Then we shall consider some possibilities that might plausibly follow if the life zones shifted by the equivalent of +1, +3 and +5°C (+ 1.8, 5.4 and 9°F).

3.1 CLIMATE CHARACTERIZATION

The Great Smoky Mountains make a relatively low range of mountains, rising up to peaks over 2000 m along the border of Tennessee and North

Carolina. They are not sufficiently high to block westerly winds and to change climates drastically from the windward towards the leeward side of the mountain range as do most western mountains like the Sierras, Cascades, and the Rocky Mountains. According to the Thornthwaite (1948) classifications, the low elevations of the Smoky Mountains have humid mesothermal climate, and the high elevations per-humid microthermal; intermediate elevations have been named differently as the classification evolved (Shanks 1954). Annual precipitation ranges generally from 127-152 cm (50-60 in.) in the lower valleys to more than 200 cm (80 in.) at high elevations, is one of the highest precipitation regions of the USA.

The precipitation is both of orographic and cyclonic origin. During the summer, thunderstorms caused by the rise of humid air from the valleys advance along the ridges often discharging large amounts of rain in relatively short periods of time. Moisture and energy of most regional cyclonic storms originate over the Gulf of Mexico. In some years hurricanes from the Atlantic Ocean or the Carribean region move northerly and/or westward over the continent, causing great amounts of precipitation and high wind velocities along the Appalachian Mountains. Two distinct maxima of precipitation occur, one in winter and the other in summer (Ward 1925, Kendrew 1937, Whittaker 1956, Stephens 1969).

The logistic problems of tending climate stations in remote and rugged mountains have limited acquisition of climatic information on the local climates of the Smoky Mountains. Most weather stations are near population centers and at low elevations. Climatic data from such stations are not applicable to nearby mountainous regions. Fortunately, the Great Smoky Mountains National Park area has been the subject of fairly detailed climate studies reported by Shanks 1954, Tanner 1963, Smallshaw 1953, Berry 1964, and especially summarized by Stephens 1969.

The four weather stations are located along a north to south transect in the Gatlinburg area of the Great Smoky Mountains National Park. The 445-m (1460-ft) elevation station is the Park Headquarters station and is T.V.A. Station 209. The 1180-m (3850-ft) elevation station is located at the Alum Cave Bluff Parking Area in the draw

through which the West Prong of the Little Pigeon River flows. The 1525-m (5000-ft) elevation station is located near the Newfound Gap Parking Area in a gap along the crest of the mountains. The fourth station at 1920 m (6300 ft) elevation is located in the Clingman's Dome Parking Area. The first three weather stations are located in Sevier County of Tennessee, the fourth station in Swain County, North Carolina.

Results of Shanks (1956, 1954) and Tanner (1963) used a combination of air and soil temperatures to indicate changes in mean temperature lapse rate of 3.86°C per 1000 m or 2.23°F lapse rate per 1000 m (3°F per 1000 ft) rise in elevation. Tanner (1963) reported a lapse rate of 3.1 to 7.96°C per 1000 m for July and found no linear regression of the temperature decrease with elevation increase. European studies of temperature lapse rates in Central European mountains indicate 3.4 to 3.5°C per 1000-m rise in elevation.

Climatic monitoring tapes for stations surrounding the Park were obtained from the NOAA offices in Asheville, North Carolina. Computer analysis of these data will be needed to develop widely applicable regressions of air temperature and other variables on elevation and location. Such analyses now underway for Tennessee and North Carolina, and weather stations should be extended from Virginia to Georgia along the Appalachian mountain chain in order to apply the following analysis over a wider area than the Great Smokies.

Stephens (1969) has given the most complete climatic characterization of the Great Smoky Mountains, near the Gatlinburg NOAA station. He summarized 1947-1950 data from elevations: 445, 1160, 1525, and 1920 m (1460, 3850, 5000, and 6300 ft) using daily and hourly temperature recordings made by TVA and Park Service personnel. Conclusions on climatic trends with elevations are: (1) Cloudiness increases generally with rise in elevation and the months of February, May and October are the least cloudy at all elevations; fog also increases with elevation. (2) Steady temperature lapse rates with elevations were shown to vary with seasons and elevations. Stephens used the 445-m (1460-ft) station (Sugarlands Visitor Center, GSMNP) as the independent variable. Linear regressions were computed for the monthly mean, mean maximum, and mean minimum temperature and high correlations were found.

Stephens (1969) studied trends in mean monthly temperature variables (Table 5) and hourly temperature variations per day and per month (Table 6). For the Appalachian Mountains January is generally the coldest month, but in the peculiar four years of the studies by Shanks (1954) and Stephens (1969) January averaged unusually warm and February was normal (slightly colder than January). Other months were cooler than normal for the surrouding region. July is generally slightly hotter than August. Average daily fluctuations of 7° - 8.5°C + (13° - 15°F) between mean temperature and mean maximum or mean minimum temperatures were observed. Ranges (2 x amplitude) are shown on Fig. 7. The colder months had wider temperature fluctuations while the July temperature fluctuated over a smaller range. Lower elevations showed more fluctuation than higher elevations, on a monthly and daily basis. Temperatures at the highest elevation fluctuated least. Influx of cold air drainage and wind protection of the GSM Park Headquarters [445-m (1450 ft) station] presumably enhanced the fluctuations there. Drainage of cold night air from the peaks, and daytime cloudiness (especially in summer) diminish the temperature fluctuations on the summits [1920 m (6300 ft) near Clingman's Dome]. Monthly mean temperature variations seasonally followed about the same pattern for all four elevation but the 445-m (1460-ft) station mean at Gatlinburg was widely separated from stations at the other elevations.

Relative humidity is high; during 42 out of the 48 months of climate observations, more than 50% of the hourly readings were 100%. Relative air humidity is not a direct measure for effect on vegetation growth, but this high level presumably helps the abundant epiphytic growth of lichens and mosses on tree trunks. Vapor pressure deficits (Fig. 8) are generally considered better indicators for the atmospheric moisture demand than relative humidity. Stephens' evapotranspiration calculation showed the highest deficit values for the 445-m (1460-ft) elevation while the 1920-m (6300-ft) elevation station showed the next highest in 9 out of the 12 months. The months of April and May indicate the greatest deficits. Correlations of vapor pressure deficits among stations with different elevations were very poor

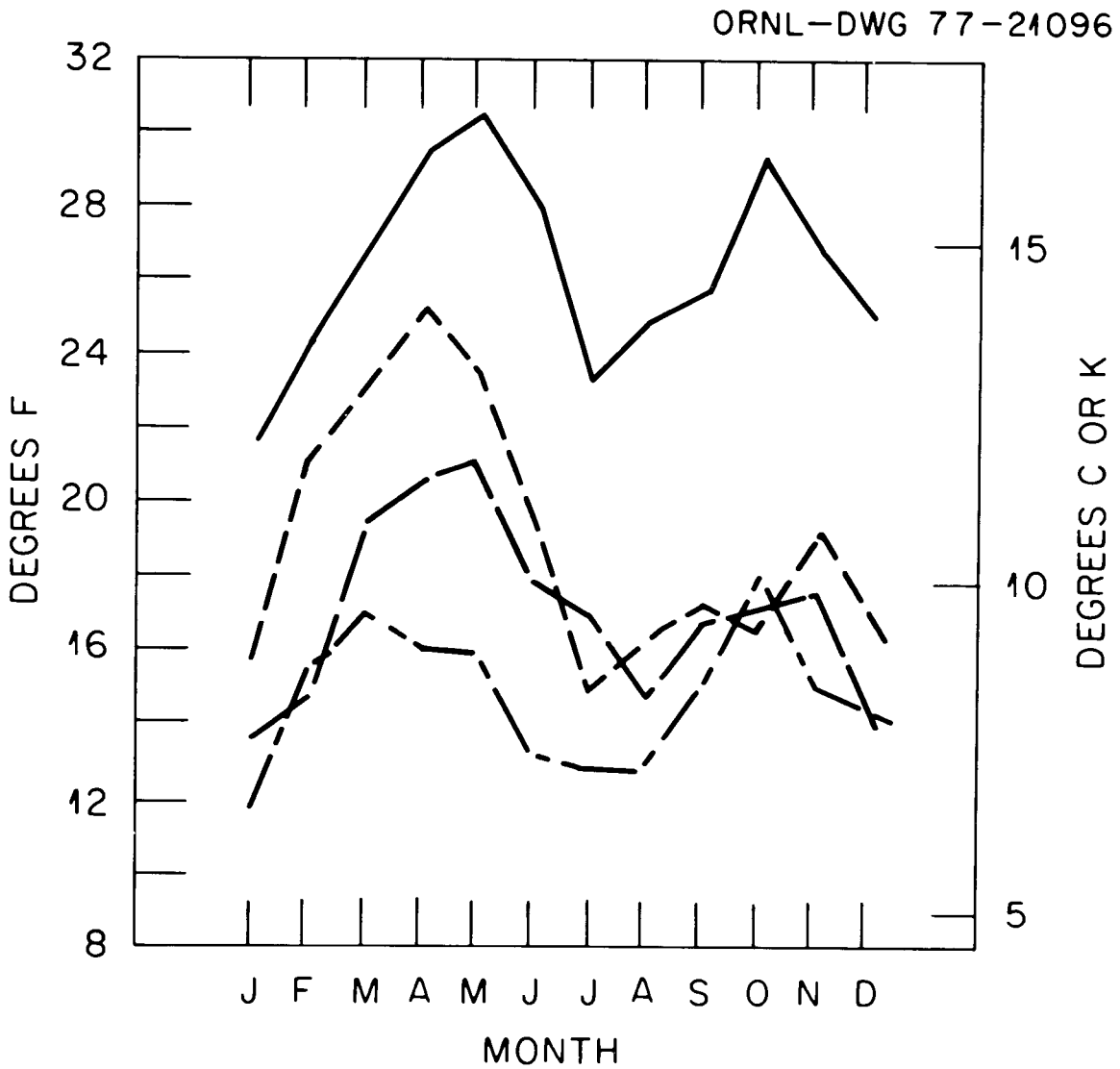

Fig. 7. Monthly mean temperature range for 1947-1950 at the 1460 ft. (———), 3850 ft. (-----), 5000 ft. (— —), and 6300 ft. (—••—) stations (Stephens 1969).

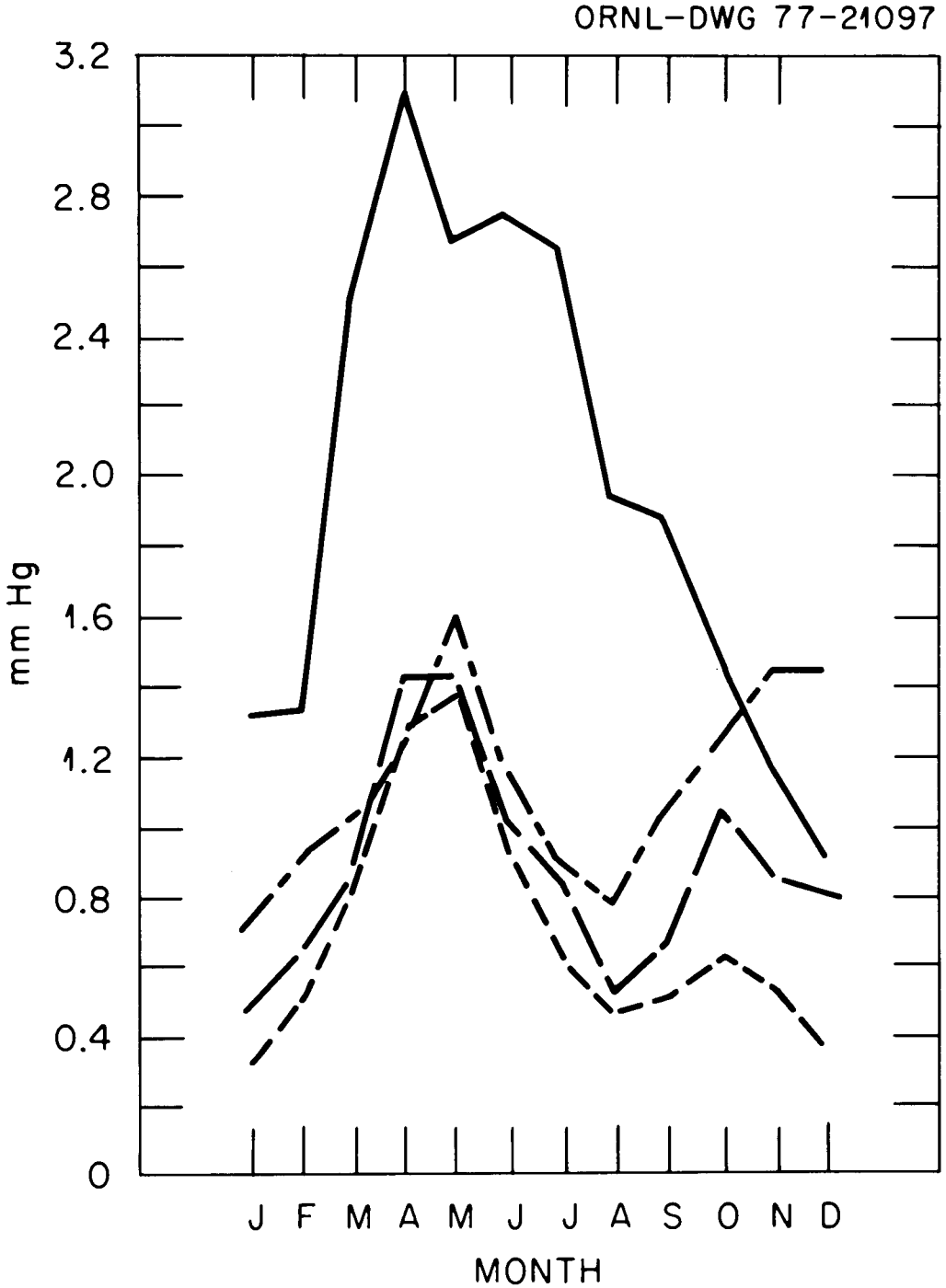

Fig. 8. Monthly mean vapor pressure deficit (mm Hg) at the 1460 ft. (———), 3850 ft. (-----), 5000 ft. (— —), and 6300 ft. (—•—) stations for 1947-1950 (Stephens 1969).

between the 445-m and other stations $r^2 = 0.195$) but are reasonable for the 1920-m elevation station ($r^2 = 0.779$).

Table 7 shows how precipitation increases with elevation (Smallshaw 1953). Correlations are not strong between any stations but the two intermediate ones, which are closest to one another (Table 8). There are two distinct maxima at all elevations, one in January and one in August. Snowfall is very limited and snow is recorded as precipitation. Snowfall tends to occur in the late fall, winter, and early spring at higher elevations but commonly melts between storms in all but the shadiest habitats. Because of the nature of orographic and cyclonic storms during the summer, precipitation can be highly variable from one ridge to another.

Potential evapotranspiration and soil moisture balances presumably indicate closer relationships of climate with vegetation. Following Thornwaite (1957) for simplicity, soil moisture field capacity was calculated as 31 cm (12.00 in.) using independent methods for monthly means (Table 10,12) and for daily means (Tables 9,11). It is interesting to note that the 445-m (1460-ft) elevation station has greater soil moisture deficiencies than the 1920-m (6300-ft) elevation station. This is primarily due to the higher air temperatures at lower elevation, although there is also more precipitation at high elevations. Soil moisture deficiencies reach their relative peak in July and are at their lowest in October, with another minimum in May and June.

"Growing seasons" have been variously identified. Most commonly applied is the definition of the time period between the last and the first killing frost (commonly approximated by 32°F = 0°C). However, Stephens (1969) has also calculated growing seasons between the 36°F and 40°F limits (Table 13). If one accepts the effective growing season to correspond with the 2°C (36°F) limit, the 1920-m (6300-ft) station corresponds closest to the 445-m (1460-ft) station in growing season days. It is interesting to note that the 1525-m (5000-ft) station in a beech gap has a disproportionally long growing season for the 5°C (40°F) limit.

3.2 CLIMATIC COOLING

Spruce-fir forests reached all elevations of the Southern Appalachian mountains and further south during major continental glaciations (Watt 1970, 1975). Several thousand years in the future, changes in solar orbit and declination are again expected to repeat similar cold climates perhaps 5 to 8°C colder than now. Fraser fir and red spruce may again march down the altitudinal gradient related to this cooling--if they have not become extinct during the warm period in the meantime.

From 1940 to the early 1970s much of the northern hemisphere has cooled a fraction of 1°C, after the extraordinarily warm (and droughty) conditions of the 1930s. Broecker (1975) predicted this trend would be reversed by early in the 1980s, while others conjecture the cooling may become more severe (at least in the eastern USA) for several decades before again warming (perhaps very suddenly!) because of increased global CO_2 and related climatic mechanisms.

It is too early to judge whether spruce invasion in certain beech gaps reflects a minor trend related to the recent cooling. The permanent plots should help to document any such trend, if and while it lasts; the plots should be ready to record the decline of cool-zone species if stimulated by warming and/or drying or other disruption. Meanwhile, ice and freeze damage from cold trends (like windthrow already evident on Mt. LeConte) may also become identified among the other sources of mortality. Unravelling other factors in ecological succession will be required in order to keep from confusing these with climatic succession in any direction.

3.3 CLIMATIC WARMING

Climatic warming caused by industrial pollution and carbon dioxide increases in the atmosphere have been under considerable study (Baes et al. 1976, NAS 1975). A critical review of the temperature increases has been undertaken by Schneider (1975) and others. He found that simulation models of climate change and of the global carbon cycle itself (Woodwell and Pecan 1973) might conceivably predict temperature increases of 0.7 to 9.6°C. Schneider (1975) expects upon critical

analysis a temperature increase of 1.5 to 3°K per doubling of the CO_2 concentration in the atmosphere. The 1974 atmospheric global CO_2 content was near 330 ppm at the Mauna Loa monitoring station. An annual increase averaging about 0.8 ppm over the preceding 16 years had been measured. Several models at Oak Ridge National Laboratory and elsewhere indicate an important possibility of the global CO_2 content doubling by early in the next century and continuing to increase if fossil fuel burning accelerates. As a part of this report it is timely to explore vegetational responses of the spruce-fir zone to such climatic changes as might occur with either low, medium, or high sensitivity of temperature to each doubling of CO_2. The increases considered below cover a range of possibilities-and may well include the most probable outcome.

1°C Increase

Between 1500 and 1920 m (about 5000 and 6300 ft, near the present lower and upper limits of the main forests dominated by spruce and fir forests), the monthly mean temperatures differ by only 0.7°F in July, November, and December, 0.8 to 1°F in October and August, and 1.2° to 3.5°F (0.7 to 2°C) in other months. We recognize, of course, the possible importance of many aspects of the temperature "signal" besides the variables listed in the tables above. Also many other environmental variables are directly or indirectly related to temperature. The main point, however, is that these temperature contrasts now observed between the above high and low elevation spruce-fir climatic stations within the Great Smoky Mountains National Park match the fairly modest temperature increases-near the lower predicted range of possibilities currently considered for recent models if CO_2 and climatic change. Other climatic variables, and the inherent capability of species to resist attack and disease, may be changing along with temperature.

One simplification thus far in interpreting the significance of temperature impacts is the neglect of ensuing moisture in such humid areas at these altitudes in the Great Smoky Mountains. The possibility of increased moisture stress is considered likely, based on physical

grounds. Conceivably, increased global air temperature may increase marit time evaporation and hence precipitation--sufficiently to balance increased vapor pressure deficits and evapotranspiration, if only for part of the year. However, it seems even more likely, in view of the climatic patterns already suggested by the tables, that the intensity and duration of moisture stress would increase, more frequently stressing ecosystems now adapted to a moisture surplus.

Since vegetation responds to temperature gradients, an upward displacement of species distributions should then follow. But such a simple displacement in altitude cannot always take place readily as migration takes time and availability of habitat. Competition depends on many physiological adaptations; genetic patterns may require corresponding changes to make the species' survival probable at their new stations. For these and other reasons, a seemingly small shift, if sudden and then sustained, seems likely to have more impact than might be expected at first from a static displacement of climatic zones.

For example, a 1°C (1.8°F) in mean temperature over the next 100 years could lead to a significant narrowing of the already limited distribution of endemic species in the spruce-fir life zones. Such rare endemics as Ceum radiatum and Calamagrostis caini on Mt. LeConte (near Fig. 2B) may become extinct without a great change in climate because they exist in very few relic stands. Increased air temperatures could lead to unfavorable respirtion, photosynthesis balances for several cold-zone species. Fraser fir may become limited by this kind of adaptation, as well as by pests which are most vigorous at the lower elevation of the fir's range, as discussed further below.

3°C Increase

A climatic change near to 3°C (5°F) warmer would have prompt and more significant effects. As can be seen from the seasonal temperature trends and other climate characterizations this increase in average air temperature would correspond roughly with an altitudinal difference near 500 m (over 1600 feet). This would mean that vegetation types and tree species currently dominating these lower elevations and commonly

referred to as the "northern hardwoods" would tend to invade the higher elevations as warming progresses. For example, beech (Fagus grandifolia) in its current montane ecotype may move upward and be replaced elsewhere by lowland ecotypes of beech; Magnolia fraseri, and Betula alleghaniensis are likely to increase in dominance on high but moist locations.

Upward displacement of zones suggests replacement first of Abies fraseri which is the most vulnerable tree species. Observations showed that Fraser fir is already under heavy attack by the woolly aphid (Adelges piceae); opening of the stand encourges rapid hardwood or spruce invasion, even without any climatic changes. Red spruce (Picea rubens) might be able to maintain only a relative subordinate rather than dominant position after climatic warming and could become limited to relics on isolated peaks. Eastern hemlock (Tsuga canadensis) may move upward on acid humus while decreasing at low elevations-maybe disappearing outside the higher mountains.

Some understory species also may change drastically or disappear. Species like Oxalis montana, Clintonia borealis, Viburnum alnifolium, Dryopteris spinulosa var. intermedia, Dryopteris spinulosa var. anstriaca, Athyrium felix-femina and Athyrium thelypteris have been found today to be narrowly limited to the spruce-fir zone. Consequently, they may be replaced by other vegetation, perhaps even by xeric vegetation with Rhododendron, Lyonia, and Kalmia species on exposed ridges.

Grassy balds are already being invaded by hardwoods and brush species like Rhododendron and Kalmia. The above changes may take place without any significant changes in precipitation, cloudiness, potential evapotranspiration and relative humidity since these climatic variables demonstrate little change from 3850 ft elevation to 6300 ft elevation.

Similar shifts in forest vegetation will occur on Mt. Mitchell, Roane Mt., and Grandfather Mountain and generally in the Blue Ridge region. Conceivably, an increase of 3°C (5°F) may mean the elimination of the Fraser fir in almost all of its botanical range. On Mt. Mitchell, Fraser fir under attack since the early 1960's have been

virtually eliminated from the tree canopy below 1680 m (5500 ft); it remains to be seen if the relic stands above 1830 m (6000 ft) and the already established young fir regeneration will survive the woolly aphid attach within the next decade. If the young fir is also attacked the species may well become almost extinct, like the American chestnut (Castanea dentata).

Attempts to introduce some 32 different parasite species for control against the woolly aphids have all failed. The U.S. Forest Service has abandoned further research on the Fraser fir and its survival. As "the nation's Christmas tree" its importance has shifted to high quality ornamental and horticultural use. Such uses also may become limited.

5°C Increase

The hypothetical increase of about 5°C (9°F) would be devastating to many other tree and herb species of the northern hardwoods. It would mean that an altitudinal shift of species equivalent to 1000 m (more than 32000 ft) would take place. This could enable lowland hardwoods of the 500-760 m (1500-2500 ft) elevation zone to invade the higher elevations. Yet many of these would be poorly adapted to summit soils and wind conditions. The attractive spruce-fir ecosystem could have vanished completely. Many heath balds would be replaced by *Vaccinium* species, *Clethra acuminatus*, *Kalmia latifolia* and *Pinus* species. Among the most prevalent hardwoods would be chestnut oak (*Quercus coccinea*, *Quercus rubra* - highland variety *borealis* displaced by the lowland variety) and white oak (*Quercus alba*).

However, such a drastic change in global temperature may affect and change worldwide climatic patterns as well. A difference of about 5°C in average global air temperature approaches the mean difference between a glacial and interglacial periods. Under the increasing heat stresses and moisture deficits many of the steep slopes and ridges with their shallow soil mantles will not even be likely to be able to support closed forests; some open and scrublike and pine-oak heaths and pine forests are likely to take their place, increasingly subject to burns after lightning storms. Cove hardwoods would survive in some of the

more protected smaller valleys and would not be so widespread at lower and middle elevations as today. Species like basswood (Tilia heterophylla, silverbell (Halesia montana), Magnolia fraseri, Stewartia ovata, yellowwood (Cladastris lutea) may become relics. Other species more adapted to drier site conditions like black locust (Robinia pseudoacacia), yellow pines (Pinus virginiana and Pinus echinata) may well take over where richer, more productive and diversified ecosystems thrive today.

3.4 IMPACTS ON HETEROTROPHS

A relative minor temperature increase of ± 1°C may have little impact upon most of the larger mammal populations if sufficient cover and food remain for their maintenance. However, currently the spruce-fir zone is characterized by several rare, endemic and endangered salamander species mostly of the genus Plethodon. These salamander species require high relative humidity, cool air temperature and a thick duff layer for their life cycles. Upon the disappearance of the mature spruce-fir forests as such the habitat of these salamander species may be significantly and negatively affected. Temperature changes of 3° or even 5°C can only further accelerate the exclusion of these species from the Smoky Mountains. Little is known about the insect populations but studies by Whittaker (1948) have indicated that there are several groups of insects especially adapted to these high elevations. These insect populations may also become extinct if they cannot adapt to the climatic warming or withstand the invasion of other insect species. Probably some other invertebrates like snails have no other contiguous areas to migrate to, and may become extinct because of a loss of habitat. Some counterparts may persist where spruce-balsam fir forests move northward across Canada.

Little is known about fungal communities. However, several interesting fungi have been recorded that are restricted to the spruce-fir zone exclusively. It is therefore, not unlikely that these fungi may subsequently disappear south of West Virginia (or New York) if the major tree components of the spruce-fir forests disappear.

4. BIOSPHERE RESERVE CONSIDERATIONS

That climatic changes coupled with industrial or technological carbon dioxide pollution are inevitable seems to be a fact hard for many people to contemplate or accept. The above predictions and contingencies may or may not occur within these ecosystems. Assuming no other disturbing or limiting factors, like lack of rainfall, the current ecosystems can nevertheless be put under significant stress by increased air temperature alone. Current evaluations of climatic change are still insufficient to predict climatic impact on vegetation, animals and man. In the Southern Appalachian Mountains an opportunity now exists to detect future change by early monitoring which considers and strives for a holocoenotic treatment of natural and managed ecosystems. Computer modeling of ecosystem responses would require periodic and more precise assessment of climatic variables and of observed and predicted biological responses to these climatic changes. New plant and/or animal species may invade. Their population response to the changing environment offers unique challenges to predictive ecology. This may lead towards monitoring to test hypotheses for a better understanding of the ecosystem dynamics. Successional patterns could be monitored over time. Transient conditions can create imbalances of production and cycling processes within the environment. Increased drying may disproportionally increase the risk of wild fires. Therefore, the Great Smoky Mountains area could serve as a benchmark study area where such impacts and new successions (e.g., balds) are to be measured and monitored.

For use of reconnaissance and planning other benchmark study sites such localized changes must account for the broad regional (or global) shifts in life zones. The experiences gained with monumentation, monitoring and classification of ecosystems in the Smoky Mountains (see below) may be useful for the Biosphere Reserve cluster already being developed in the Appalachians (Johnson, Olson and Reichle 1976). We advocate the establishment of continuing benchmark study sites within the Great Smoky Mountains National Park to gain experience for a more

detiled and integral biological monitoring for a global environmental monitoring system. This monitoring program should experiment with the most intensive and detailed study of permanently monumented research plots, even if this kind cannot be numerous. Establishment of less detailed permanent or even temporary plots may also be required in order to collect the needed environmental information over many combinations of conditions. A strong commitment of time and manpower is needed to successfully meet overall monitoring goals. The balance between the intensiv and extensive sampling may be governed as much by local and regional history as it will be by standards eventually established internationally.

A significant consideration in selecting any sample size or design is the consideration of repeated monitoring or destructive sampling for biomass. If samples are to be taken seasonally or monthly there will be human impact upon the sample area. Repeated access to observation points may create significant trampling effects and introduction of exotic weeds into the sampling site. If the sample area is to be preserved in its natural status, periodic monitoring and destructive sampling must have sufficient areas around the permanent plots to accomodate them.

4.1 CHOICE OF SAMPLE LOCATION, SIZE AND DESIGN

The choice of sample location, sample size as well as of what to measure will determine the limits of interpretability of the data collected. No matter what statistical manipulations are performed the quality and validity of the data cannot be improved beyond the quality of the field work. In general any sampling consideration must rationally resolve the following questions and make the corresponding choices as a consequence:

WHY? What is the purpose of the sampling, short-term versus long-term sampling? What is the main problem to be investigated?

Purposes of the 1976 field sampling were (a) to detect whether disturbances affected any of the plots established in

1959, and (b) to provide definite boundaries and procedures for monitoring either drastic or subtle changes which may be anticipated if our hypotheses of climatic change prove true.

WHAT? What attribute will be best measured? Will the measurement of this attribute finally answer the main question under investigation? To what accuracy must the attribute be measured to warrant a meaningful interpretation?

Precise measurements of tree diameters (preferably to 2 mm or 0.1 inch at heights marked by nails) on definitely bounded areas are needed for noting shifts in vigor, which underlie competition and survival among individuals and species in the course of climatic or other gradual successional change. Less refined measurements may suffice in areas known to be undergoing sudden impacts (e.g., windthrow, aphid infestation), and may permit a broader sampling of existing conditions and new reproduction.

WHERE? Where should the samples be best located to develop the answer to the problem? How many replications are needed?

Samples (like those reported here) well within typical stands of a climatic zone should remain central for documenting long term changes like we presently expect for the spruce-fir zone in the Appalachian Mountains. However, additional samples near the altitudinal limits of spruce-fir may show earlier evidence of this ecosystem's deterioration, or other shifts.

WHEN? When would be the most advantageous time period to collect the most meaningful measurements? Would the dormant season or the growing season be the best?

Summer proved satisfactory for spruce and fir forests. However, beech and some other deciduous forests with winter annuals would require additional observations for completeness in recording the non-tree composition and the activities of heterotrophic organisms (fungi, animals).

WHO? Who would do the measurement of the attributes? This would determine directly the instruments to be used, data collecting techniques and the precision of the measurements.

An experienced ecologist or forester should supervise the biological monitoring work and remain alert to aspects or explanations of change which may not all be reduced to routine data recording. Two additional crew persons make the division of work effective for completing plots of considerable detail in 1 day's time, on average.

Circular versus Rectangular Plot Shape

The circular and rectangular plot shapes have been commonly used in vegetation research. Both plot shapes have their own advantages and disadvantages:

CIRCULAR PLOT SHAPE	RECTANGULAR PLOT SHAPE
-- One center stake defines the plot perimeter	-- Four corner stakes or center-line stakes define the plot boundaries
-- Plot perimeter is the shortest but curved requiring frequent measurement for inclusion/exclusion of perimeter trees - perhaps optically	-- Assessment of inclusion/exclusion of perimeter trees can be optically done because of linearity of boundary
-- Nested circles of different areas have one common center stake	-- Nested quadrats are easily laid out with the possibility of random location of nested quadrats
-- Subdivision of circular plot can be best done by pie-shaped segments subtending an equal degree angle	-- Subdivision into smaller quadrants is much easier

-- Upon destruction of part of the plot it is difficult to remeasure and analyze data for the remainder of the plot area	-- Upon partial destruction the remainder of the plot can be readily measured in terms of surviving subplots
-- Loss of the center stake will jeopardize the entire plot perimeter	-- Loss of even two corner stakes will not significantly jeopardize the plot perimeter
-- Plot size can be increased with a minimum extension of radial distances from the center stake	-- Plot size increases would add to relative distance increments away from the plot center with the risk of increasing environmental inhomogeneity

Although circular plots have been widely used we recommend the use of the rectangular plots for intensive biological monitoring.

Horizontal Area and Slope Corrections

Considerable discussions among foresters have centered around the problem of correcting slope surface area to horizontal area. Maps and cadastral surveys only represent the horizontal projection of the terrain. Forest yields on slopes are affected by many additional complications like slope exposure, aspect, depth to bedrock, moisture seepage and parent materials. Corrections to horizontal surfaces are simple but of far less importance than the above environmental variables. Generally, slope corrections have been of no concern in phytosociological work.

We recommend establishing plot size exactly as to surface area on whatever slope angle may exist. Varying degrees of slopes may occur within one sampling site requiring a derived average slope correction. If there is need to readjust results from this basis to a truly horizontal basis, e.g., in relation to remote sensing area covered, then a correction factor must be estimated from the cosine of the area's effective mean slope.

General Summary

No unique set of plot criteria and procedures would fit all vegetation types and environmental conditions. Each vegetation type will require special considerations. For the efforts of the Biosphere Reserve Program, sampling designs can be categorized according to sampling intensity and sampling effort. The various needs of the Biosphere Reserve or other Environmental Monitoring Program would require flexibility as to choice of intensity of sampling and expenditure of sampling efforts. Schematically, the following sampling designs are ranked in terms of their sampling intensity and sampling effort:

	Expenditure of time, manpower and effort		
Intensity of Sampling	low - - -	medium - - - -	high
Intensive			20x50 m plot Whittaker & Becking 1959-1976
		CFI circular plot[a]	
Medium		ZM relevee[b]+soil+BA/acre Becking 1959-1962	
		transects Whittaker 1956	
Extensive	ZM relevee[b] Becking 1959-76		
	Vegetation type maps Frank Miller 1940		

[a]CFI = continuous forest inventory

[b]ZM = Zurich-Montpellier plant sociology lists, or relevee - a list of species cover classes and codes for "sociability" or clustering.

4.2 ESTABLISHMENT OF A HEATH PLOT

In forest stands with a dense understory of Rhododendron or Kalmia species and in open heaths great difficulties arise when a tree inventory will be made according to the forest plot inventory procedures. It is meaningless to tally stems at DBH level for a heath shrubs since they all come from the same root crown and often branch many times before reaching the DBH level. Therefore, the following procedures have been adopted to establish a permanent inventory plot in a heath community. This inventory applies only to heath species and heath plots.

Inventories for forest heaths and open heaths will be limited to quadrats of 20 x 25 m size and their corners will be permanently marked. Because penetration into the heath will lead to destruction of heath plants the idea was abandoned to establish sample plots along the center line. The 20 x 25 m quadrat will be divided into 5 x 10 m blocks for mapping and inventory purposes.

It is virtually impossible and impractical to execute a 100% heath inventory. The first modification is that stem diameters are to be measured at ground level or as close to ground level as feasible. This would eliminate tedious measurments at any other level. The main stem of each clump is to be measured to the nearest 0.1 centimeter in diameter and it is tagged with a numbered aluminum tag. A frequency count is then made of all the stems arising from the same sprout clump by one-centimeter classes separated into live and dead stems. These counted stems are not individually tagged. All herb species and seedlings are to be tagged. If the stem is too small to nail the tag into the stem, the aluminum tag is wrapped around the stem. The tag is placed at ground level facing outwardly out of the plot for easy recognition.

The heath plot size adopted is a quadrat of 2 x 2 m or in dense heath a quadrat of 1 x 1 m. The approximate location of the tagged specimens is mapped for each quadrat to facilitate future relocation. Dead stems are recorded but are not tagged.

The location and orientation of the 2 x 2 m or 1 x 1 m quadrat is that its corner is to coincide with the outer corners of the heath plot

(Fig. 9). The most Nw corner of the heath plot will have Heath Quadrat #1, heath quadrat #2 will at the 10 m station and heath quadrat #3 at the 20 m station. Continuing along its eastern border heath quadrat #4 will be at the 25 m station, heath quadrat #5 at the 15 m station and heath quadrat #6 at the 5 m station.

This will systematically distribute the heath plots over the entire heath plot and there is no need for acces and destruction of the heath plot. It is hoped that future remeasurements of tagged specimens will reveal growth rates and mortality of heath species. Considered heath species are the following:

Rhododendron maximum
Rhododendron catawbiense
Rhododendron carolianum

Kalmia latifolia

Clethra acuminata

Vaccinium constablei
Vaccinium corymbosum
Vaccinium stamineum
Vaccinium erythrocarpum
Vaccinium vaccillans
Vaccinium hirsutum

Gaylusackia baccata
Gaylusackia ursina

Pieris floribunda

Lyonia ligustrina

4.3 PLOT RECOMMENDATIONS OF R. W. BECKING

(1) A rectangular plot size of 20 x 50 m is best suited for intensive sampling. The longest plot axis should be oriented to follow contour lines or areas with the greatest homogeneity unless there is a particular reason to do otherwise. The center line should be laid out first and its magnetic bearing be read. At each end point the distances of 10 m on either side of the center line should be laid out and marked. Subsequently the distance between these end points should be checked for the exact distance of 50 m length and minor adjustments should be made. The center line at least and the corners (or longest sides if possible) should be marked with steel pipes at every 10 m distance. All distances should be measured as slope distances of 10 m. The effective slope should be measured.

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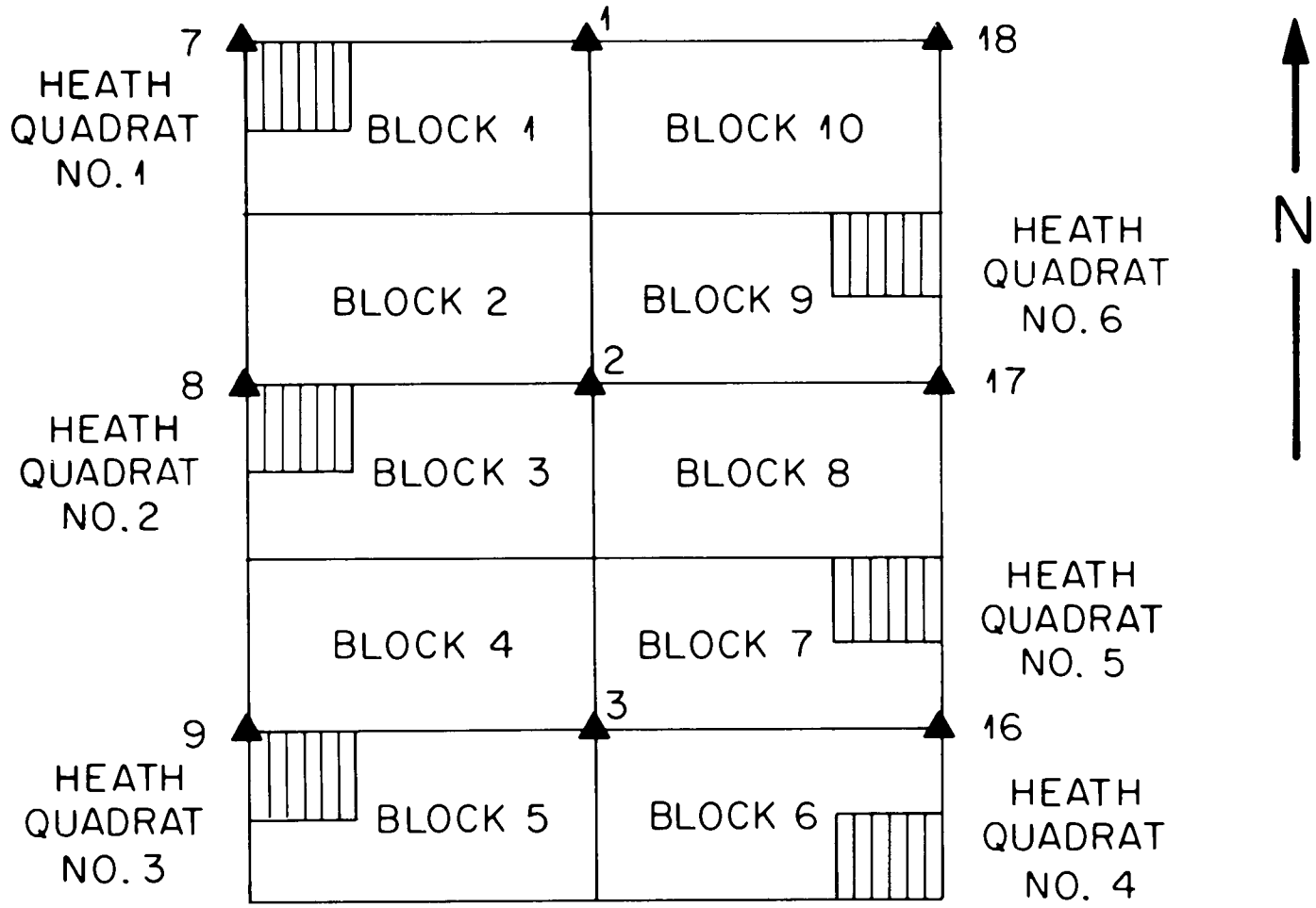

Fig. 9. Diagram of the heath plot and heath quadrat.

Stainless steel pipes should be used for the permanent marking of the corner points and the 10 m distance points. Stainless steel rods of approximately 1.2 m (4 ft) length are to be driven into the soil until they only protrude about 50 cm (20 inches). The following pipe numbering system was adopted uniformly in 1976 (see Fig. 10). The numbering system always starts at the most northerly end of the center line and continues from the most northwesterly corner southwards and again northwards until it reaches the most northeasterly corner. Small colored strips of good quality plastic flagging are tightly wrapped around the tip of each pipe for easy identification. Generally, the pipes are driven into the ground until they are fully covered by the normal herb layer.

(2) All the trees with a DBH of one cm and up are tagged with an aluminum numbered small tag at the DBH level facing the center line. Aluminum nails of 5 to 7 length are used to attach these aluminum tags to the tree. The aluminum nails are driven into the tree for about 1 cm at a downward slant. The aluminum tag is then pushed towards the tip of the nail in a vertical position. Dead standing trees are not tagged but are measured for their DBH.

(3) All tree DBH values are to be read with a diameter tape reading to the nearest millimeter. The diameter tape is to be tightly wrapped around the tree trunk but the tape pressure should not unduly compress the bark. The tape is to be placed horizontally around the tree in such a manner that one end of the tape will go directly below the aluminum nail and the other tape end directly above the aluminum nail. The aluminum nail thus forms the permanent marking point for future remeasurement of the DBH. In case the aluminum nail is misplaced in DBH level on the tree the aluminum nail should not be moved but the remeasurement of the DBH should proceed at that level in the same manner as indicated above.

(4) Upon reinventory and remeasurement of the DBH's of the trees, the new DBH should be at hand also. In case there is a discrepancy in the DBH values between the former and the present remeasurement, this discrepancy should be immediately resolved in the field. Proper notes

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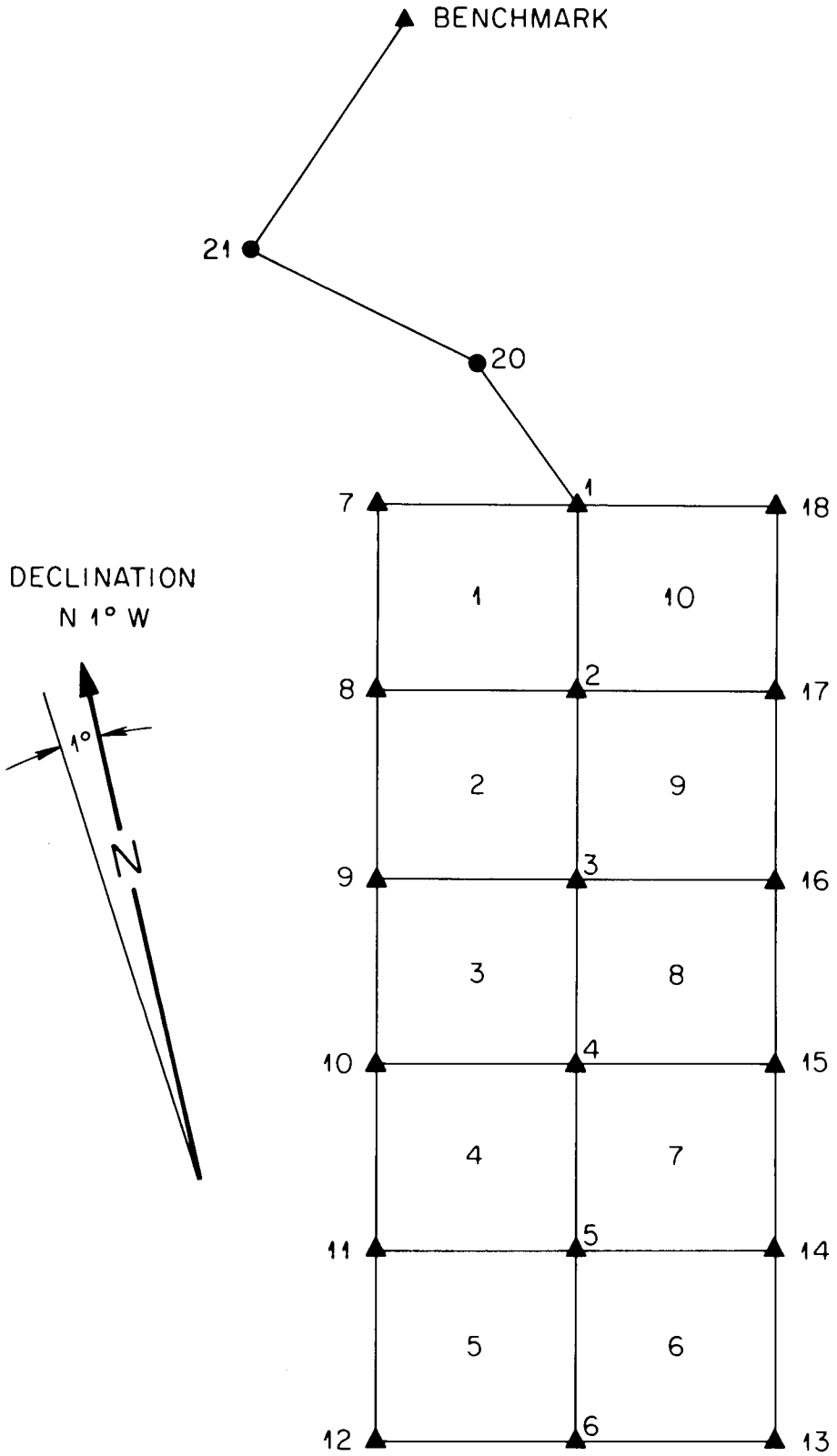

Fig. 10. Sample plot diagram.

should indicate how these record adjustments have been resolved and what the latest DBH record is. In case the aluminum nail is missing upon remeasurement the exact DBH level is to be reestablished by direct measurement of 1.3 m or 1.37 height, whichever was originally used. The bark at that level should be carefully inspected to detect the former nail hole. If it is found the new aluminum nail should be driven into the bark of the tree within the former nail hole. Otherwise, a new aluminum nail should be placed in the tree.

(5) The tree inventory should proceed per block and records are to be separated by block. A sketch map with the numbered trees per 10 x 10 m block is to be provided. This sketch would aid significantly in relocating the numbered trees and to identify any missing tree numbers. In the sketch also the upcoming tree regeneration of 50 cm to 130 cm is to be sketched in as to its relationship with the overstory trees. Any plots for ground cover or special study should be located precisely on the map. Details on such ground plots were beyond the scope of 1976 work.

(6) Any new incoming regeneration of the tree species will be numbered and tagged as soon as its DBH level reaches one cm in diameter. This new ingrowth would be significant in determining the population dynamics of the tree species.

(7) Each tallied tree should be recorded as to its species, its DBH and its crown class. Crown classes are to express the relative dominance of the individual tree in relation to its immediate neighbors. This record would help in the interpretation of growth patterns among dominant, codominant, intermediate and suppressed trees. Also the mortality by crown class can be significant for future growth projections.

(8) Representative tree specimens representing all the major tree species should be selected for additional measurements. These so-called sample trees are to be equally distributed among all crown classes. A minimum of ten sample trees of all species combined are to be selected. The sample tree should be a normal tree devoid of any deformity or abnormality and should well represent the average tree of its DBH and crown class. The following measurements are to be made on

each sample tree: Species, crown class, tag number, DBH, total height to the nearest meter, total age at DBH level, the measurement of its radial increment at DBH level for the first 10-year period and the next 10-year period, and its bark thickness. Radial increments and bark thickness should be measured to the nearest 0.1 millimeter. Upon field measurement of the DBH core, the core should be reinserted into the tree to avoid any possible infection. Within a few weeks the core becomes well sealed into the trunk with a minimum of bleeding and damage. In other cases, there may be a need to examine the yearly patterns for analysis of climatic patterns in which case increment cores must be retained and preserved.

Upon remeasurement of a sample tree only its height and DBH are to be remeasured and its crown class is to be checked. No additional tree coring is to be done. Upon remeasurement, an additional minimum of five new trees are to be cored as new sample trees and the data recorded as above. The selection of these additional and new sample trees may improve the information of the then prevalent crown classes.

(9) Incoming seedling regeneration of the major tree species are to be measured for their total height and age. Generally, it will be relatively easy to measure the total tree height to the nearest centimeter. The tree age should be recorded as the age above DBH level and the number of years up to DBH level, e.g., based on whorls. This kind of information may give an insight into the time-spans involved for trees to reach DBH levels. A minimum of about five young seedlings per major species would be desirable.

(10) A soil profile description should be made near the center line of the sample plot. Its location should be noted on the block sketch as well as the nearest numbered trees should be noted. The sputogram technique* should be useful to develop an appreciation of the

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*Becking developed this technique in 1950. Using semi-bleached groundwood note-pad paper small amounts of soil are rubbed or smeared on the paper mixed with saliva. Each horizon is smeared on separately. The note pad is then air-dried and treated with fixative for preservation of the soil colors. Sputograms are glued on heavy weight paper and can be filed in a standard ring binder. The field information and profile description copied on the same sheet will supplement the mounted Sputogram.

soil formation trends. Each soil horizon should be checked for its dry and wet coloration utilizing the Munsell Soil Color Chart. The determination of its pH would be desirable. Additional analyses as to nutrient content, texture analysis, etc., are desirable but not necessary for all the sample plots. The soil development should be checked at the start and at the end of the center line to determine if sufficient variation exists in the soil to make two soil profiles and to stratify the tree inventory and subtotal the vegetation analysis accordingly.

The sputogram should be properly mounted and preserved for future reference. Upon remeasurement of the sample plot a new soil profile near the former location should be described and analyzed to determine any changes in profile characteristics.

(11) A vegetation record should be made following the ZM methodology of a 100% inventory of all vascular and cryptogram plant species. Upon remeasurement a new vegetation record should be made and compared with the former one to determine if any floristic changes have taken place in the interval. If uncertain as to specils identify voucher specimens are to be retained for future identification.

(12) Additional vegetation sampling methods can be applied at the same for ordination or gradient analysis. Appropriate records as to methodology and plot dimensions are to be maintained in the field notes for future reference. The design of the subplots are to be indicated by a sketch with reference to the numbered pipes.

(13) The BA/hectare is to be determined by the Bitterlich method using just the relascope. Total basal area per species is to be determined following the recommendations of Becking (1960, 1976) using two independent BAF's. The point sampling is to be done for each of the six numbered pipes of the center line. Upon plot remeasurement the same stations are to be used for BA/hectare determinations. Only the basal area of live trees is to be determined. Only recognized and inventoried tree species are to be included, no shrub species.

(14) The center line of the sample plot should be connected with a surveyed line to the nearest bench marker or permanent identification

point. This would significantly aid in the future relocation of the sample plot. Upon remeasurement of the sample plot this survey line should be rechecked and modified if necessary in order to update the resurvey and to modify its course if necessary.

The above is for the most intensive and complete sample plot yielding the maximum amount of information on the vegetation. In the Biosphere Program there may be additional needs for less intensive sampling of vegetation. Two levels of decreasing intensity in time and effort are suggested: (1) the ZM vegetation plot with soil profile description and BA/hectare determination, and (2) the ZM vegetation plot alone.

For the ZM vegetation plot with soil profile and BA/hectare determinations follow the above (10); (11); (13); and (14). The plot marking should be done by two stainless steel pipes positioned 10 m apart in the center of the sampled area and the soil profile should be extracted midway between these pipes. These two center pipes are also to be used for the BA/hectare determinations. The survey line should run from the most northerly or northwesterly pipe to a known and permanent bench mark.

For the simple ZM plot follow from the above (11) and (13). A single stainless steel pipe is to mark the plot center.

4.4 Resource Allocations and Time

The present field work experience has indicated that under normal weather and travel conditions and utilizing a crew of 3 persons plus a principal investigator a sample plot can be completely established, inventoried, analyzed for soil and vegetation and BA/acre or BA/hectare within approximately 8 hours. If longer than one hour travel is needed toward and from the sample plot this extra time should be added to the above time expenditure. A well-trained plant ecologist familiar with the ZM methodology and the local flora and cryptogams can finish the 100% floristic inventory of the 20 x 50 m plot in approximately one hour. An additional hour is needed to complete the soil profile description plus sputograms.

Normally, these activities can be dovetailed into the stem inventory procedures. The determination of the BA/hectare would require at least one-half hour perhaps much more if there are many small saplings. An estimate of the line survey to the nearest bench marker or permanent marker is hard to give depending upon the distances involved. However, under normal field conditions approximately 200-300 meter can be recorded and surveyed within half of an hour. This depends also on the obstacles involved, the steepness of slopes, and other aspects of terrain and cover. A heath plot inventory depends upon the density of the heath but generally would require about 4 hours.

It would be ideal to have a reinventory and remeasurement of the sample plot every five years. Normally, it would be more feasible to reinventory every 10-year period. However, the shorter inventory periods will generally yield better data and a good chance of correcting former observation errors. In young successional stages even shorter than five-year intervals may be desirable. However, priorities for early years are likely to require new plots in geographic areas and ecosystem types not covered sufficiently by any existing plots. For such coverage, medium and extensive plot technique rather than the intensive detail outlined here may also have priority over the same expenditure on intensive plots.

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APPENDIX

Table 1. Stand inventory summary (N trees/hectare), Great Smoky Mountains 1959-1976 and 1977**

	Live Trees					Dead Trees				
(cm)	1.3-23.9	23.9-43.5	43.5-74.9	74.9-254		1.3-23.9	23.9-43.5	43.5-74.9	74.9-254	
(inch)	1-9	10-19	20-29	30-100	Total	1-9	10-19	20-29	30-100	Total
H1 Plot 590607			Inventory 6-16-59 Mingus Lead S							
Picea	570*	200	—	—	770	140*	—	—	—	140
Abies	430	250	—	—	680	280	—	—	—	280
Betula	10	10	—	—	20	—	—	—	—	—
Fagus	—	—	—	—	—	20	—	—	—	20
Total	1010	460	—	—	1470	440	—	—	—	440
H1 Plot 760807			Inventory 8-27-76 Mingus Lead S							
Picea	470	390	—	—	860	250	—	—	—	250
Abies	90	180	—	—	280	70	—	—	—	70
Betula	20	—	—	—	20	—	—	—	—	—
Fagus	—	—	—	—	—	—	—	—	—	—
Sorbus	30	—	—	—	30	—	—	—	—	—
Total	610	570	—	—	1190	320	—	—	—	320
H2 Plot 590609			Inventory 6-17-59 Mingus Lead E							
Picea	560	60	20	20	660	320	—	10	—	330
Abies	390	110	20	—	520	180	10	—	—	190
Betula	80	—	—	—	80	—	—	—	—	—
Fagus	150	—	—	—	150	40	—	—	—	40
Acer spicatum	—	—	—	—	—	—	—	—	—	—
Sorbus	—	—	—	—	—	—	—	—	—	—
Total	1180	170	40	20	1040	540	10	10	—	560
H2 Plot 760910			Inventory 8-27-76 Mingus Lead E							
Picea	300	40	50	30	420	—	—	—	—	—
Abies	1480	100	—	—	1580	230	110	—	—	340
Betula	80	30	10	—	120	—	—	—	—	—
Fagus	—	—	—	—	—	—	—	—	—	—
Acer spicatum	10	—	—	—	10	—	—	—	—	—
Sorbus	10	—	—	—	10	—	—	—	—	—
Total	1880	170	60	30	2140	230	110	—	—	340

Table 1. (continued)

	Live Trees					Dead Trees				
(cm)	1.3-23.9	23.9-43.5	43.5-74.9	74.9-254		1.3-23.9	23.9-43.5	43.5-74.9	74.9-254	
(inch)	1-9	10-19	20-29	30-100	Total	1-9	10-19	20-29	30-100	Total
H4 Plot 590611			Inventory 6-19-59 Mt. Collins							
Picea	60	50	80	—	190	210	10	10	—	230
Abies	390	170	—	—	560	190	20	—	—	210
Betula	—	20	—	—	20	—	—	—	—	—
Acer spicatum	40	—	—	—	40	10	—	—	—	10
Total	490	240	80	—	810	410	30	10	—	450
H4 Plot 590611 / 760704, 760801			Inventory 8-15-76 Mt. Collins							
Picea	230	40	40	20	330	—	0	10	—	10
Abies	350	110	10	—	470	230	40	10	—	280
Betula	130	20	—	—	150	10	—	—	—	10
Acer spicatum	110	—	—	—	110	—	—	—	—	—
Total	820	170	50	20	1160	240	40	20	—	300
RWB#20 Plot 590614 / 760802, 760803, 760804			Inventory 9-16-76							
Picea	190	30	10	—	230	100	20	—	—	120
Abies	630	280	—	—	910	940	30	—	—	970
Betula	160	20	10	—	190	40	—	—	—	40
Total	980	330	20	—	1330	1080	50	—	—	1130
RWB#21 Plot 590618 / 760806			Inventory 8-25-76							
Picea	80	40	10	—	130	—	—	—	—	—
Abies	400	430	—	—	830	320	60	—	—	380
Betula	10	—	—	—	10	—	—	—	—	—
Sorbus	50	20	—	—	70	—	—	—	—	—
Total	540	490	10	—	1040	320	60	—	—	380

Table 1. (continued

	Live Trees					Dead Trees				
(cm)	1.3-23.9	23.9-43.5	43.5-74.9	74.9-254		1.3-23.9	23.9-43.5	43.5-74.9	74.9-254	
(inch)	1-9	10-19	20-29	30-100	Total	1-9	10-19	20-29	30-100	Total
RWB#22 Plot 590617 / 760805			Inventory 8-25-76							
Picea	10	20	—	—	30	—	—	—	—	—
Abies	410	260	—	—	670	180	140	—	—	320
Sorbus	180	20	—	—	200	10	—	—	—	10
Betula	—	—	—	—	—	10	—	—	—	10
Total	600	300	—	—	900	200	140	—	—	340
RWB#23 Plot 590619 / 760907			Inventory 8-26-76							
Picea	30	70	130	—	230	—	—	20	—	20
Abies	1490	100	20	—	1610	410	40	—	—	450
Betula	10	—	—	—	10	—	—	—	—	—
Sorbus	10	—	—	—	10	30	—	—	—	30
Total	1540	170	150	—	1860	440	40	20	—	500
L3 Plot 590904 / 590907			Inventory 9-2-59 Newfound Gap							
Picea	40	20	10	—	70	—	—	10	—	10
Abies	1800	90	—	—	1890	220	20	—	—	240
Betula	—	—	—	—	—	—	—	—	—	—
Amelanchier	130	—	—	—	130	—	—	—	—	—
Acer saccharum	10	—	—	—	10	—	—	—	—	—
Total	1980	110	10	—	2100	220	20	10	—	250
L3 Plot 760911			Inventory 9-14-76 Newfound Gap							
Picea	40	—	—	—	40	—	—	—	—	—
Fagus	2490	190	—	—	2680	130	—	—	—	130
Betula	—	10	10	—	20	—	—	—	—	—
Amelanchier	—	10	—	—	10	—	—	—	—	—
Acer Saccharum	—	20	10	10	40	—	—	—	—	—
Total	2530	230	20	10	2790	130	—	—	—	130

Table 1. (continued)

	Live Trees					Dead Trees				
(cm)	1.3-23.9	23.9-43.5	43.5-74.9	74.9-254		1.3-23.9	23.9-43.5	43.5-74.9	74.9-254	
(inch)	1-9	10-19	20-29	30-100	Total	1-9	10-19	20-29	30-100	Total
L3 Suppl. Plot 590904 / 590907, 760911				Inventory 9-2-59 Newfound Gap South Slope						
Picea	30	—	—	—	30	10	—	—	—	10
Fagus	3790	210	—	—	4000	50	20	—	—	70
Betula	10	20	—	—	30	—	—	—	—	—
Amelanchier	150	—	—	—	150	10	—	—	—	10
Acer saccharum	—	20	30	—	50	—	—	—	—	—
Acer spicatum	10	—	—	—	10	—	—	—	—	—
Aesculus	—	—	10	—	10	—	—	—	—	—
Total	3990	250	40	—	4280	70	20	—	—	90
L4 Plot 590901 / 590902				Inventory 8-19-59 Newfound Gap						
Picea	70	—	—	—	70	—	—	—	—	—
Fagus	1220	150	—	—	1370	10	—	—	—	10
Betula	190	20	—	—	210	—	—	—	—	—
Acer saccharum	—	10	—	—	10	—	—	—	—	—
Acer spicatum	480	—	—	—	480	40	—	—	—	40
Aesculus	30	10	—	—	40	—	—	—	—	—
Acer pensylvanicum	—	—	—	—	—	—	—	—	—	—
Sorbus	—	—	—	—	—	—	—	—	—	—
Total	1990	190	—	—	2180	50	—	—	—	50
L4 Plot 760912				Inventory 9-15-76 Newfound Gap						
Picea	350	—	—	—	350	20	—	—	—	20
Fagus	500	190	10	—	700	10	10	—	—	20
Betula	20	10	—	10	40	10	—	—	—	10
Acer saccharum	—	—	—	—	—	10	—	—	—	10
Acer spicatum	210	—	—	—	210	—	—	—	—	—
Aesculus	20	30	—	—	50	—	—	—	—	—
Acer pensylvanicum	120	—	—	—	120	—	—	—	—	—
Sorbus	10	10	—	—	20	—	—	—	—	—
Total	1230	240	10	10	1490	50	10	—	—	60

Table 1. (continued)

	Live Trees					Dead Trees				
(cm)	1.3-23.9	23.9-43.5	43.5-74.9	74.9-254		1.3-23.9	23.9-43.5	43.5-74.9	74.9-254	
(inch)	1-9	10-19	20-29	30-100	Total	1-9	10-19	20-29	30-100	Total
L5 Plot 590903			Inventory 9-9-59 Newfound Gap							
Picea	200	40	10	—	250	10	20	—	—	30
Fagus	1970	110	—	—	2080	70	10	—	—	80
Betula	60	20	20	—	100	40	—	—	—	40
Acer saccharum	40	—	10	—	50	—	—	—	—	—
Acer spicatum	70	—	—	—	70	—	—	—	—	—
Acer epnsylvanicum	30	—	—	—	30	—	—	—	—	—
Aesculus	10	10	10	—	30	—	10	—	—	10
Total	2380	180	50	—	2610	120	40	—	—	160
L5 Plot 760913			Inventory 9-16-76 Newfound Gap							
Picea	60	10	—	—	70	—	—	—	—	—
Fagus	660	80	—	—	740	30	—	—	—	30
Betula	180	30	10	—	220	10	—	—	—	10
Acer saccharum	80	50	—	—	130	—	—	—	—	—
Total	980	170	10	—	1160	40	—	—	—	40
B-1 Plot 590701			Inventory 7-2 & 6-59							
Halesia	500	30	—	—	530	70	10	—	—	80
Aesculus	120	—	—	10	130	—	—	—	—	—
Tilia	40	20	—	—	60	10	—	—	—	10
Fagus	190	10	—	—	200	10	—	—	—	10
Fraxinus americana	10	—	10	—	20	20	—	—	—	20
Acer saccharum	10	30	10	10	60	—	—	—	—	—
Liriodendron	10	—	—	10	20	—	—	—	—	—
Magnolia acuminata	—	—	—	10	10	—	—	—	—	—
Tsuga canadensis	50	—	—	—	50	—	—	—	—	—
Betula alleghaniensis	—	—	—	—	—	—	10	10	—	20
Total	930	90	20	40	1080	110	20	10	—	130

Table 1. (continued)

	Live Trees					Dead Trees				
(cm) (inch)	1.3-23.9 1-9	23.9-43.5 10-19	43.5-74.9 20-29	74.9-254 30-100	Total	1.3-23.9 1-9	23.9-43.5 10-19	43.5-74.9 20-29	74.9-254 30-100	Total
C-3 Plot None				Inventory July 1960						
Quercus prinus	10	10	30	20	70	—	10	20	20	50
Castanea dentata	—	—	—	—	—	120	20	60	30	230
Acer rubrum	1270	10	—	—	1280	140	10	10	—	160
Liriodendron	20	—	—	—	20	—	—	—	—	—
Oxydendron	460	—	—	—	460	110	—	—	—	110
Cornus florida	60	—	—	—	60	—	—	—	—	—
Halesia	140	—	—	—	140	70	—	—	—	70
Quercus borealis	50	—	10	—	60	—	—	10	—	10
Magnolia fraseri	50	10	—	—	60	40	10	—	—	50
Fagus	20	—	—	—	20	—	—	—	—	—
Acer pensylvanicum	10	—	—	—	10	10	—	—	—	10
Nyssa	30	—	—	—	30	10	—	—	—	10
Sassafras	10	—	—	—	10	—	—	—	—	—
Robinia	10	—	—	—	10	—	—	—	—	—
Total	2150	30	40	20	2230	500	50	100	50	700
E-1 Plot None				Inventory 7-4-60						
Tsuga canadensis	20	10	20	60	110	10	—	50	—	60
Betula alleghaniensis	—	—	—	10	10	—	—	—	—	—
Magnolia fraseri	100	10	—	—	110	—	—	—	—	—
Total	120	20	20	70	230	10	—	50	—	60

Table 1. (continued)

	Live Trees					Dead Trees				
(cm)	1.3-23.9	23.9-43.5	43.5-74.9	74.9-254		1.3-23.9	23.9-43.5	43.5-74.9	74.9-254	
(inch)	1-9	10-19	20-29	30-100	Total	1-9	10-19	20-29	30-100	Total
E-2 Plot None				Inventory July 1960						
Tsuga canadensis	340	20	10	—	370	100	10	10	30	150
Magnolia fraseri	10	—	—	—	10	—	—	—	—	—
Halesia	200	10	—	—	210	40	10	—	—	50
Acer saccharum	30	50	30	—	110	20	40	30	—	90
Fagus	370	40	—	—	410	80	20	—	—	100
Tilia	10	—	—	—	10	—	—	—	—	—
Betula alleghaniensis	20	—	—	—	20	10	—	—	—	10
Betula lenta	30	—	—	—	30	20	—	—	—	20
Total	1010	120	40	—	1170	270	80	40	30	420
F-2 Plot None				Inventory 8-21-59						
Pinus strobus	1860	20	—	—	1880	160	—	—	—	160
Pinus virginiana	160	150	10	—	320	70	—	—	—	70
Pinus rigida	20	30	—	—	50	—	—	—	—	—
Quercus coccinea	50	20	—	—	70	10	—	—	—	10
Quercus prinus	20	—	—	—	20	—	—	—	—	—
Quercus alba	120	—	—	—	120	30	—	—	—	30
Nyssa	310	—	—	—	310	10	—	—	—	10
Acer rubrum	420	—	—	—	420	110	—	—	—	110
Oxydendron	240	—	—	—	240	20	—	—	—	20
Castanea	10	—	—	—	10	10	—	—	—	10
Ilex montana	10	—	—	—	10	—	—	—	—	—
Tsuga canadensis	20	—	—	—	20	—	—	—	—	—
Sassafras	—	—	—	—	—	20	—	—	—	20
Total	3250	220	10	—	3470	440	—	—	—	440

Table 1. (continued)

	Live Trees					Dead Trees				
(cm)	1.3-23.9	23.9-43.5	43.5-74.9	74.9-254		1.3-23.9	23.9-43.5	43.5-74.9	74.9-254	
(inch)	1-9	10-19	20-29	30-100	Total	1-9	10-19	20-29	30-100	Total
J-2 Plot 590707				Inventory 7-13-59						
Pinus pungens	1910	190	—	—	2100	20	20	—	—	40
Nyssa	370	—	—	—	370	10	—	—	—	10
Acer rubrum	90	—	—	—	90	—	—	—	—	—
Sassafras	40	—	—	—	40	—	—	—	—	—
Castanea dentata	20	—	—	—	20	—	—	—	—	—
Robinia	10	—	—	—	10	—	—	—	—	—
Total	2440	190	—	—	2630	30	20	—	—	50
M-2 Plot None				Inventory 8-8-60						
Aesculus	40	80	30	30	180	—	—	10	—	10
Tilia	10	—	20	—	30	—	—	—	—	—
Acer saccharum	320	20	—	—	340	—	—	—	—	—
Acer pensylvanicum	110	—	—	—	110	—	—	—	—	—
Tsuga canadensis	40	—	—	—	40	—	—	—	—	—
Prunus serotina	—	—	10	10	20	—	—	—	10	10
Betula alleghaniensis	30	20	—	—	50	—	—	—	—	—
Cornus alternifolia	20	—	—	—	20	—	—	—	—	—
Acer spicatum	670	—	—	—	670	10	—	—	—	10
Fraxinus americana	50	10	—	—	60	—	—	—	—	—
Total	1290	130	60	40	1520	10	—	10	10	30

Table 1. (continued)

	Live Trees					Dead Trees				
(cm)	1.3-23.9	23.9-43.5	43.5-74.9	74.9-254		1.3-23.9	23.9-43.5	43.5-74.9	74.9-254	
(inch)	1-9	10-19	20-29	30-100	Total	1-9	10-19	20-29	30-100	Total
P-1 Plot None				Inventory July 1960						
Liriodendron	70	220	10	—	300	20	—	—	—	20
Oxydendron	230	—	—	—	230	—	—	—	—	—
Acer rubrum	810	20	—	—	830	130	—	—	—	130
Halesia	170	30	—	—	200	60	—	—	—	—
Robinia	70	10	—	—	80	290	—	—	—	290
Acer pensylvanicum	20	—	—	—	20	—	—	—	—	—
Fraxinus americana	20	—	—	—	20	—	—	—	—	—
Sassafras	20	—	—	—	20	—	—	—	—	—
Cornus florida	10	—	—	—	10	—	—	—	—	—
Total	1420	280	10	—	1710	500	—	—	—	500
W-7 and W-8				No inventories available for July 1959						

* Rounded to nearest full unit.

— No present in 1959 and 1976 inventories.

** The 1976 inventories recorded tree diameters in niches while the 1977 inventories recorded the tree diameters in centimeters.

Table 2. Stand inventory summary. The 1959-1976 inventories are in basal area ft.^{2}/hectare and the 1977 inventories are in basal area m^2/hectare. Great Smoky Mountains 1959-1976 and 1977.

	Live Trees					Dead Trees				
(cm)	1.3-23.9	23.9-43.5	43.5-74.9	74.9-254		1.3-23.9	23.9-43.5	43.5-74.9	74.9-254	
(inch)	1-9	10-19	20-29	30-100	Total	1-9	10-19	20-29	30-100	Total
H1 Plot 590607			Inventory 6-16-59 Mingus Lead S							
Picea	138	135	–	–	273	12*	–	–	–	12
Abies	97	252	–	–	349	21	–	–	–	21
Betula	+	20	–	–	20	+	–	–	–	+
Fagus	–	–	–	–	–	3	–	–	–	3
Total	235	407	–	–	642	36	–	–	–	36
H1 Plot 760807			Inventory 8-27-76 Mingus Lead S							
Picea	130	338	22	–	490	20	–	–	–	20
Abies	28	178	–	–	206	11	–	–	–	11
Betula	1	–	–	–	1	–	–	–	–	–
Fagus	–	–	–	–	–	–	–	–	–	–
Sorbus	1	–	–	–	1	–	–	–	–	–
Total	160	516	22	–	698	30	–	–	–	30
H2 Plot 590609			Inventory 6-17-59 Mingus Lead E							
Picea	44	58	67	134	303	22	–	29	–	51
Abies	57	120	44	–	221	6	22	–	–	28
Betula	11	–	–	–	11	–	–	–	–	–
Fagus	5	–	–	–	5	+	–	–	–	+
Acer spicatum	–	–	–	–	–	–	–	–	–	–
Sorbus	–	–	–	–	–	–	–	–	–	–
Total	117	178	110	134	504	29	22	29	–	79
H2 Plot 760910			Inventory 8-27-76 Mingus Lead E							
Picea	8	51	154	164	398	–	–	–	–	–
Abies	52	95	–	–	147	28	108	–	–	136
Betula	3	35	24	–	62	–	–	–	–	–
Fagus	–	–	–	–	–	–	–	–	–	–
Acer spicatum	+	–	–	–	+	–	–	–	–	–
Sorbus	+	–	–	–	+	–	–	–	–	–
Total	63	181	178	164	587	28	108	–	–	136

Table 2. (continued)

	Live Trees					Dead Trees				
(cm)	1.3-23.9	23.9-43.5	43.5-74.9	74.9-254		1.3-23.9	23.9-43.5	43.5-74.9	74.9-254	
(inch)	1-9	10-19	20-29	30-100	Total	1-9	10-19	20-29	30-100	Total
H4 Plot 590611			Inventory 6-19-59 Mt. Collins							
Picea	10	71	282	—	364	19	8	43	—	70
Abies	57	133	—	—	190	12	17	—	—	29
Betula	—	28	—	—	28	—	—	—	—	—
Acer spicatum	+	—	—	—	+	+	—	—	—	+
Total	68	231	282	—	582	31	25	43	—	99
H4 Plot 760704, 760801			Inventory 8-15-76 Mt. Collins							
Picea	15	50	116	108	289	—	—	40	—	40
Abies	32	131	24	—	187	25	55	37	—	117
Betula	8	17	140	—	165	—	—	—	—	—
Acer spicatum	2	—	—	—	2	+	—	—	—	+
Total	57	198	280	108	635	25	55	77	—	157
RWB#20 Plot 590614, 760802, 760803, 760804				Inventory 9-16-76						
Picea	15	42	24	—	81	6	16	—	—	23
Abies	128	247	—	—	375	68	20	—	—	88
Betula	17	25	26	—	68	2	—	—	—	2
Total	160	314	50	—	524	76	36	—	—	112
RWB#21 Plot 590618, 760806				Inventory 8-25-76						
Picea	13	37	26	—	77	—	—	—	—	—
Abies	68	370	—	—	439	35	40	—	—	75
Betula	3	—	—	—	3	—	—	—	—	—
Sorbus	9	11	—	—	20	—	—	—	—	—
Total	94	418	26	—	539	35	40	—	—	75

Table 2. (continued)

	Live Trees					Dead Trees				
(cm)	1.3-23.9	23.9-43.5	43.5-74.9	74.9-254		1.3-23.9	23.9-43.5	43.5-74.9	74.9-254	
(inch)	1-9	10-19	20-29	30-100	Total	1-9	10-19	20-29	30-100	Total
RWB#22 Plot 590617, 760805				Inventory 8-25-76						
Picea	+	16	—	—	16	—	—	—	—	—
Abies	65	223	—	—	228	38	107	—	—	145
Sorbus	18	16	—	—	34	+	—	—	—	+
Betula	—	—	—	—	—	1	—	—	—	1
Total	83	225	—	—	337	39	107	—	—	146
RWB#23 Plot 590619, 760907				Inventory 8-26-76						
Picea	8	81	432	—	521	—	—	65	—	65
Abies	120	54	55	—	230	29	36	—	—	64
Betula	+	18	—	—	18	—	—	—	—	—
Sorbus	+	—	—	—	+	1	—	—	—	1
Total	129	152	488	—	768	30	36	65	—	130
L3 Plot 590904, 590907				Inventory 9-2-59						
Picea	2	26	27	—	54	—	—	37	—	37
Fagus	156	71	—	—	227	11	27	—	—	38
Betula	—	—	—	—	—	—	—	—	—	—
Amelanchier	13	—	—	—	13	—	—	—	—	—
Acer saccharum	3	—	—	—	3	—	—	—	—	—
Total	179	97	27	—	298	11	27	37	—	75
L3 Plot 760911				Inventory 9-14-76						
Picea	23	—	—	—	23	—	—	—	—	—
Fagus	132	168	—	—	301	4	—	—	—	4
Betula	—	16	22	—	38	—	—	—	—	—
Amelanchier	—	7	—	—	7	—	—	—	—	—
Acer saccharum	—	30	31	49	111	—	—	—	—	—
Total	156	221	53	49	479	4	—	—	—	4

Table 2. (continued)

	Live Trees					Dead Trees				
(cm)	1.3-23.9	23.9-43.5	43.5-74.9	74.9-254		1.3-23.9	23.9-43.5	43.5-74.9	74.9-254	
(inch)	1-9	10-19	20-29	30-100	Total	1-9	10-19	20-29	30-100	Total
L3 Suppl. Plot 590904, 590907, 760911				Inventory 9-2-59						
Picea	+	–	–	–	+	1	–	–	–	1
Fagus	141	167	–	–	308	9	14	–	–	23
Betula	4	19	–	–	23	–	–	–	–	–
Amelanchier	15	–	–	–	15	+	–	–	–	+
Acer saccharum	–	14	77	–	91	–	–	–	–	–
Acer spicatum	+	–	–	–	+	–	–	–	–	–
Aesculus	–	–	32	–	32	–	–	–	–	–
Total	161	200	108	–	469	10	14	–	–	24
L4 Plot 590901, 590902				Inventory 8-19-59						
Picea	1	–	–	–	1	–	–	–	–	–
Fagus	95	104	–	–	199	1	–	–	–	1
Betula	3	23	–	–	26	–	–	–	–	–
Acer saccharum	–	8	–	–	8	–	–	–	–	–
Acer spicatum	8	–	–	–	8	+	–	–	–	+
Aesculus	+	16	–	–	16	–	–	–	–	–
Acer pensylvanicum	–	–	–	–	–	–	–	–	–	–
Sorbus	–	–	–	–	–	–	–	–	–	–
Total	107	151	–	–	258	1	–	–	–	1
L4 Plot 760912				Inventory 9-15-76						
Picea	15	–	–	–	15	+	–	–	–	+
Fagus	40	135	2	–	198	+	12	–	–	12
Betula	4	8	–	67	78	1	–	–	–	1
Acer saccharum	–	–	–	–	–	+	–	–	–	+
Acer spicatum	5	–	–	–	5	–	–	–	–	–
Aesculus	4	55	–	–	59	–	–	–	–	–
Acer pensylvanicum	2	–	–	–	2	–	–	–	–	–
Sorbus	+	14	–	–	14	–	–	–	–	–
Total	70	212	22	67	371	1	12	–	–	14

Table 2. (continued)

	Live Trees					Dead Trees				
(cm)	1.3-23.9	23.9-43.5	43.5-74.9	74.9-254		1.3-23.9	23.9-43.5	43.5-74.9	74.9-254	
(inch)	1-9	10-19	20-29	30-100	Total	1-9	10-19	20-29	30-100	Total
L5 Plot 590903				Inventory 9-9-59						
Picea	12	53	43	—	108	2	19	—	—	21
Fagus	84	80	—	—	164	2	6	—	—	8
Betula	+	23	61	—	84	5	—	—	—	5
Acer saccharum	2	—	29	—	31	—	—	—	—	—
Acer spicatum	+	—	—	—	+	—	—	—	—	—
Acer pensylvanicum	+	—	—	—	+	—	—	—	—	—
Aesculus	+	12	31	—	44	—	14	—	—	14
Total	99	168	164	—	431	10	38	—	—	48
L5 Plot 760913				Inventory 9-16-76						
Picea	1	—	—	—	1	—	—	—	—	—
Fagus	42	82	—	—	125	3	—	—	—	3
Betula	11	37	26	—	75	3	—	—	—	3
Acer saccharum	9	76	—	—	85	—	—	—	—	—
Total	63	196	26	—	285	7	—	—	—	7
B-1 Plot 590701				Inventory 7-2 & 6-59						
Halesia	21	29	—	—	50	2	8	—	—	10
Aesculus	6	—	—	147	151	—	—	—	—	—
Tilia	+	22	—	—	22	1	—	—	—	1
Fagus	1	16	—	—	17	+	—	—	—	+
Fraxinus americana	—	—	22	—	22	+	—	—	—	+
Acer sachharum	—	40	31	96	167	—	—	—	—	—
Liriodendron	1	—	—	63	64	—	—	—	—	—
Magnolia acuminata	—	—	—	71	71	—	—	—	—	—
Tsuga canadensis	2	—	—	—	2	—	—	—	—	—
Betula alleghaniensis	—	—	—	—	—	—	11	29	—	40
Total	29	107	53	377	566	4	19	29	—	51

Table 2. (continued)

	Live Trees					Dead Trees				
(cm)	1.3-23.9	23.9-43.5	43.5-74.9	74.9-254		1.3-23.9	23.9-43.5	43.5-74.9	74.9-254	
(inch)	1-9	10-19	20-29	30-100	Total	1-9	10-19	20-29	30-100	Total
C-3 Plot non				Inventory July 1960						
Quercus prinus	+	14	100	81	197	–	14	34	169	217
Castanea dentata	–	–	–	–	–	17	15	189	147	369
Acer rubrum	58	8	–	–	66	13	7	24	–	43
Liriodendron	+	–	–	–	+	–	–	–	–	–
Oxydendron	31	–	–	–	31	11	–	–	–	11
Cornus florida	1	–	–	–	1	–	–	–	–	–
Halesia	10	–	–	–	10	4	–	–	–	4
Quercus borealis	1	–	26	–	27	–	–	29	–	29
Magnolia fraseri	1	7	–	–	8	3	–	29	–	32
Fagus	2	–	–	–	2	–	–	–	–	–
Acer pensylvanicum	1	–	–	–	1	1	–	–	–	1
Nyssa	+	–	–	–	+	+	–	–	–	+
Sassafras	+	–	–	–	+	–	–	–	–	–
Robinia	4	–	–	–	4	–	–	–	–	–
Total	111	29	127	82	349	50	36	305	316	707
E-1 Plot none				Inventory 7-4-60						
Tsuga canadensis	4	20	77	438	539	1	–	166	–	167
Betula alleghaniensis	–	–	–	56	56	–	–	–	–	–
Magnolia fraseri	3	9	–	–	13	–	–	–	–	–
Total	7	29	77	494	607	1	–	166	–	167
E-2 Plot none				Inventory July 1960						
Tsuga canadensis	41	27	21	–	90	17	18	24	350	409
Magnolia fraseri	+	–	–	–	+	–	–	–	–	–
Halesia	5	7	–	–	12	2	7	–	–	9
Acer saccharum	4	68	94	–	166	11	32	114	–	158
Fagus	20	50	–	–	70	1	16	20	–	36
Tilia	+	–	–	–	+	–	–	–	–	–
Betula alleghansiensis	+	–	–	–	+	+	–	–	–	+
Betula lenta	+	–	–	–	+	–	–	–	–	–
Total	77	146	116	–	338	31	112	118	350	612

Table 2. (continued)

	Live Trees					Dead Trees				
(cm)	1.3-23.9	23.9-43.5	43.5-74.9	74.9-254		1.3-23.9	23.9-43.5	43.5-74.9	74.9-254	
(inch)	1-9	10-19	20-29	30-100	Total	1-9	10-19	20-29	30-100	Total
F-2 Plot none				Inventory 8-21-59						
Pinus strobus	69	14	—	—	84	2	—	—	—	2
Pinus virginiana	28	112	22	—	161	7	—	—	—	7
Pinus rigida	5	31	—	—	36	—	—	—	—	—
Quercus coccinea	10	15	—	—	25	+	—	—	—	+
Quercus prinus	2	—	—	—	2	—	—	—	—	—
Quercus alba	18	—	—	—	18	1	—	—	—	1
Nyssa	6	—	—	—	6	+	—	—	—	+
Acer rubrum	21	—	—	—	21	2	—	—	—	2
Oxydendron	19	—	—	—	19	+	—	—	—	+
Castanea	+	—	—	—	+	+	—	—	—	+
Ilex montana	+	—	—	—	+	—	—	—	—	—
Tsuga canadensis	+	—	—	—	+	—	—	—	—	—
Sassafras	—	—	—	—	—	+	—	—	—	+
Total	179	172	22	—	373	12	—	—	—	12
J-2 Plot 590707				Inventory 7-13-59						
Pinus	84	185	—	—	269	5	13	—	—	19
Nyssa	3	—	—	—	3	+	—	—	—	+
Acer rubrum	1	—	—	—	1	—	—	—	—	—
Sassafras	+	—	—	—	+	—	—	—	—	—
Castanea dentata	+	—	—	—	+	—	—	—	—	—
Robinia	+	—	—	—	+	—	—	—	—	—
Total	88	185	—	—	274	5	13	—	—	19

Table 2. (continued)

	Live Trees					Dead Trees				
(cm)	1.3-23.9	23.9-43.5	43.5-74.9	74.9-254		1.3-23.9	23.9-43.5	43.5-74.9	74.9-254	
(inch)	1-9	10-19	20-29	30-100	Total	1-9	10-19	20-29	30-100	Total
M-2 Plot none				Inventory 7-8-60						
Aesculus	6	86	78	232	403	—	—	40	—	40
Tilia	+	—	53	—	53	—	—	—	—	—
Acer saccharum	9	13	—	—	22	—	—	—	—	—
Acer pensylvanicum	6	—	—	—	6	—	—	—	—	—
Tsuga canadensis	1	—	—	—	1	—	—	—	—	—
Prunus serotina	—	—	31	110	142	—	—	—	106	106
Betula alleghaniensis	1	30	—	—	30	—	—	—	—	—
Cornus alternifolia	+	—	—	—	+	—	—	—	—	—
Acer spicatum	10	—	—	—	10	1	—	—	—	1
Fraxinus americana	1	16	—	—	17	—	—	—	—	—
Total	34	145	162	343	684	1	—	40	106	146
P-1 Plot none				Inventory July 1960						
Liriodendron	10	217	24	—	251	1	—	—	—	1
Oxydendron	12	—	—	—	12	—	—	—	—	—
Acer rubrum	34	13	—	—	47	3	—	—	—	3
Halesia	8	22	—	—	30	2	—	—	—	2
Robinia	19	7	—	—	25	20	—	—	—	20
Acer epnsylvanicum	+	—	—	—	+	—	—	—	—	—
Fraxinus americana	+	—	—	—	+	—	—	—	—	—
Sassafras	2	—	—	—	2	—	—	—	—	—
Cornus florida	+	—	—	—	+	—	—	—	—	—
Total	86	258	24	—	368	26	—	—	—	26

W-7 and W-8 No inventories available for July 1959

* Rounded to nearest full unit. Additions may not add since the summations are also rounded to nearest full unit value.

— Not present in 1959 and 1976 inventories.

\+ Present in insignificant amount (<0.50 ft.^{2}/hectare).

Table 3. Stand summary inventory (N trees/hectare). Great Smoky Mountains 1959-1976. The 1976 inventory as a percentage ratio of the 1959 inventory. The 1977 inventories are based upon the metric system and cannot be compared with the 1959 inventories.

	Live Trees					Dead Trees				
(cm)	1.3-23.9	23.9-43.5	43.5-74.9	74.9-254		1.3-23.9	23.9-43.5	43.5-74.9	74.9-254	
(inch)	1-9	10-19	20-29	39-100	Total	1-9	10-19	20-29	30-100	Total
H1 Plot 590607 / 760807				Inventory 8-27-76 / 6-16-59						
Picea	0.82	1.95	–	–	1.12	1.79	–	–	–	1.79
Abies	0.21	0.72	–	–	0.41	0.25	–	–	–	0.25
Betula	2.00	1.00	–	–	1.00	–	–	–	–	–
Fagus	–	–	–	–	–	0.00	–	–	–	0.00
Sorbus	**	–	–	–	**	–	–	–	–	–
Total	0.60	1.24	–	–	0.81	0.73	–	–	–	0.73
H2 Plot 590609 / 760910				Inventory 8-27-76 / 6-17-59						
Picea	0.54	0.67	2.50	1.50	0.64	0.00	–	0.00	–	0.00
Abies	3.79	0.91	0.00	–	3.04	1.28	11.00	–	–	1.79
Betula	1.00	**	**	–	1.50	–	–	–	–	–
Fagus	0.00	–	–	–	0.00	0.00	–	–	–	0.00
Acer spicatum	**	–	–	–	**	–	–	–	–	–
Sorbus	**	–	–	–	**	–	–	–	–	–
Total	1.59	1.00	1.50	1.50	1.52	0.43	11.00	0.00	–	0.61
H4 Plot 590611 / 760704, 760801				Inventory 8-15-76 / 6-19-59						
Picea	3.83	0.80	0.50	**	1.74	0.00	0.00	1.00	–	0.00
Abies	0.90	0.65	**	–	0.84	1.21	2.00	**	–	1.33
Betula	**	1.00	–	–	7.50	**	–	–	–	**
Acer spicatum	2.75	–	–	–	2.75	0.00	–	–	–	0.00
Total	1.67	0.71	0.63	**	1.43	0.59	1.33	2.00	–	0.67
L3 Plot 590904, 590907 / 760911				Inventory 9-14-76 / 9-2-59						
Picea	1.00	0.00	0.00	–	0.57	–	–	0.00	–	0.00
Fagus	1.38	2.11	–	–	1.42	0.59	0.00	–	–	0.54
Betula	–	**	**	–	**	–	–	–	–	–
Amelanchier	0.00	**	–	–	+	–	–	–	–	–
Acer saccharum	0.00	**	**	**	4.00	–	–	–	–	–
Total	1.28	1.09	2.00	**	1.33	0.59	0.00	0.00	–	0.52

Table 3. (continued)

	Live Trees					Dead Trees				
(cm)	1.3-23.9	23.9-43.5	43.5-74.9	74.9-254		1.3-23.9	23.9-43.5	43.5-74.9	74.9-254	
(inch)	1-9	10-19	20-29	30-100	Total	1-9	10-19	20-29	30-100	Total
L4 Plot 590901, 590902 / 760912				Inventory 9-15-76 / 8-19-59						
Picea	5.00	—	—	—	5.00	0.00	—	—	—	**
Fagus	0.41	1.27	**	—	0.51	1.00	**	—	—	2.00
Betula	0.11	0.50	—	**	0.19	**	—	—	—	**
Acer saccharum	—	0.00	—	—	0.00	**	—	—	—	**
Acer spicatum	0.44	—	—	—	0.44	0.00	—	—	—	0.00
Aesculus	0.67	3.00	—	—	1.25	—	—	—	—	—
Acer pensylvanicum	**	—	—	—	**	—	—	—	—	—
Sorbus	**	**	—	—	**	—	—	—	—	—
Total	0.61	1.26	**	**	0.68	1.00	**	—	—	1.20
L5 Plot 590903 / 760913				Inventory 9-16-76 / 9-19-59						
Picea	0.30	0.25	0.00	—	0.28	0.00	0.00	—	—	0.00
Fagus	0.34	0.73	—	—	0.36	0.43	0.00	—	—	0.38
Betula	3.00	1.50	0.50	—	2.20	0.25	—	—	—	0.25
Acer saccharum	2.00	**	0.00	—	2.60	—	—	—	—	—
Acer spicatum	0.00	—	—	—	0.00	—	—	—	—	—
Acer pensylvanicum	0.00	—	—	—	0.00	—	—	—	—	0.00
Aesculus	0.00	0.00	0.00	—	0.00	—	0.00	—	—	0.00
Total	0.41	0.94	0.20	—	0.44	0.33	0.00	—	—	0.25

** New in 1976 inventory; not present in 1959 inventory.

— Not present in 1959 and 1976 inventories.

0.00 Present in 1959 inventory but absent in 1976 inventory.

1.00 Present in 1959 and 1976 inventories in equal quantities.

+ Present but in insignificant amount (<0.01).

Table 4. Stand summary inventory. The 1976 inventory as a percentage ratio of the 1959 inventory (basal area/hectare). The 1977 inventories are in the metric system and are not comparable with the 1959 inventories. Great Smoky Mountains 1959-1976.

	Live Trees					Dead Trees				
(cm)	1.3-23.9	23.9-43.5	43.5-74.9	74.9-254		1.3-23.9	23.9-43.5	43.5-74.9	74.9-254	
(inch)	1-9	10-19	20-29	30-100	Total	1-9	10-19	20-29	30-100	Total
H1 Plot 590607 / 760807			Inventory 8-27-76 / 6-16-59							
Picea	0.94	2.50	—	—	1.79	1.67	—	—	—	1.67
Abies	0.35	0.71	—	—	0.59	0.52	—	—	—	0.52
Betula	2.00	0.00	—	—	0.05	0.00	—	—	—	0.00
Fagus	—	—	—	—	—	0.00	—	—	—	0.00
Sorbus	—	—	—	—	—	—	—	—	—	—
Total	0.68	1.27	—	—	1.09	0.83	—	—	—	0.83
H2 Plot 590609 / 760910			Inventory 8-27-76 / 6-17-59							
Picea	0.18	0.88	2.30	1.22	1.31	0.00	—	0.00	—	0.00
Abies	0.91	0.79	0.00	—	0.67	4.67	4.91	—	—	4.86
Betula	0.27	**	**	—	5.64	—	—	—	—	—
Fagus	0.00	—	—	—	0.00	0.00	—	—	—	0.00
Acer spicatum	**	—	—	—	**	—	—	—	—	—
Sorbus	**	—	—	—	**	—	—	—	—	—
Total	0.54	1.02	1.62	1.22	1.16	0.97	4.91	0.00	—	1.72
H4 Plot 590611 / 760704, 760801			Inventory 8-15-76 / 6-19-59							
Picea	1.50	0.70	0.41	**	0.79	0.00	0.00	0.94	—	0.57
Abies	0.56	0.98	**	—	0.98	2.08	3.24	**	—	4.03
Betula	**	0.61	**	—	5.89	—	—	—	—	—
Acer spicatum	40.00	—	—	—	40.00	1.00	—	—	—	1.00
Total	0.84	0.86	0.99	**	1.09	0.81	2.20	1.79	—	1.59

Table 4. (continued)

	Live Trees					Dead Trees				
(cm)	1.3-23.9	23.9-43.5	43.5-74.9	74.9-254		1.3-23.9	23.9-43.5	45.3-74.9	74.9-254	
(inch)	1-9	10-19	20-29	30-100	Total	1-9	10-19	20-29	30-100	Total
L3 Plot 590904 / 590907, 760911				Inventory 9-14-76 / 9-2-59						
Picea	+	—	—	—	+	**	—	—	—	**
Fagus	1.07	0.99	—	—	1.02	2.25	**	—	—	5.75
Betula	**	1.19	0.00	—	0.61	—	—	—	—	—
Amelanchier	**	0.00	—	—	2.14	**	—	—	—	**
Acer saccharum	—	0.47	2.48	0.00	0.82	—	—	—	—	—
Acer spicatum	**	—	—	—	**	—	—	—	—	—
Aesculus	—	—	**	—	**	—	—	—	—	—
Total	1.03	0.90	2.04	0.00	0.98	2.50	**	—	—	6.00
L4 Plot 590901 / 590902, 760912				Inventory 9-15-76 / 8-19-59						
Picea	15.00	—	—	—	15.00	**	—	—	—	**
Fagus	0.42	1.30	**	—	0.99	0.55	**	—	—	12.00
Betula	1.33	0.35	—	**	3.00	**	—	—	—	**
Acer saccharum	—	0.00	—	—	0.00	**	—	—	—	**
Acer spicatum	0.63	—	—	—	0.63	0.00	—	—	—	0.00
Aesculus	4.00	3.44	—	—	3.69	—	—	—	—	—
Acer pensylvanicum	**	—	—	—	**	—	—	—	—	—
Sorbus	**	**	—	—	**	—	—	—	—	—
Total	0.65	1.40	**	**	1.44	0.00	**	—	—	14.00
L5 Plot 590903 / 760913				Inventory 9-16-76 / 9-9-59						
Picea	0.08	0.00	**	—	0.01	0.00	0.00	—	—	0.00
Fagus	0.50	1.03	0.00	—	0.76	1.50	0.00	—	—	0.38
Betula	11.00	1.61	**	—	0.89	0.60	—	—	—	0.60
Acer saccharum	4.50	**	**	—	2.74	—	—	—	—	—
Acer spicatum	0.00	—	—	—	0.00	—	—	—	—	—
Acer pensylvanicum	0.00	—	—	—	0.00	—	—	—	—	—
Aesculus	0.00	0.00	**	—	0.00	—	0.00	—	—	0.00
Total	0.64	1.17	0.16	—	0.66	0.70	0.00	—	—	0.15

** New in 1976 inventory; not present in 1959 inventory.
— No present in 1959 and 1976 inventories.
0.00 Present in 1959 inventory but absent in 1976 inventory.
1.00 Present in 1959 and 1977 inventories in equal quantities.
+ Present but in insignificant amount (<0.01).

Table 5. Monthly mean, mean maximum, and mean minimum temperatures (degrees F) at four Great Smoky Mountain climate stations for 1947 - 1950 (Stephens, 1969 p. 35)

Month	Mean temp.				Mean max. temp.				Mean min. temp.			
(m)	445	1180	1525	1920	495	1180	1525	1920	495	1180	1525	1920
(ft.)	1460	3850	5000	6300	1460	3850	5000	6300	1460	3850	5000	6300
Jan.	42.7	37.0	35.0	33.2	54.7	46.0	42.2	40.0	32.7	27.0	28.2	27.3
Feb.	40.0	33.2	30.7	28.7	53.0	44.5	40.7	37.7	27.7	24.7	23.2	22.2
Mar.	45.2	36.7	33.5	32.3	59.0	51.0	44.7	42.0	31.5	26.0	24.7	24.6
Apr.	55.5	47.7	44.0	40.5	70.5	62.2	56.2	49.5	40.0	36.0	35.0	32.7
May	63.5	54.7	52.5	49.2	79.7	69.0	65.7	58.5	48.5	44.0	44.0	42.7
Jun.	69.7	61.0	57.0	55.0	85.5	72.7	70.2	63.5	56.2	52.0	52.0	50.0
Jul.	71.7	62.5	57.2	56.5	85.5	72.5	70.2	65.2	60.5	55.2	52.2	51.2
Aug.	70.0	61.7	57.0	56.0	84.5	70.7	68.7	65.2	59.2	55.0	52.7	51.0
Sep.	63.5	56.2	53.7	51.5	79.7	66.5	64.5	61.5	53.0	49.0	47.2	46.0
Oct.	55.7	49.2	48.5	46.7	73.0	61.0	59.5	55.7	43.0	41.5	42.2	41.0
Nov.	42.0	36.2	34.7	34.0	57.2	47.0	45.0	43.0	30.0	28.2	27.0	27.5
Dec.	37.0	32.0	31.2	30.5	51.0	41.7	39.2	38.7	25.2	23.7	24.2	24.0
Mean	54.7	47.3	44.6	42.8	69.4	58.7	55.6	51.7	42.3	38.5	37.7	36.7

Table 6. Monthly maximum and minimum temperatures (degrees F) at four Great Smoky Mountain climate stations for 1947-1950 (Stephens, 1969 p.36)

Month	445 m 1,460 ft. Max.	Min.	1,180 m 3,850 ft. Max.	Min.	1,525 m 5,000 ft. Max.	Min.	1,920 m 6,300 ft. Max.	Min.
Jan.	80	-3	64	-4	60	-6	57	-8
Feb.	81	2	66	-5	65	-8	60	-12
Mar.	86	8	82	4	71	3	64	0
Apr.	91	17	85	9	79	9	67	6
May	94	27	87	24	82	23	74	25
June	99	42	85	35	86	35	77	38
July	100	44	89	41	89	39	80	41
Aug.	99	49	83	42	86	45	81	40
Sept.	93	30	83	29	77	27	75	29
Oct.	88	19	76	20	80	16	74	16
Nov.	82	3	69	-11	71	-11	70	-17
Dec.	74	5	61	2	57	2	60	1

Table 7. Mean monthly inches of precipitation at four Great Smoky Mountain climate stations for 1947-1950 (Stephens 1969 p. 49)

Month	445 m 1,460 ft. Station	1,180 m 3,850 ft. Station	1,525 m 5,000 ft. Station	1,920 m 6,300 ft. Station
Jan.	6.80	10.19	12.83	11.86
Feb.	5.09	6.57	8.12	6.05
Mar.	5.74	8.05	9.25	8.25
Apr.	3.69	4.52	4.71	5.01
May	3.60	5.83	6.04	6.76
June	5.03	4.89	5.74	8.36
July	6.93	6.79	7.67	9.59
Aug.	7.03	6.73	7.71	10.14
Sept.	3.09	3.95	5.21	5.71
Oct.	3.53	4.45	4.94	4.97
Nov.	4.39	7.51	8.13	7.66
Dec.	4.39	6.70	7.46	6.12
Mean	4.94	6.35	7.32	7.54

Table 8. Coefficients of determination and regression equations for the monthly mean precipitation for six combinations of stations for 1947-1950 (Stephens, 1969 p. 51)

X ft	Y ft	r^2	Regression equation
1460	3850	.503	Y = 1.96 + .886X
1460	5000	.505	Y = 1.51 + 1.17X
1460	6300	.787	Y = .77 + 1.37X
3850	5000	.959	Y = -.88 + 1.29X
3850	6300	.582	Y = 1.56 + .942X
5000	6300	.601	Y = 2.26 + .723X

Table 9. Annual soil moisture balance in inches at the 445 m (1460 ft.) station based on daily means for 1947-1950 (Stephens 1969, p. 64)

Month	Temp.	PET[a]	Prec.	P-PET[b]	SM[c]	MD[d]	MS[e]	SMB[f]
Jan.	42.7	0.87	6.80	5.92	11.96	0.01	6.33	13.18
Feb.	40.0	0.62	5.09	4.46	11.97	0.00	4.79	13.69
Mar.	45.2	1.18	5.74	4.55	11.95	0.01	5.24	13.27
Apr.	55.5	2.26	3.69	1.87	11.77	0.02	2.96	12.82
May	63.5	3.64	3.60	-0.04	11.31	0.13	2.41	12.06
June	69.7	4.70	5.03	1.19	10.66	0.32	3.33	11.55
July	71.7	5.07	6.93	2.05	10.60	0.21	4.66	11.83
Aug.	70.0	4.55	7.03	2.46	11.13	0.20	5.26	12.47
Sep.	63.5	3.15	3.09	-0.06	10.93	0.19	2.18	11.92
Oct.	55.7	2.02	3.53	2.15	10.60	0.13	2.94	11.18
Nov.	42.0	0.68	4.39	3.95	11.77	0.02	4.33	13.00
Dec.	37.0	0.40	4.39	3.98	11.98	0.00	4.18	13.22
Sum		29.14	59.31	32.49		1.29	48.61	

Table 10. Annual soil moisture balance in inches at the 445 m (1460 ft) station based on monthly means for 1947-1950 (Stephens 1969, p.60)

Month	Temp.	PET[a]	Prec.	P-PET[b]	SM[c]	MD[d]	MS[e]	SMB[f]
Jan.	42.7	.52	6.80	6.28	12.00	0	6.28	15.14
Feb.	40.0	.51	5.09	4.58	12.00	0	4.58	15.86
Mar.	45.2	.92	5.74	4.82	12.00	0	4.82	16.34
Apr.	55.5	2.31	3.69	1.38	12.00	0	1.38	14.91
May	63.5	3.63	3.60	-.03	11.97	0	0.00	13.48
June	69.7	4.75	5.03	.28	12.00	0	.25	12.83
July	71.7	5.20	6.93	1.73	12.00	0	1.73	13.28
Aug.	70.0	4.52	7.03	2.51	12.00	0	2.51	13.89
Sep.	63.5	3.09	3.09	0.00	12.00	0	0.00	13.89
Oct.	55.7	2.03	3.53	1.50	12.00	0	1.50	13.22
Nov.	42.0	.51	4.39	3.88	12.00	0	3.88	14.55
Dec.	37.0	.50	4.39	3.89	12.00	0	3.89	
Sum		28.49	59.31	30.54		0	30.82	

[a]PET = Potential evapotranspiration.

[b]P-PET = Precipitation minus potential evapotranspiration.

[c]SM = Soil moisture content.

[d]MD = Moisture deficit.

[e]MS = Moisture surplus.

[f]SMB = Soil moisture balance.

Table 11. Annual soil moisture balance in inches at the 1920 m (6300 ft) station based on daily means for 1947-1950 (Stephens 1969, p. 67)

Month	Temp.	PET[a]	Prec.	P-PET[b]	SM[c]	MD[d]	MS[e]	SMB[f]
Jan.	33.2	0.57	11.86	11.29	11.98	0.00	11.40	14.68
Feb.	28.7	0.44	6.05	5.78	11.98	0.00	5.91	14.28
Mar.	32.3	0.60	8.25	8.31	11.97	0.00	8.62	14.04
Apr.	40.5	1.34	5.01	4.01	11.88	0.01	4.87	13.46
May	49.2	2.61	6.76	3.89	11.72	0.04	5.53	13.17
June	55.0	3.37	8.36	4.83	11.78	0.02	6.81	13.78
July	56.5	3.65	9.59	6.55	11.72	0.05	8.50	14.17
Aug.	56.0	3.41	10.14	6.22	11.69	0.05	11.69	13.92
Sep.	51.0	2.52	5.71	3.07	11.53	0.06	4.82	13.41
Oct.	46.7	1.83	4.97	3.37	11.59	0.04	4.55	12.53
Nov.	34.0	0.64	7.66	6.77	11.94	0.01	7.19	13.87
Dec.	30.5	0.34	6.12	6.31	11.98	0.00	6.44	13.99
Sum		21.32	90.48	70.40		0.28	86.33	

Table 12. Annual soil moisture balance in inches at the 1920 m (6300 ft) station based on monthly means for 1947-1950 (Stephens 1969, p. 63)

Month	Temp.	PET[a]	Prec.	P-PET[b]	SM[c]	MD[d]	MS[e]	SMB[f]
Jan.	33.2	0.26	11.86	11.60	12.00	0	11.60	17.80
Feb.	28.7	0.00	6.05	6.05	18.05	0	0.00	20.95
Mar.	32.3	0.00	8.25	8.25	12.00	0	8.25	22.43
Apr.	40.5	1.32	5.01	3.69	12.00	0	3.69	19.82
May	49.2	2.54	6.76	4.22	12.00	0	4.22	17.81
June	55.0	3.29	8.36	5.07	12.00	0	5.07	18.78
July	56.5	3.72	9.59	5.87	12.00	0	5.87	18.31
Aug.	56.0	3.13	10.14	7.01	12.00	0	7.01	18.66
Sep.	51.0	2.47	5.71	3.24	12.00	0	3.24	16.95
Oct.	46.7	1.74	4.97	3.23	12.00	0	3.23	16.09
Nov.	34.0	0.25	7.66	7.41	12.00	0	7.41	17.75
Dec.	30.5	0.00	6.12	6.12	12.00	0	0.00	20.99
Sum		18.72	90.48	71.76			59.59	

[a]PET = Potential evapotranspiration.

[b]P-PET = Precipitation minus potential evapotranspiration.

[c]SM = Soil moisture content.

[d]MD = Moisture deficit.

[e]MS = Moisture surplus.

[f]SMB = Soil moisture balance.

Table 13. Mean number of days between the last occurrence in spring and the first occurrence in fall of 32° F, 36° F, and 40° F as minimum temperatures and the average date of the last and first occurrence of minimum temperatures (Stephens 1969, p. 20)

Temperature	Altitude of station m	Altitude of station ft	Number of consecutive days	Avg. date of last occurrence	Avg. date of first occurrence
32°	445	1460	155.75	May 3	Oct. 7
	1180	3850	152.25	May 4	Oct. 4
	1525	5000	148.00	May 9	Oct. 4
	1920	6300	152.25	Apr. 30	Oct. 2
36°	445	1460	135.50	May 3	Oct. 7
	1180	3850	125.00	May 28	Sep. 30
	1525	5000	116.75	May 31	Sep. 25
	1920	6300	136.25	May 14	Sep. 27
40°	445	1460	122.25	May 18	Sep. 17
	1180	3850	94.75	June 11	Sep. 13
	1525	5000	104.50	June 3	Sep. 16
	1920	6300	96.50	June 4	Sep. 8

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