PROJECT REPORT SUBMITTED TO THE BLACK ROCK FOREST CONSORTIUM

DEVELOPMENT OF TREE-RING RECORDS FROM THE BLACK ROCK FOREST

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Introduction

This research project produced three precisely-dated, annual tree-ring width time series or chronologies from three separate old growth stands of eastern hemlock [*Tsuga canadensis*], in the Black Rock Forest (BRF), Cornwall New York (Figure 1). Eastern hemlock is an evergreen, coniferous tree species native to North America (Fowells 1965). Hemlock typically grows in cool, humid environments and is very shade tolerant. Below, we identify several key climate variables which influence hemlock growth in the BRF. The chronologies produced provide a background history of tree growth and inferred climate variations for the Black Rock forest ecosystem. The actual tree core samples and chronologies produced from this project will become part of the archives of the BRF and will be available for future reference or research.

Methods

Tree core samples from both the understory and overstory of three old growth stands of eastern hemlock, were collected in the BRF for dendrochronological analysis (Figure 1). Approximately 40 trees (20 understory and 20 overstory) were sampled from Mineral Springs and Canterbury Brook. At site No. 1 (Lower Chlorinater), approximately 20 overstory trees were sampled, but there were too low a number of understory trees to sample at this site. The sampling involved the use of an increment borer, a standard, nondestructive method for the collection of tree-ring samples (Stokes and Smiley 1968, Fritts 1976). While initially it was planned that two cores per tree would be sampled from both understory and overstory trees, once on site it was decided that for the smaller understory trees two cores might be destructive and that for the overstory trees the extreme slopes on which many grew made two core samples prohibitive.

Samples were returned to the Lamont-Doherty Earth Observatory's Tree-Ring Laboratory (TRL) for subsequent processing. Sample preparation included drying, mounting, surfacing, and cataloging the cores. The core samples were then dated and measured with a precision of +/- .01 mm, using a computer-assisted encoder-translation mechanism (Jacoby 1982, Schweingruber 1988). Precise dating was ensured by the procedure of cross-dating (i.e., matching the patterns of narrow/wide rings among cores at a site (Stokes and Smiley 1968, Fritts 1976) and by COFECHA, a computer-assisted cross-dating quality control program (Holmes 1983). The goal of crossdating is to assign an exact year date to every ring of every tree sampled from within a site, based on ring-width patterns common throughout the site. The raw measurements were then processed into time series or chronologies using standard techniques (Fritts 1976, Cook and Kairiukstis 1990).

These final time series or chronologies differ from the raw data in that the effects of age and stand dynamics, which confound the climate or environmental signal of interest, are removed. Therefore the chronologies have a relatively stable mean and variance across the time span (Cook 1985 & 1987). The new tree-ring chronologies were compared to meteorological data from nearby West Point: adjusted total precipitation and monthly mean temperatures. In addition, the chronologies were compared to the Palmer Drought Severity Index (PDSI), which integrates recent past climatic trends plus soil characteristics into values of moisture deficiency or excess (Palmer 1965). These comparisons, using correlation and regression analysis techniques, helped to determine some of the key climatic variables influencing tree growth in the forest.

Results

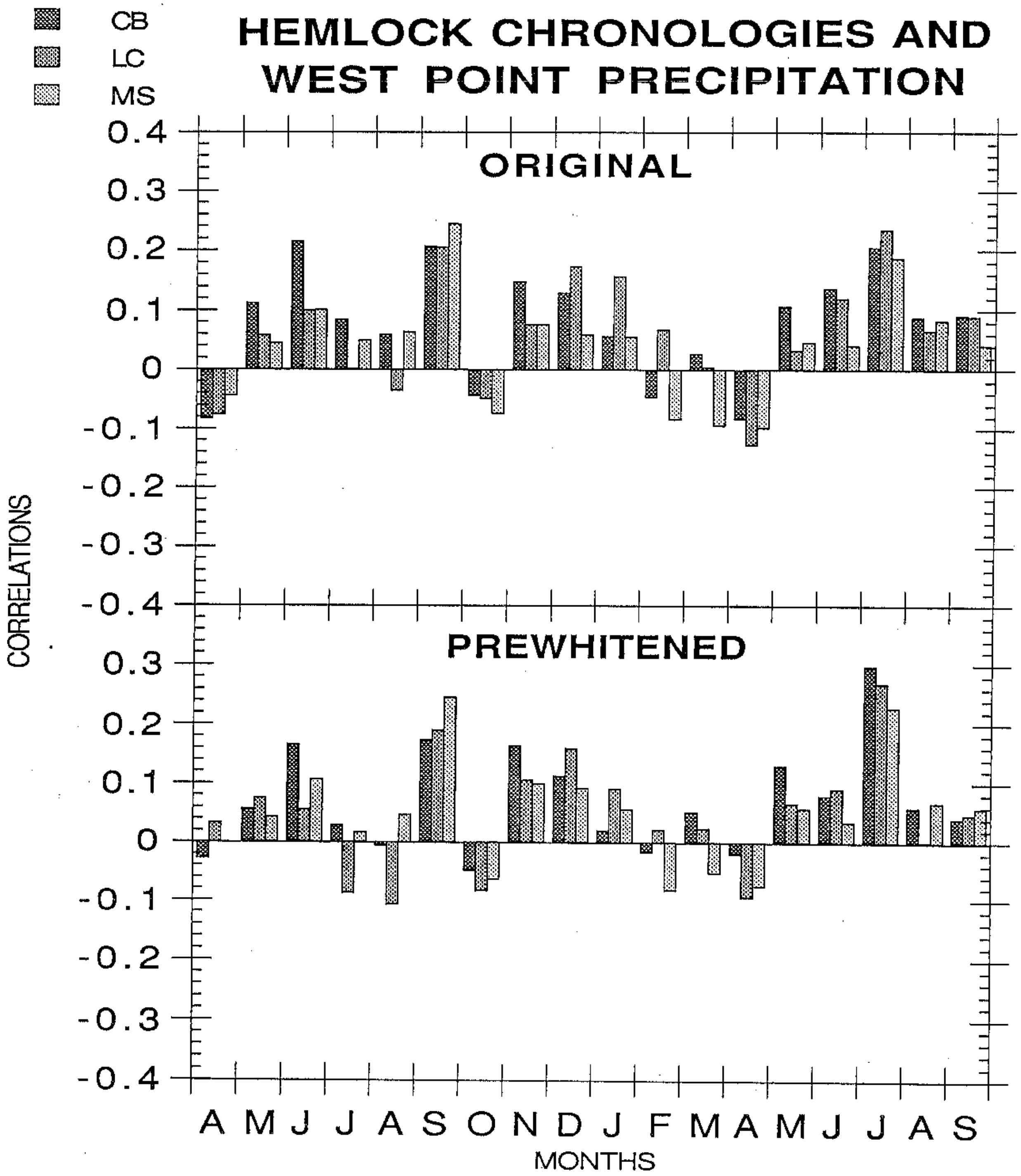
In processing the chronologies, it was found that the tree-ring widths for neither of the understory sites would cross-date. This is common for low ring count, suppressed trees such as understory eastern hemlock. Figure 2 shows a comparison of the three overstory chronologies for the common period from 1820 to 1992. The chronologies have a relatively high correlation (r = 0.6 to 0.7) with each other. Although a few of the trees sampled dated back to the 1700s, the sample size was insufficient to extend the chronologies back further than around 1820.

For the correlation between tree growth and climatic response, a dendroclimatic year was used. A dendroclimatic year used in this case began in April of the previous year and extended through September of the current growth year. This 18-month interval includes two radial growth seasons and the intervening cold months, when usually no growth occurs (Fritts, 1976).

Figure 3 shows the correlation between the three chronologies and West Point temperature for the common period from 1850-1992. Correlations were computed for both the original data and that prewhitened to remove the effects of autoregressive persistence (Box and Jenkins 1976) in both the tree-ring and meteorological data. Correlations exceeding approximately .20 were significant at the 95% level, using a two-tailed test. The prewhitened comparisons are more strictly valid statistically and are a clearer indication of the high-frequency correlation between tree growth and climate. It is apparent that hemlock at all three sites responds negatively to previous summer temperatures, especially for the prior June. This indirect (lag 1) negative relationship is indicative of an expected drought response related to increasing evapotranspiration demand with increasing temperature (Cook and Cole 1991). Positive correlations are found with early spring temperatures, especially for the month of March, just prior to the growth season. Above average temperatures at this time may improve thermal conditions by removing snow cover and allowing for early photosynthesis (Cook and Cole 1991). These temperature results are very similar to those found by Cook and Cole (1991) for several eastern hemlock sites in the Shawangunk Mountains of southeastern New York State, and to other sites throughout its range in eastern North America. This similarity is an indication that the climatic response of this species is independent of site in terms of temperature (Cook and Cole 1991).

Figure 4 shows the correlation between the three chronologies and West Point precipitation. Here it can be seen that the hemlocks respond positively to prior September and current July precipitation. All three sites show low index values in the year 1981. According to the West Point meteorological data, the previous summer had an exceptionally dry and relatively hot August and September. The climatic response for BRF hemlock for precipitation is similar to that for the well drained hemlock sites in the Shawangunks discussed by Cook and Cole (1991), which also showed positive correlations with prior September and current summer precipitation (although the highest correlation is with July precipitation at BRF vs June precipitation in the Shawangunks). Yet the response of hemlock to precipitation appears to be very site dependent throughout its range. Dissimilarity in climate response may also be due in part to the poorer spatial representation of precipitation compared to temperature (Cook and Cole 1991).

Figure 5 shows the correlation between the three chronologies and the West Point Palmer Drought Severity Index, or PDSI. This index incorporates the effects of both temperature and precipitation at the same time to produce a relative index of wetness and dryness.


CB
LC
MS
HEMLOCK CHRONOLOGIES AND WEST POINT PRECIPITATION
ORIGINAL
PREWHITENED
CORRELATIONS
0.4
0.3
0.2
0.1
0
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-0.2
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A M J J A S O N D J F M A M J J A S
MONTHS

Fig. 4.

Summary

The hemlock chronologies which we have developed for BRF provide a background history of tree growth and inferred climate variations for the Black Rock forest ecosystem. The climate analyses with West Point temperature and precipitation data indicate that the eastern hemlock at BRF responds to climate in a manner similar to that of other hemlock studied in this region of the eastern United States.

Literature Cited

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Figure Captions

Figure 1. Map of the Black Rock Forest, New York showing locations of the three eastern hemlock sites investigated for this project.

Figure 2. Plot showing a comparison of the three hemlock chronologies developed for the Black Rock Forest, beginning in 1820 for the oldest site (Mineral Springs) and ending in 1992.

Figure 3. Correlation plots between three hemlock chronologies and West Point temperatures for common period from 1850-1992 for interval beginning in April of year prior to growth and ending in September of the current growth year. Upper graph, for original and lower graph for prewhitened tree-ring and climatic data. Values exceeding .16 indicate significance at the .05 level, using a two-tailed test. Results strictly valid only for prewhitened results.

Figure 4. As in Figure 3, but for West Point precipitation.

Figure 5. As in Figure 3, but for West Point PDSI for common period from 1908-1990. Values exceeding .22 indicate significance at the .05 level, using a two-tailed test.

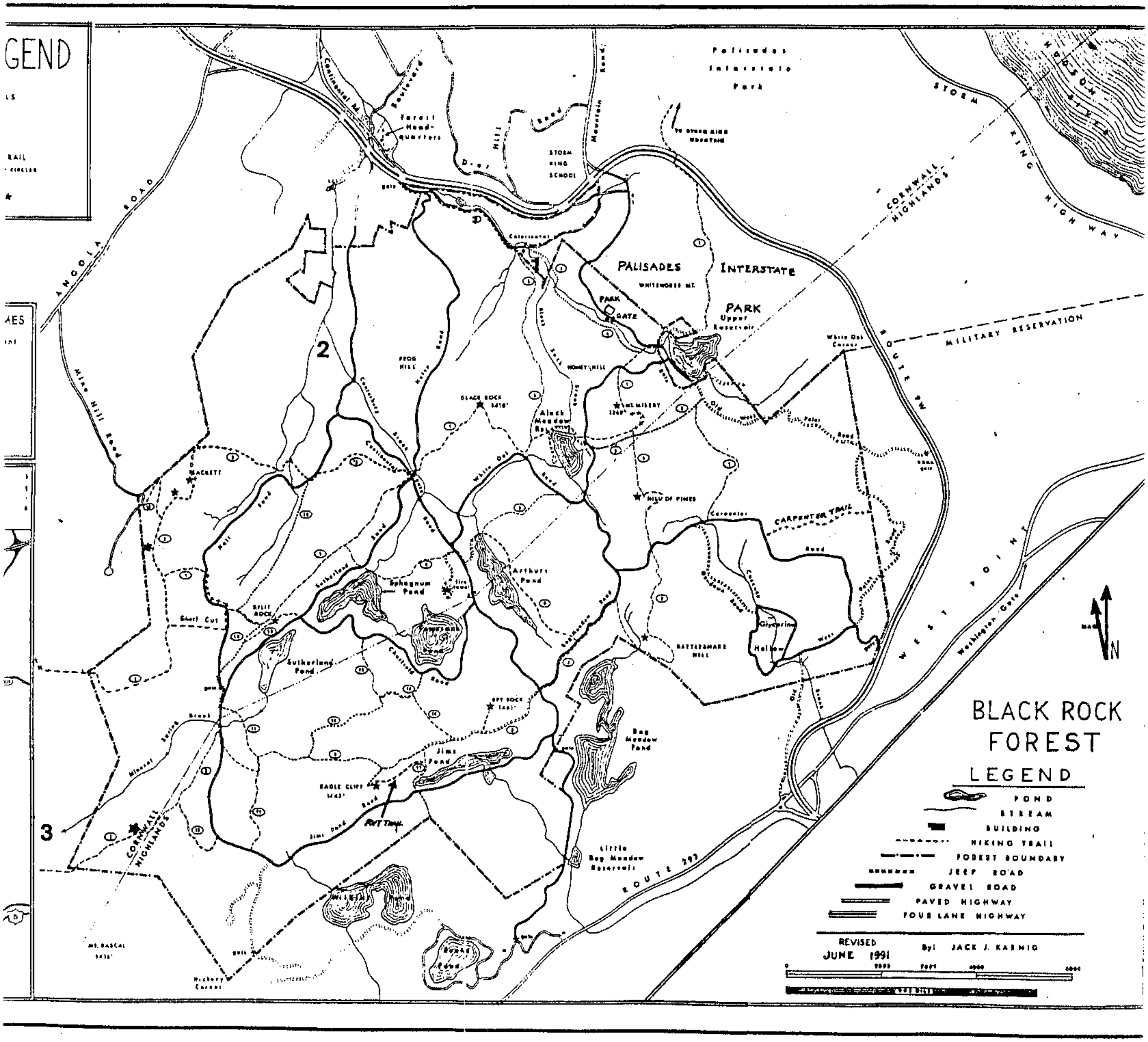


Fig. 1 Site Locations

SITES

1. Lower Chlorinater
2. Canterbury Brook
3. Mineral Springs

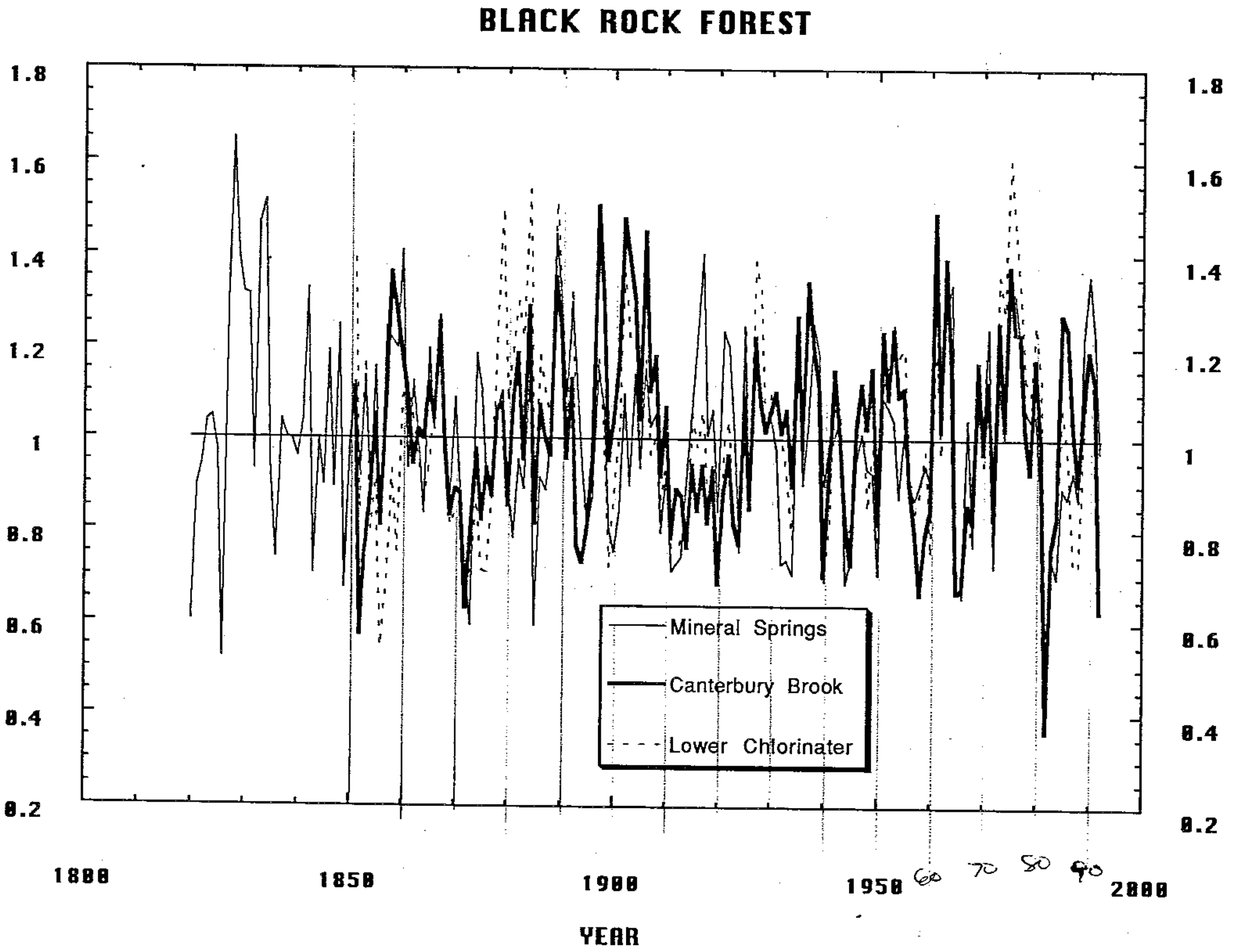
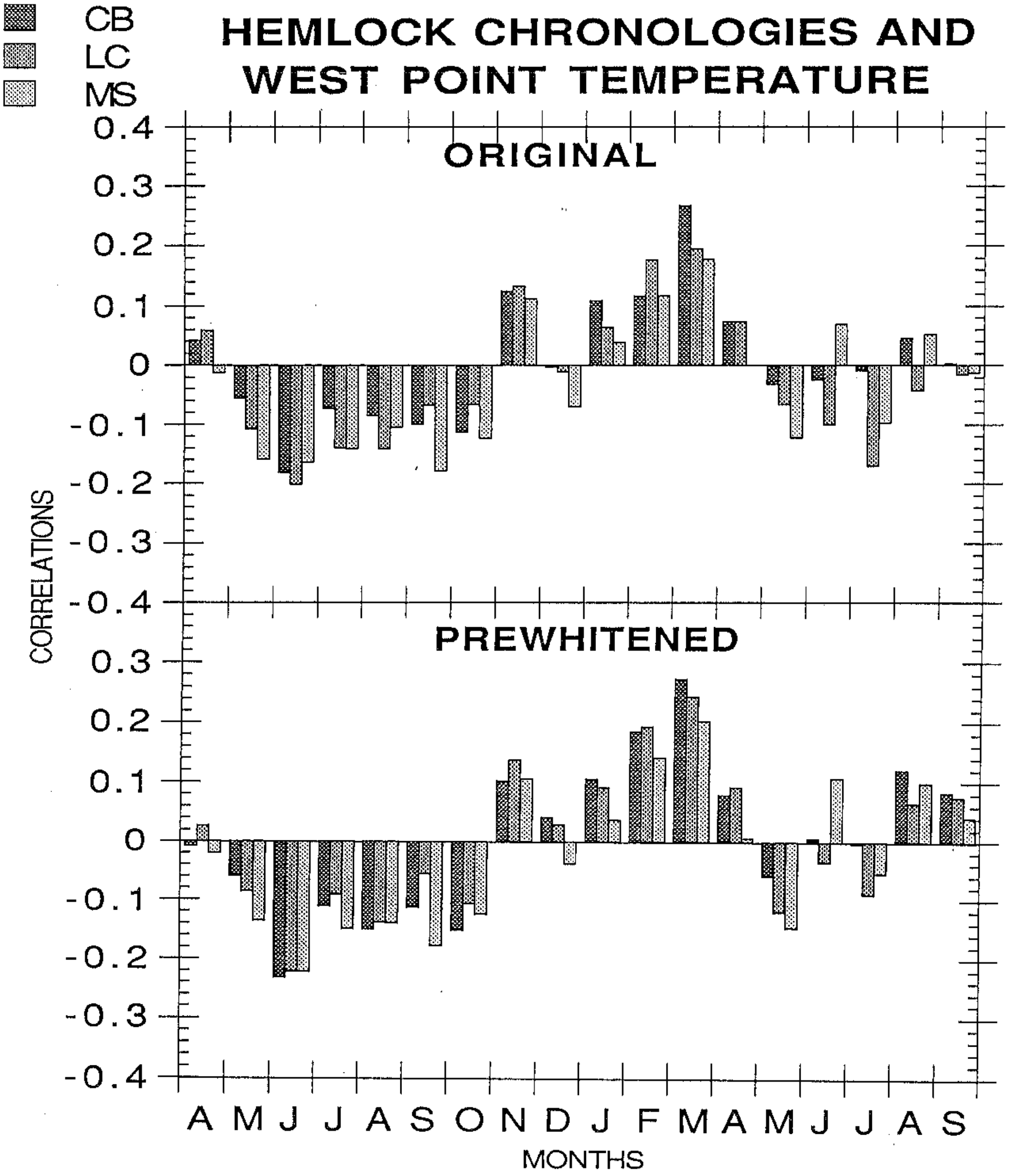

BLACK ROCK FOREST
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
1800
1850
1900
1950
60
70
80
90
2000
YEAR
Mineral Springs
Canterbury Brook
Lower Chlorinater

Fig. 2.


CB
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MS
HEMLOCK CHRONOLOGIES AND WEST POINT TEMPERATURE
ORIGINAL
PREWHITENED
CORRELATIONS
0.4
0.3
0.2
0.1
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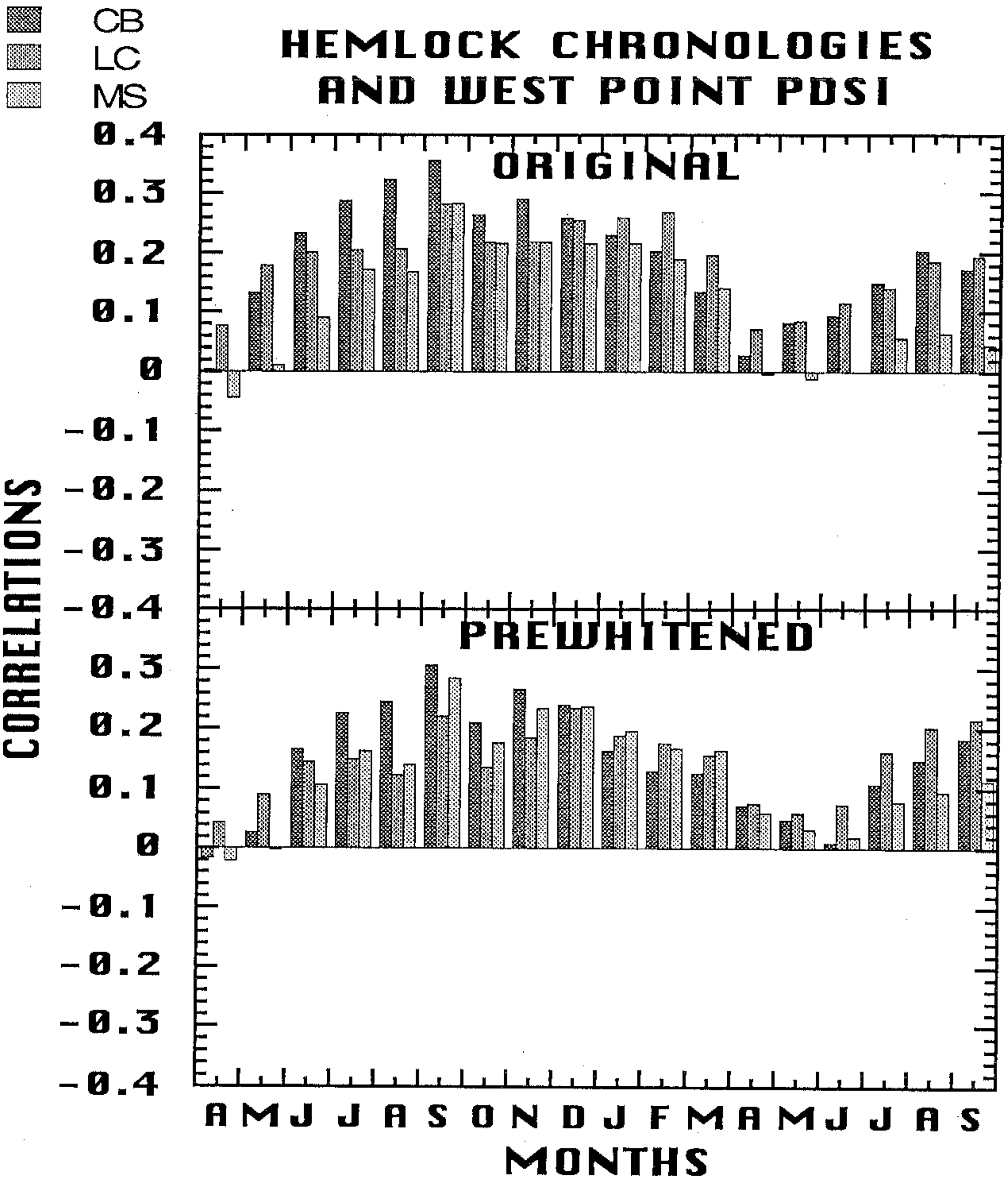
A M J J A S O N D J F M A M J J A S
MONTHS

Fig. 3.


CB
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HEMLOCK CHRONOLOGIES AND WEST POINT PDSI
ORIGINAL
PREWHITENED
CORRELATIONS
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0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
A M J J A S O N D J F M A M J J A S
MONTHS

Fig. 5.