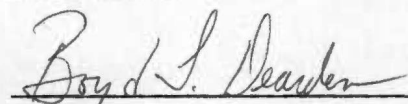


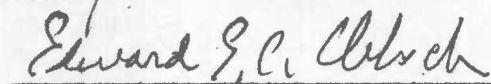
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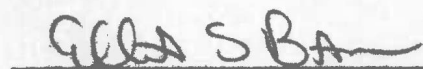
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Michael R. Pelton, Major Professor

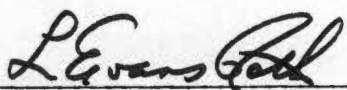
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AN ANALYSIS OF TREES MARKED BY BLACK BEARS
IN THE GREAT SMOKY MOUNTAINS NATIONAL PARK

A Thesis
Presented for the
Master of Science
Degree
The University of Tennessee, Knoxville

Thomas L. Burst

June 1979

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ABSTRACT

With the study area for the Great Smoky Mountains National Park, 691 black bear (Ursus americanus) mark trees were located. Mark trees along 135 km of preselected index trails were tagged, physiognomic parameters around the trees measured, and characteristics of the tree and mark recorded. Trees along the index trails were reobserved periodically from April to December, 1976-1977, to monitor fresh marking. Additional mark trees located away from manmade trails were characterized and classified as to their position on the slope. Multivariate analyses on an around mark tree were attempted to further delineate the relationship between environmental parameters and marking.

All mark trees were found near some type of trail. Marks on trees generally faced the trail and up the slope. The marks were centered at approximately 1.6-1.7 m above the ground. Eight coniferous and 26 hardwood species were marked. The choice of species apparently reflects their availability in areas of high bear use. Most mark trees were located along abandoned trails and ridge tops. Most fresh marking occurred during May, June, and July, but some fresh marks were observed during all portions of the year in which the bears were active. Thirty-one percent and 23% of the mark trees along index routes were marked fresh during 1976 and 1977, respectively.

The incidence of fresh marking from year to year or location to location may be useful as an index to population density. The form and function of bear marking was discussed and hypotheses were proposed. None of the discussed functions could be disproved and the data indicated that marking by bears has more than one function. A comparison of bear

marking with scent gland marking in other mammals demonstrated a close resemblance of their respective characteristics. Stepwise regression and discriminant function analysis indicated that physiognomic parameters affected both the time of year trees were marked and which trees were marked to a measurable extent. This study establishes baseline data for further investigations into the role of marking in the natural history of the black bear.

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I. INTRODUCTION

Bear mark trees, sign post, or scratching trees have puzzled naturalists and biologists for many years. The function of and motivation for bears' biting, clawing, and rubbing against trees have prompted a variety of theories. Most hypotheses have not been tested and none seem satisfactory for all the different types of bear marking.

Detailed investigations have been minimal; information has usually been anecdotal, and/or the study was carried out as an aside to a larger, more general project. The information is also complicated by the implicit assumption of most authors that marking is essentially the same in both black bears and brown/grizzly bears (U. arctos). This assumption is retained in this study due to the sparsity of information in general and the lack of evidence to the contrary.

Early writing about bear marking consisted exclusively of anecdotes and speculation. Mills (1919) considered the trees as "information places" and did not speculate any further. Seaton (1925) also described the trees as information places and additionally suggested that they had the same function as the urinary signpost of the canids.

Meyer-Holsapfel (1957) made no firm conclusions, but suggested marking might serve as some type of body care and possibly functioned in social communication. In a later paper (Meyer-Holsapfel 1968) she proposed that rubbing resinous objects on the body could reduce ectoparasite numbers.

Tschanz et al. (1970) studied rubbing behavior in captive brown bears. Four adult male/female pairs were kept in 2 zoo bear pits. Pairs did not have contact with other pairs; they were temporally spaced. The following observations were reported: (1) one form of rubbing (standing and rubbing the dorsal side of the body against an object) was exhibited in 78% of all rubbing incidents; (2) males rubbed more frequently and "more generously" than females; (3) males have more rubbing forms than females; (4) rolling in front of rubbing places was only observed in males; (5) the males did not always cover each others marks; (6) the bears rubbed most on optically changed places; (7) immature bears hesitated to approach rubs made by strange adults; (8) immature bears rarely exhibited the more prominent forms of rubbing; (9) while there were several rubbing places scattered around each pit, the lone tree in each pit was the center of rubbing activity; (10) while rubbing occurred during all non-denning months, the peak of male rubbing occurred during the breeding season; (11) the peak of female rubbing occurred at the end of the moult; and (12) males could distinguish female rubs from male rubs. By manipulation of the bears between pits, Tschanz et al. (op. cit.) may also have demonstrated that the marking bear uses the marks as part of a spatial relations (orientation) system.

Most recent studies tend to agree with those portions of the work of Tschanz et al. (1970) to which each pertains. Both Harger (1974) and Rogers (1977) observed mark trees of black bears and found that most marking occurred during or just prior to the breeding season. Shaffer (1971) found no seasonal pattern of visits of black and grizzly bears to mark trees in Montana. However, he marked all of his trees with

conspicuous red bands; that could have caused more visits to the trees due to curiosity. Rogers (1977) also observed that most marking was done by adult male bears.

Some data have been collected on the characteristics of the mark trees themselves. Most trees found were conifers (Mills 1919, Seaton 1925, Dokken 1954, Meyer-Holsapfel 1957, Shaffer 1971, Rogers 1977); only Spencer (1966) and Rogers (1977) mentioned angiosperm mark trees. Mark trees are located along trails (Grinnel et al. 1937), and they are marked on the portion of the tree facing the trail (Shaffer 1971).

The conspicuousness of mark trees is their most notable feature. This ease of observability combined with the relative permanence of marks makes an ideal bear sign for continued observation. The marks may then also be useful as an indirect population monitor. The use of animal "sign" as a population index is considered less reliable than more direct methods, but the amount of effort needed to use more standard methods for the annual monitoring of a bear population is prohibitive to most agencies, particularly when kill data are not available.

For black bears, scent stations and "sign" routes have been used to estimate relative abundance. Spencer (1966) used sign (including mark trees) to estimate relative black bear abundance with limited success in Maine. Lindzey and Meslow (1977) used scent stations to derive a relative index for an island population in Washington. Pelton (1972) used scats and hikers' bear sightings to estimate black bear activity in the Great Smoky Mountains National Park (GSMNP or Park). Matthews (1977) determined that the incidence of black bear scats varied with season, altitude, and ecological site and such variability

must be taken into consideration before accurate and precise indices can be developed. None of the authors demonstrated that a change in bear density accompanied a change in their index value or criterion.

The present effort was undertaken as a descriptive study of mark trees and marking occurrence and to evaluate the potential use of mark trees as a population monitor.

II. STUDY AREA

This study was conducted within the Great Smoky Mountains National Park. The 50,607 ha study area comprises the northwest quadrant of the Park; it is bounded by the transmountain road (U.S. 441) to the east and by the Tennessee-North Carolina boundary to the south (Figure 1). Access to the study area is limited to 64 km of improved roads, 88 km of unimproved roads, 400 km of maintained foot trails, and over 240 km of abandoned trails and railroad beds. Elevations within the study area range from 270 to 2,024 m above sea level; half of the study area is over 1000 m. Drainage of the steep v-shaped valleys and long, narrow ridges is provided by approximately 960 km of rocky, fast flowing streams.

High relief, varied aspects, and high precipitation are responsible for a wide range of sites with much intermingling of diverse forest types. Shanks (1954) and Whittaker (1956) reported 6 forest types; Golden (1974) gave 20 and compared the various classification systems. The 6 types of Shanks are the most apparent; major tree species from each type are presented in Table 1.

Vegetation within the Park is best known for its denseness, complexity, and diversity. The distribution of forest types may be simplified as follows. The spruce-fir forest is located at the highest elevations. The northern hardwoods occupy the slopes just below the spruce-fir and the more exposed slopes within the spruce-fir elevation range. Cove hardwoods occur in the sheltered valleys. Open oak-pine stands and heath thickets are located on dry exposed ridge tops.

Figure 1. Map of the study area showing index routes within the Great Smoky Mountains National Park.

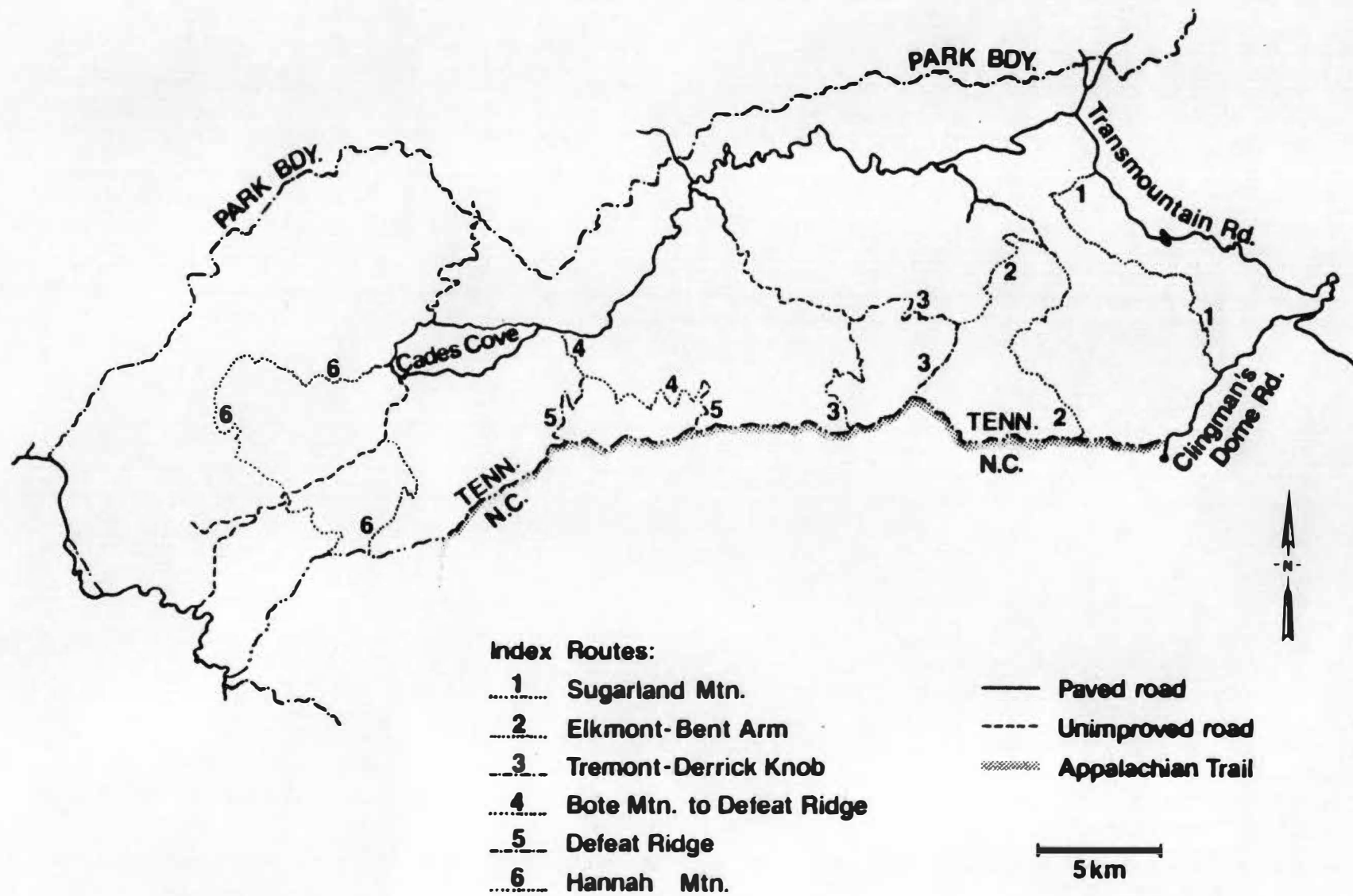


Figure 1

Table 1. Forest associations and their important tree species in the Great Smoky Mountains National Park.

Forest association type	Important species
Cove Hardwood	Eastern hemlock (<u>Tsuga canadensis</u>) Silverbell (<u>Halesia monticola</u>) Yellow buckeye (<u>Aesculus octandra</u>) Tulip poplar (<u>Liriodendron tulipifera</u>) Beech (<u>Fagus grandifolia</u>) Yellow birch (<u>Betula allegheniensis</u>) Black cherry (<u>Prunus serotina</u>) Rhododendron (<u>Rhododendron spp.</u>)
Hemlock	Eastern hemlock (<u>Tsuga canadensis</u>) Yellow birch (<u>Betula allegheniensis</u>) Silverbell (<u>Halesia monticola</u>) Fraser magnolia (<u>Magnolia fraseri</u>)
Northern hardwood	Beech (<u>Fagus grandifolia</u>) Sugar maple (<u>Acer saccharum</u>) Yellow buckeye (<u>Aesculus octandra</u>) Yellow birch (<u>Betula allegheniensis</u>)
Closed oak	Chestnut oak (<u>Quercus prinus</u>) White oak (<u>Quercus alba</u>) Black oak (<u>Quercus velutina</u>) Northern red oak (<u>Quercus rubra</u>) Pignut hickory (<u>Carya glabra</u>) Mockernut hickory (<u>Carya tomentosa</u>) Sourwood (<u>Oxydendrum arboreum</u>)
Open oak and pine	Sassafras (<u>Sassafras albidum</u>) Scarlet oak (<u>Quercus coccinea</u>) Pitch pine (<u>Pinus rigida</u>) Virginia pine (<u>Pinus virginiana</u>) Mountain laurel (<u>Kalmia latifolia</u>)
Spruce-fir	Red spruce (<u>Picea rubens</u>) Fraser fir (<u>Abies fraseri</u>)

Source: R. E. Shanks, "Reference list of native plants in the Great Smoky Mountains." Botany Department, The University of Tennessee, Knoxville, 1954. (mimeographed).

Closed oak forest occur on slopes with intermediate exposure. The hemlock forest type also occupies the streamsides at low elevations but changes to more exposed sites as elevation increases.

Rhododendron spp., Kalmia latifolia, Smilax spp. and/or numerous minor associates frequently form nearly impenetrable understory thickets on almost all types of sites, and especially on dry ridges. Vaccinium sp. and Gaylussacia sp. are frequent and continuous understory shrubs in the open oak-pine forest.

A few grassy "balds" are present at the higher elevations and Cades Cove (Figure 1) is maintained in pastures and fields.

III. METHODS AND MATERIALS

Definitions

Actual black bear mark trees must be distinguished from other bear "sign" associated with trees. Specifically a mark tree is not an Aspen (Populus sp.) that has been climbed and retained the claw marks as reported by Minor (1946), and it is not a tree which has had its bark ripped off and its cambium eaten by a bear (Poelker and Hartwell 1973). A mark tree is a tree that has been bitten, clawed, and/or rubbed by a bear at approximately the height of a standing animal such that the damage did not occur while feeding upon or climbing the tree. The mark will persist for a single season or several years, depending upon the intensity of the mark and re-marking.

Marking itself is defined as making a persistent change in the environment and consequently leaving information for or causing a change in the behavior or physiology of conspecifics, the marker, or members of another species upon perception or contact with the mark. The responder perceives the signal (mark) in the absence of the marker except by coincidence and when the responder is the marker.

Data Collection

Beginning in August 1975, mark trees were located throughout the study area and identified to the lowest taxon, usually species. Searches were conducted both on and off trail. Trails were classified as abandoned or maintained; maintained trails were classified into 2 categories as the Appalachian Trail or other trails. Off-trail searches

were classified according to the type of search. Unstructured searches were conducted in the immediate vicinity of 6 well-used panhandler bear sites along the transmountain road and in the spruce-fir forest; 3 sites were located on the original road and 3 on a newer portion of the road. Additional off-trail searching was conducted away from manmade alterations of the environment such as trails and campsites. Twenty-five 1000 m random transects were searched throughout the study area. Other off-trail searches followed ridge tops, valley bottoms, or nothing (cross-country). These wilderness searches were conducted in all forest types, but not proportionately so.

Among the trails searched, 135 km of preselected trails were classified as index routes. These 6 routes (Figure 1 and Table 2) have portions located in all major vegetation types. The routes are composed of 116 km of maintained trails (18 km of which are part of the Appalachian Trail) and 18 km of abandoned trails. Mark trees located on index routes were inconspicuously tagged with a permanent, numbered metal tag placed at the base of the tree away from the trail. The index routes were hiked and trees checked biweekly from late spring (May) to early fall (October) and monthly as weather permitted during other months of 1976 and 1977. When a fresh mark or other change in a tree's appearance was observed, it was noted and a sketch of the mark was drawn for comparison during the following checks. For most mark trees along index routes, measurements of the tree, mark, and surrounding area were made (Table 3).

Seventy-eight of the mark trees on the index routes were randomly selected for plot samples on the nearby vegetation; these are referred

Table 2. Length of trail, length of trail types, and elevation extremes for index routes in the Great Smoky Mountains National Park.

Route name	Total	Length (km)		Abandoned	Minimum elevation (m)	Maximum elevation (m)
		Maintained	Other			
		AT				
Sugarland Mountain	17.2	0	17.2	0	573	1828
Elkmont-Bent Arm	28.8	7.2	13.6	8.0	890	1755
Tremont-Derrick Knob	24.8	4.8	20.0	0	792	1584
Bote Mountain to Defeat Ridge	12.8	0	6.4	6.4	599	1219
Defeat Ridge	15.2	6.4	4.8	4.0	777	1671
Hannah Mountain	36.0	0	36.0	0	441	1508
Total	134.8	18.4	98.0	18.4		

Table 3. Identification of variables measured around mark trees on index routes in the Great Smoky Mountains National Park.

Variable name	Variable description or method of measurement
DBH ^a	Diameter of the mark tree in cm at 1.4 m above the ground.
DISTANCE ^a	Distance to nearest mark tree along the trail with an arbitrary maximum of 999 m.
DISTANCE TO TRAIL	Distance from mark tree to nearest edge of trail.
UPDOWN ^a	Position of mark tree with respect to the trail. Down = 0, Level = 1, Up = 2.
DOMINANCE ^a	Expressed in terms: Broken off = 0, Overtopped = 1, Subdominant = 2, Codominant = 3, Dominant = 4.
SLOPE OF GROUND ^a	Slope of the ground near the mark tree measured with a clinometer in degrees.
ASPECT ^a	Aspect of the slope at the mark tree. 0 = no slope 3 = 135° 6 = 270° 1 = 45° 4 = 130° 7 = 315° 2 = 90° 5 = 225° 8 = 0° or 360°
HEIGHT TO SCAR	Distance in cm from the ground to the lowest portion of the scar.
LENGTH OF SCAR	Vertical distance in cm from the lowest portion of the scar to the highest portion of the scar.
WIDTH OF SCAR	Maximum horizontal measure of the scar.
MARK AGE	Classified as either fresh or old.
SPECIES ^a	The number of mark trees of that species found on index route. Yellow pines were grouped together.
GENUS ^a	Every genus was ranked by phylogenetic order and numbered consecutively. The number was the value of the variable.
LOCATRAIL	Location of the mark on the tree with respect to the trail.
LOCASLOPE	Location of the mark on the tree with respect to the slope.

Table 3 (continued)

Variable name	Variable description or method of measurement
SAP	Presence or absence of sap and consistency. Noted again when rechecked during good weather.
ELEVATION ^a	Taken from 7½ minute contour map. Contour interval = 40 ft.
HUMAN DAMAGE	Noted presence of human damage to mark tree.
OTHER SIGN	Noted presence of other animal sign on the mark tree.
TIME MARKED	The dependent variable for the stepwise regression of "time of marking." The value was 1 through 12 for 2-week periods from May to mid-October.
PERCENTAGE CIRCUMFERENCE	Percentage of the mark tree's circumference which consisted of the scar.

^aThese variables and those in Table 4, page 16, were used in the multivariate and multiple regression analyses on the first runs.

to as the intensively-sampled trees. Four circular 1 m² plots centered 2, 4, 6, and 8 m from the base of the mark tree and away from the trail were used to conduct stem counts of woody vegetation up to 0.75 m high and all stems of the genres Vaccinium and Gaylussacia and of dog-hobble (Leucothoe fontanesiana). One circular 50 m² plot, adjacent to the back of the mark tree and centered 3.99 m from the tree away from the trail, was used to conduct stem counts of woody vegetation greater than 0.75 m high and less than 5 cm in diameter at breast height (dbh). Vaccinium spp., Gaylussacia spp., and dog-hobble were not counted on these plots. The same plot was used to conduct stem counts of woody vegetation greater than 5 cm dbh. The center of the plot was used as the sample point for a stem count made through a prism angle gauge with a basal area factor of 10. On all plots each stem counted was classified as an angiosperm or gymnosperm. Variables derived from these plots are given in Table 4.

Analytical Methods

Factor analysis was applied to the set of intensively sampled trees to find if any variable or groups of closely related variables (factors) could account for the majority of variation among parameters measured (Marriott 1974); it was hoped this would elucidate particular parameters for further study. Iterated principal axis factoring and oblique rotation with nearly orthogonal angles of obliqueness were used. All variables in Table 4 and those variables followed by an asterisk in Table 3 were used for the initial analysis. For later analysis, variables were selectively discarded based upon final communality estimates and factor loadings after rotation.

Table 4. Identification of variables measured on and around the intensively sampled mark trees in the Great Smoky Mountains National Park.

Variable name	Plot size	Variable description
BASAL AREA OF GYMNASPERMS		Count of the gymnosperms observed through the prism angle gauge.
BASAL AREA OF ANGIOSPERMS		Count of the angiosperms observed through the prism angle gauge.
STEM COUNT OF LARGE GYMNASPERMS	50m ²	Count of gymnosperms greater than 5 cm dbh.
STEM COUNT OF LARGE ANGIOSPERMS	50m ²	Count of angiosperms greater than 5 cm dbh.
STEM COUNT OF GYMNASPERMS	50m ²	Count of the gymnosperms less than 5 cm dbh and greater than 0.75 m high.
STEM COUNT OF ANGIOSPERMS	50m ²	Count of the angiosperms less than 5 cm dbh and greater than 0.75 m high excluding <u>Vaccinium</u> sp., <u>Gaylussacia</u> sp., and dog hobble (<u>Leucothoe fontanesiana</u>).
STEM COUNT OF SMALL GYMNASPERMS	1m ²	Count of the gymnosperms less than 0.75 m high in all 4 plots.
STEM COUNT OF SMALL ANGIOSPERMS	1m ²	Counts of the angiosperms less than 0.75 m high including all <u>Vaccinium</u> sp., <u>Gaylussacia</u> sp., and dog hobble regardless of size, in all 4 plots.
HIKER VALUE		Number between 0 and 5 based upon the number of hikers seen by persons hiking index routes and knowledge of trail use patterns.
LIVE		Dead = 0; Live = 1 (refers to the mark tree).
SLOPE OF TRAIL		Measured with a clinometer in degrees.
WIDTH OF TRAIL		Width of the used portion of the trail measured in centimeters.
DISTANCE TO RIDGE TOP		Distance in meters to the nearest ridge top.

Among the intensively sampled trees, some individuals were known to have been re-marked during the study. Stepwise regression and discriminant function analysis were used to distinguish between re-marked and not re-marked trees based upon the variables measured. Stepwise regression was used in an attempt to eliminate superfluous or redundant variables prior to the discriminant function analysis and to ascertain vector values for the discriminant function analysis. The stepwise regression technique entitled maximum R^2 improvement (Barr et al. 1976: 251) was used; it was considered superior to simple stepwise regression (Barr et al. 1976: 251).

The vector of weights (b) giving the best least squares fit for a given number of variables is given by

$$b = S^{-1}u$$

where S is the matrix of the sums of squares and products of the x's (independent variables), and u is the vector of the sums of products of the x's and y's (dependent variable) (Marriott 1974).

Discriminant function analysis was used to actually assign each observation to 1 of 2 groups (re-marked or not re-marked) based upon the independent variables (the measured parameters). The generalized squared distance was based upon the within-group covariance matrices. Prior probabilities were proportional to the number observed in each group.

Stepwise regression was also used in an effort to predict the time of marking for each tree marked based upon the variables measured around mark trees from the intensively sampled set.

IV. RESULTS AND DISCUSSION

Description of Mark Trees

Most marks were easily seen, the optical disruption of the bark pattern was severe. The marks were centered at 1.6-1.7 m above the ground and most often faced the trail and up the slope (Table 5). Bark, and often sapwood, were removed from the trunk of mark trees by the biting and clawing of bears (Figures 2-8). Individual tooth and claw marks were obvious (Figures 3 and 4). Sap commonly exuded from conifers (140 of 211 trees) and some hardwoods (7 of 204 trees), but was more noticeable and more frequent on conifers. Bear hair and/or mud was sometimes left on the tree stuck in the sap or to a rough place on the tree. The size of the scar varied with the size and species of tree marked and with the age, intensity, and number of marks (Figures 2, 5-8, and Table 20 in the Appendix). The mark completely encircled 31 of 378 trees. If not re-marked, bark grows over the scar. The exposed sapwood on old marks eventually fades to a dirty gray.

Recent markings appeared yellow or red and were distinguished from older marks (Figure 2) for up to 2 years and possibly longer; however, the mark did not appear fresh for this long. Fading of some new marks was detected in less than 2 weeks on some trees but often took longer. More accurate aging of marks was generally not feasible.

While the size of the scar was relatively large, fresh marks varied from only a single bite or scratch to multiple bites and scratches leaving fresh marks nearly as large as the previous scar (marks). Most fresh marks were small (Figures 2 and 4).

Table 5. Location of black bear marks and mark trees along index routes in the Great Smoky Mountains National Park with respect to the trail and slope.

Location of trees with respect to the trail			Location of mark with respect to the trail			Location of mark with respect to the slope		
Category	No. of trees in	% in	Category	No. of trees in	% in	Category	No. of trees in	% in
	category	category		category	category		category	category
Below the trail	333	75	Facing trail	334	84	Facing up slope	291	76
Level ground or along ridge top	42	10	Facing up or down the trail, but not facing the trail	56	14	Facing along the contour of the slope, but not up slope	56	15
Above the trail	67	15	Facing away from the trail only	6	2	Facing down slope only	11	3
						Level ground	24	6
Total	442		Total	396		Total	382	

Figure 2. Yellow pine mark tree with fresh mark.

Figure 3. Close up of yellow pine mark tree showing the bite.

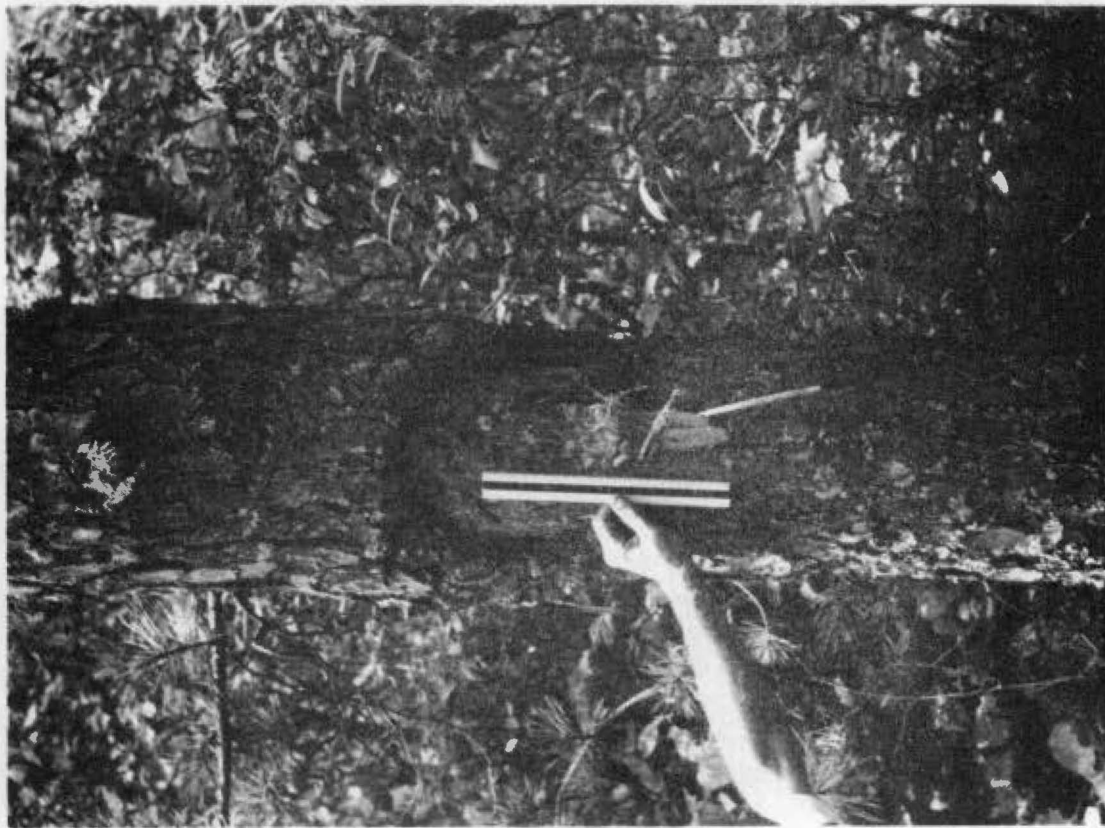


Figure 2

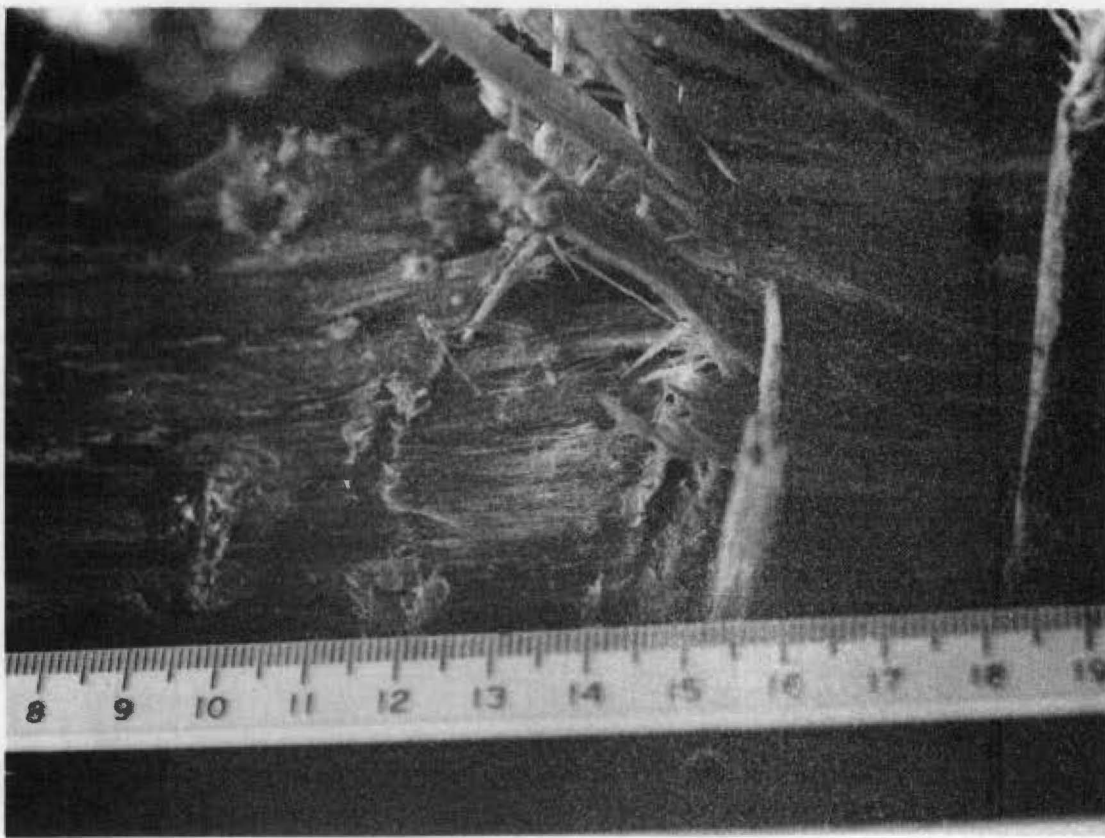


Figure 3

Figure 4. Yellow buckeye mark tree with tooth marks. The white card is 3 x 5 in.

Figure 5. Eastern hemlock mark tree.

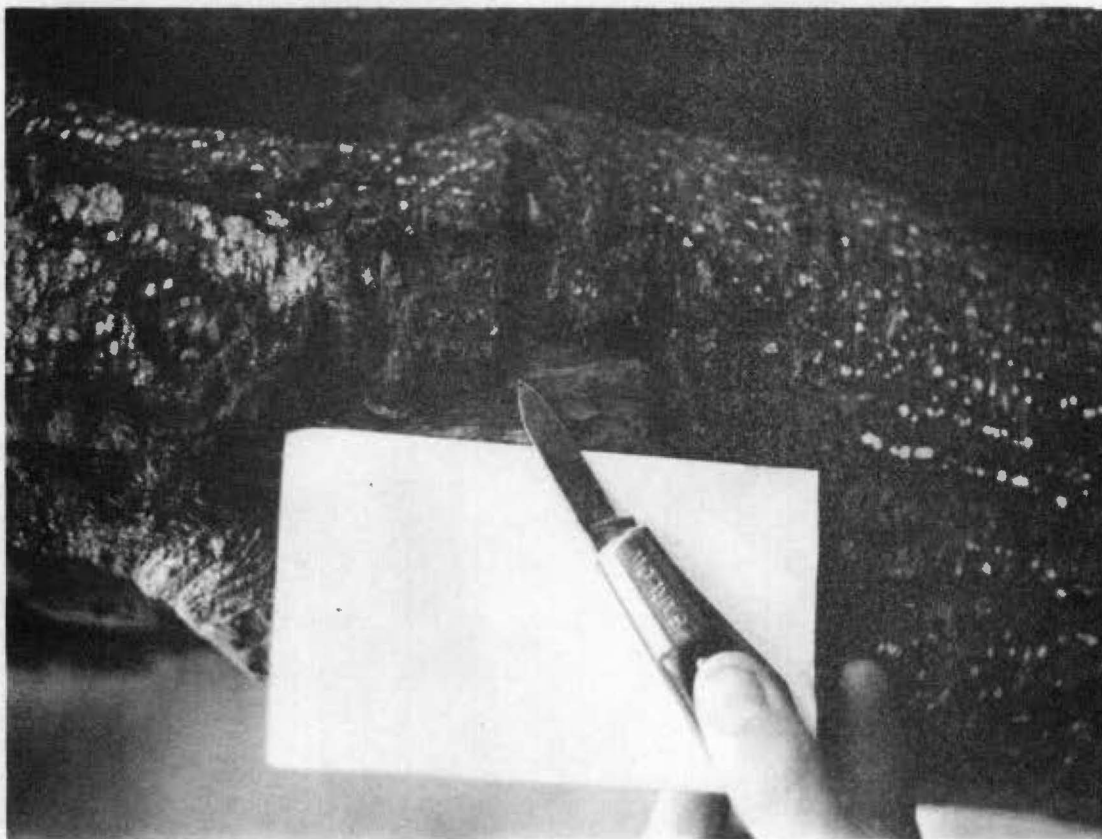


Figure 4

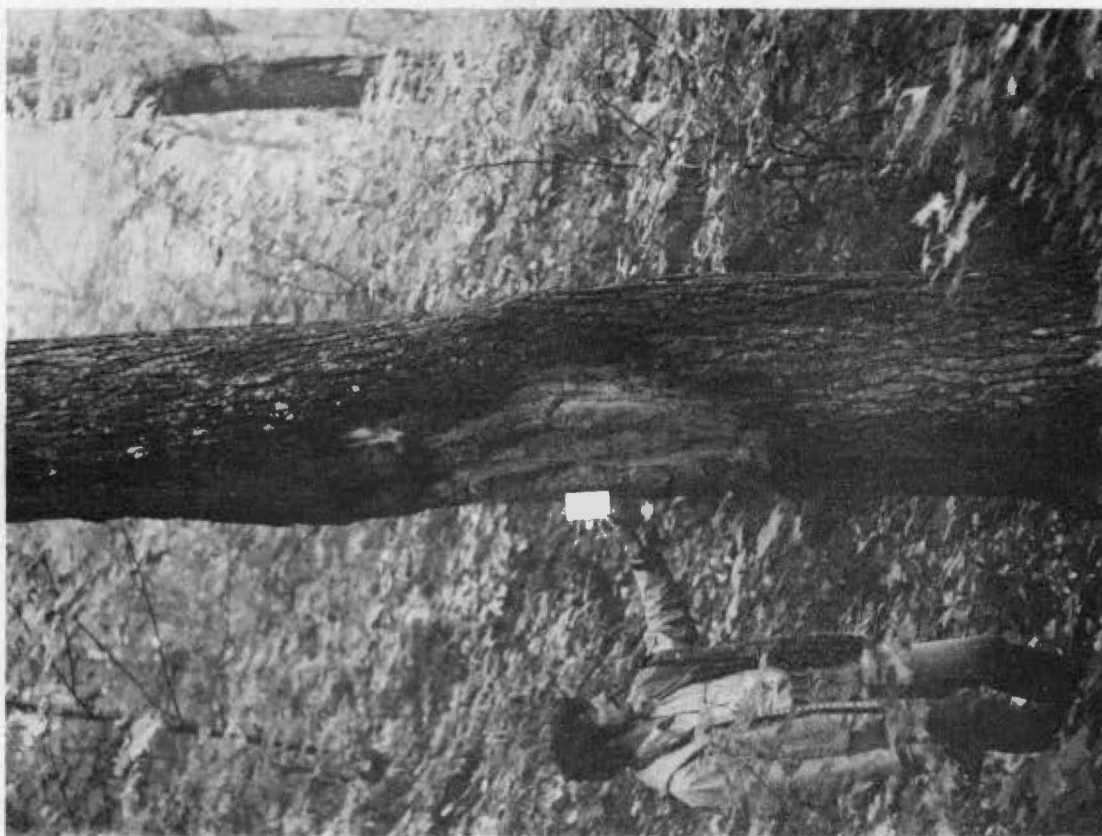


Figure 5

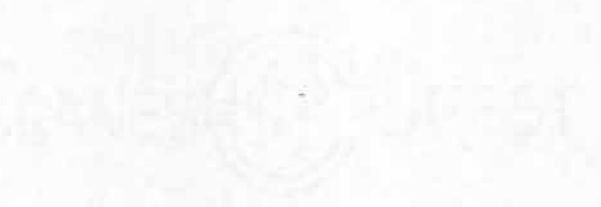


Figure 6. Striped maple mark tree.

Figure 7. Red maple mark tree showing bulge at the mark and the most typical spatial relation to the trail.



Figure 6

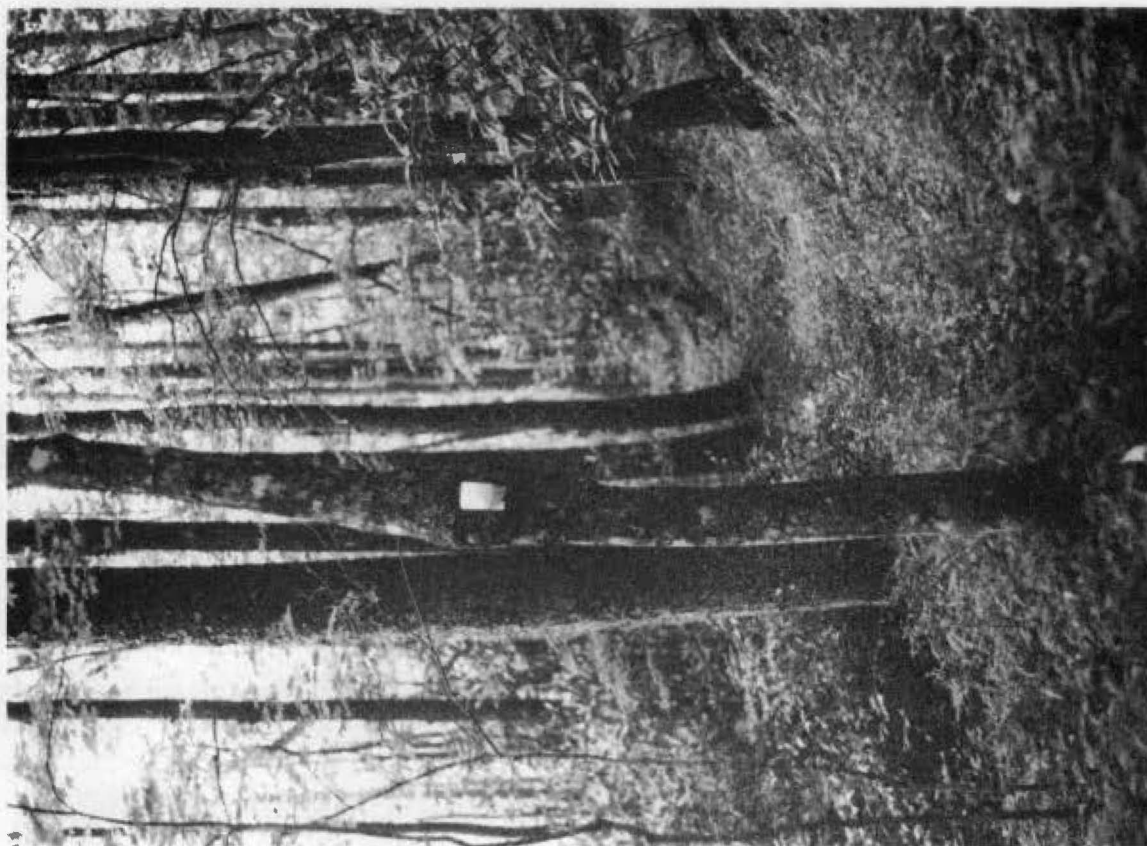


Figure 7



Figure 8. Sugar maple mark tree showing bulge at the mark and growth over old marks.



Figure 8

The use of mark trees as opposed to the substrate has several advantages. The elevated mark and sap may help dispersal and retention of scent (Rogers 1977). The optical mark would also attract attention to the tree when the odor is not perceivable from a distance; however, the location of at least some mark trees is apparently known to resident bears (Mills 1919, Rogers 1977). The optical mark also has a greater possibility for patterned information transmission.

Angiosperm and gymnosperm mark trees and their marks differed considerably in appearance (Figures 2-8). Marks were generally longer on gymnosperms ($\bar{X} = 84$ cm, $n = 205$) than angiosperms ($\bar{X} = 41$ cm, $n = 176$). The angiosperms often had large conspicuous bulges at the location of the mark (Figures 7 and 8); these were not so conspicuous on the gymnosperms. More bark was missing from the gymnosperms and the average gymnosperm was larger in diameter ($\bar{X} = 28$ cm, $n = 204$) than the average angiosperm ($\bar{X} = 15$ cm, $n = 187$).

The different physical appearances of angiosperms and gymnosperms were apparently due to the properties of the wood and the tree's healing patterns as opposed to any different marking behavior. Fresh marks occurred at approximately the same times ($P > 0.25$) for both groups for marks over 12 index trail periods during 1977 (Table 6). Proportionately and absolutely more angiosperms than gymnosperms received fresh marks during the study (Table 21, Appendix, $P > 0.05$).

The variety of tree species marked was unexpected (Table 21, Appendix). Only Spencer (1966) and Rogers (1977) have reported angiosperm mark trees; Spencer found no preference among the species marked. Observations during this study indicate that preference and

Table 6. Number of fresh marks by tree class for each index route period during 1977 in the Great Smoky Mountains National Park.

Date	Angiosperm	Gymnosperm
1-8 May	7	3
20-22 May	10	5
4-8 June	11	6
17-20 June	9	9
2-5 July	10	2
15-19 July	9	9
29 July-1 Aug.	4	3
12-15 Aug.	2	4
25-29 Aug.	4	1
9-12 Sept.	5	1
23-27 Sept.	2	3
7-10 Oct.	2	4
Total	75	50

availability are both important in determining the species marked; however, preference can only be inferred from the limited number of species marked.

The importance of availability is self evident, but the pattern of species marked supports the assertion. When following an old railroad bed, the present trail takes up only a small portion of the bed. The mineral soil covering the bed is conducive to the germination and growth of sweet birch. Therefore, many sweet birch are marked along old railroad beds. Sweet-birch mark trees are also found in other areas, but they are not so numerous.

Generally, pines were marked along dry ridge tops, but red maples, oaks and sourwoods were also marked frequently in these areas. Yellow birch, silverbell and American beech were used at higher elevations. Red spruce and Fraser fir were used almost exclusively in the spruce-fir forest type. The use of manmade trails has probably increased the variety of species marked since 86% of the off-trail mark trees were along ridge tops and valley bottoms (Table 7).

In addition to trees, front porch posts and various types of sign posts (with and without creosote) were marked. Harger (1974) reported marked telephone posts and Tschanz et al. (1970) reported rubbing activity on the walls of zoo bear pits. A live tree is not a necessary condition for a marking post.

Distribution in Space

All mark trees located were very near or adjacent to some type of trail. If the tree was not along a manmade trail, ridge top, or valley

Table 7. Frequency of black bear mark trees along different search and trail types in the Great Smoky Mountains National Park.

Search or trail type	Distance searched ^a (km)	Frequency (n)	Trees km
Off-trail	59	67	1.1
Along ridge tops	9	48	5.2
Along valley bottoms	12	7	0.6
Cross-country	12	9	0.8
Line Transects ^b	25	3	0.1
6 panhandler bear sites ^c	—	26	—
On-trail	173	598	3.5
Index routes	135	448	3.3
Maintained trails	116	276	2.4
Appalachian trail	18	8	0.4
Other trails	98	268	2.7
Abandoned trails	18	172	9.3
Non-index routes	38	150	3.9
Maintained trails	25	72	2.9
Appalachian trail	13	15	1.2
Other trails	12	57	4.7
Abandoned trails	14	78	5.7

^aAll off-trail distances estimated; line transects were paced off.

^bAll 3 trees located on ridge tops.

^cNot included in totals or trees/km calculations.

bottom, there was a distinct game trail passing close to the tree. These game trails were usually short and hard to follow, but were more distinct near mark trees. Along ridge tops with distinct game trails, mark trees were often found 1-3 m from the main game trail but having paths leading to the mark tree and back to the main trail. Such paths may be less than 5 m long and have distinct track-like depressions in the duff which appeared to have been formed over several years by repeated visits to the tree. Most mark trees found along index routes were adjacent to the trail (74%); the farthest from the trail was 15 m; most mark trees not adjacent to the trail were much closer. Mark trees are most often found on the downhill side of the trail (Figure 7, Table 5, page 19).

The number of mark trees found per km of searching varied with trail and search type (Table 7). The differences are significant in many cases (Tables 8 and 9). Abandoned manmade trails and ridge tops had more mark trees per km searched than any other type of trail. The Appalachian Trail and valley bottoms had the fewest mark trees per km of trail. Cross-country walking and line transects also had few mark trees per km, but trails were not followed. Trails along index routes were compared separately because the trails were walked so often, and all mark trees along these trails were found. The higher proportion of mark trees along trails with low visitor use was expected due to the high scat occurrence reported in these areas by Matthews (1977).

Black bears in the GSMNP make extensive use of the manmade trails (Pelton 1972, Matthews 1977). The location of game trails and mark trees demonstrates a similar use of ridge tops.

Table 8. Test results of the comparison of mark tree frequency by different search and trail types in the Great Smoky Mountains National Park.^a

	Off-trail				On-trail		Abandoned trail
	Ridge tops	Valley bottoms	Cross-country	Line transects	Maintained trail AT	Other	
Ridge tops		P<0.001	<0.001	<0.001	<0.005	0.9>P>0.75	>0.9
Valley bottoms			0.75>P>0.5	<0.05	0.5>P>0.25	<0.001	<0.001
Cross-country				<0.005	0.5>P>0.25	<0.001	<0.001
Line transects					<0.005	<0.001	<0.001
Appalachian trail						<0.005	<0.001
Other maintained							0.75>P>0.5
Abandoned							

^aIndex routes compared separately in Table 9.

Table 9. Test results of the comparison of mark tree frequency by different trail types for index routes in the Great Smoky Mountains National Park.

	Maintained trail		Abandoned trail
	Appalachian trail	Other trail	
Appalachian trail		< 0.001	< 0.001
Other trail			< 0.001
Abandoned trail			

Rogers (1977) found that mark trees in Minnesota were located in open areas with less vegetation; he proposed that sparse vegetation would allow better odor dispersal. While open areas are scarce in the Park, ridge tops could serve a similar function. The abundance of mark trees along ridge tops could also be coincidental to the bears' use of them in moving from 1 place to another, particularly at higher elevations.

The location of mark trees along trails would increase the efficiency of a communications system involving the trees. It would also make relocation of the trees easier for bears in novel areas. It is also possible, though unlikely, that bears maintain trails (through use) to all mark trees. It seems unlikely that all mark trees were found along trails completely coincidental to the bears' extensive use of the trails.

The distribution of mark trees along the index routes appeared clumped; however, runs above and below the median tests of the distance from the last mark tree indicated that the distribution was clustered for only 1 index route ($P < 0.05$). (The median was arbitrarily given the value of 100 m.) Other index routes exhibited either randomness or slight mixing.

Two factors should contribute to a clumped distribution along the trails. First, fresh marks were usually discovered in groups. It appears that a fresh mark in an area increases the likelihood of finding other fresh marks in that area. Second, mark trees were more numerous along trails where they were on ridge tops. This could be due to a joining of 2 trails (the manmade trail and the ridge top game

trail), or to a preference for marking along ridge tops, to lower visitor use along some ridge top trails, or to a combination of all 3 factors.

Extensive searches for mark trees at 6 known panhandler bear sites along the transmountain and Clingman's Dome roads yielded 26 mark trees. Of the 6 panhandler bear sites searched, the 3 along the more recently constructed portion of the transmountain road yielded only 1 mark tree; it was along the top of a protruding ridge. Panhandling activity was essentially equal at all sites. The lack of mark trees near panhandler bear sites by the newer road probably relates to the bears' traditional habits.

Circumstantial evidence indicated that mark trees are frequently used for many years. Most fresh marks on the index routes (90%) were on previously marked trees. The track-like depressions in seldom used (by man) game trails and the sheer size and appearance of some mark trees and groups of mark trees also indicate a long history of marking. However, the largest mark trees, which usually have large marks, are not open to the tree's center at the mark. This would not be true if the tree had been marked frequently since the tree was small. One of the largest mark trees found (a 106 cm dbh Eastern hemlock) had a very small mark; unfortunately the tree fell the first winter. Other large mark trees had a flattened front with a bulge on the back and sides which is typically found on injured trees. Frequent marking over many years would prevent symmetric growth around the tree and predispose it to wind breakage, eliminating that type of tree. Thirty-three mark trees had broken off. Still, once marking sites are established, they are probably slow to change.

Marking Patterns

Amount.—Mark trees were numerous. In 1976, 399 mark trees were found along index routes; in 1977, 54 additional trees were found along the same routes. Five mark trees had fallen since the previous year. Of the 54 additional trees found in 1977, 12 had no signs of pre-1977 marking as did 15 mark trees found in 1976. Any type of previous injury which could not be attributed to a non-bear source was considered an indicator of previous marking.

The number of mark trees found was much more than expected. Less than 21% of the trails in the study area produced 448 standing mark trees at the end of 1977. If only half the mark trees in the study area are on manmade trails (a very conservative estimate), over 4000 mark trees are located in the study area. If one half the trees are in current use (page 55, this paper), an estimated 138 black bears (Eagar 1977) are currently using over 2000 mark trees in the study area. If most marking is done by dominant adult males (Rogers 1977), the energy and time expenditure per animal is quite large and attest to the importance of marking.

In 1976, 152 fresh marks were found on 125 different trees along index routes. Marking activity declined to 126 fresh marks on 104 trees during 1977. The difference between years in the number of fresh marks or trees prior to mid-October (Table 10) is not significant ($P > 0.05$) for the whole study area or for any individual index route. It is unlikely that the decline in marking during 1977 was due to counting 1975 marks as early 1976 marks even though mis-aging of some marks early in the study probably occurred.

Table 10. Number and percentage of fresh marks found each index route period, with cumulative totals for 1976 and 1977 in the Great Smoky Mountains National Park.

Date:	1976 ^a 8 May 16 May 1977: 8 May	25 May 20 May 22 May	5 Jun 6 Jun 8 Jun	14 Jun 22 Jun 20 Jun	3 Jul 7 Jul 5 Jul	15 Jul 21 Jul 19 Jul	30 Jul 2 Aug 29 Jul 1 Aug	13 Aug 16 Aug 12 Aug 15 Aug	28 Aug 31 Aug 25 Aug 29 Aug	11 Sep 13 Sep 9 Sep 12 Sep	25 Sep 27 Sep 23 Sep 27 Sep	9 Oct 10 Oct 7 Oct 10 Oct	1976 Total 1977
Trail													
Sugarland Mtn.	$\frac{0}{2}$	$\frac{-^b}{4}$	$\frac{4}{3}$	$\frac{1}{9}$	$\frac{2}{2}$	$\frac{0}{4}$	$\frac{20}{0}$	$\frac{0}{2}$	$\frac{0}{0}$	$\frac{1}{3}$	$\frac{0}{0}$	$\frac{1}{0}$	$\frac{29}{29}$
Elkmont-Bent Arm	$\frac{4}{5}$	$\frac{-}{6}$	$\frac{2}{3}$	$\frac{1}{2}$	$\frac{-}{0}$	$\frac{22}{0}$	$\frac{0}{2}$	$\frac{0}{1}$	$\frac{2}{0}$	$\frac{3}{1}$	$\frac{0}{0}$	$\frac{2}{0}$	$\frac{36}{20}$
Tremont-Derrick Knob	$\frac{3}{-}$	$\frac{-}{0}$	$\frac{1}{0}$	$\frac{0}{0}$	$\frac{0}{0}$	$\frac{0}{3}$	$\frac{2}{0}$	$\frac{0}{0}$	$\frac{0}{2}$	$\frac{0}{1}$	$\frac{3}{2}$	$\frac{1}{0}$	$\frac{10}{8}$
Bote Mtn. to Defcat Ridge	$\frac{8}{0}$	$\frac{-}{0}$	$\frac{16}{0}$	$\frac{1}{4}$	$\frac{0}{7}$	$\frac{0}{7}$	$\frac{1}{0}$	$\frac{1}{2}$	$\frac{0}{1}$	$\frac{0}{0}$	$\frac{1}{0}$	$\frac{0}{2}$	$\frac{28}{23}$
Defeat Ridge	$\frac{3}{3}$	$\frac{-}{5}$	$\frac{3}{11}$	$\frac{19}{2}$	$\frac{1}{2}$	$\frac{2}{1}$	$\frac{0}{5}$	$\frac{0}{1}$	$\frac{1}{2}$	$\frac{0}{0}$	$\frac{0}{0}$	$\frac{5}{2}$	$\frac{34}{34}$
Hanna Mtn.	$\frac{-}{0}$	$\frac{4}{0}$	$\frac{a}{0}$	$\frac{2}{1}$	$\frac{2}{1}$	$\frac{2}{3}$	$\frac{0}{0}$	$\frac{2}{0}$	$\frac{0}{0}$	$\frac{0}{1}$	$\frac{0}{3}$	$\frac{0}{2}$	$\frac{12}{11}$
Total	$\frac{18}{10}$	$\frac{4}{15}$	$\frac{26}{17}$	$\frac{24}{18}$	$\frac{5}{12}$	$\frac{26}{18}$	$\frac{23}{7}$	$\frac{3}{6}$	$\frac{3}{5}$	$\frac{4}{6}$	$\frac{4}{5}$	$\frac{9}{6}$	$\frac{149}{125}$
%	$\frac{12}{18}$	$\frac{3}{12}$	$\frac{17}{14}$	$\frac{16}{14}$	$\frac{3}{10}$	$\frac{17}{14}$	$\frac{15}{6}$	$\frac{2}{5}$	$\frac{2}{4}$	$\frac{3}{5}$	$\frac{3}{4}$	$\frac{6}{5}$	$\frac{100}{100}$
Cumulative total	$\frac{18}{10}$	$\frac{22}{25}$	$\frac{48}{42}$	$\frac{72}{60}$	$\frac{77}{72}$	$\frac{103}{90}$	$\frac{126}{97}$	$\frac{129}{103}$	$\frac{132}{108}$	$\frac{136}{114}$	$\frac{140}{119}$	$\frac{149}{125}$	—
Cumulative %	$\frac{12}{8}$	$\frac{15}{20}$	$\frac{32}{34}$	$\frac{48}{48}$	$\frac{52}{58}$	$\frac{69}{72}$	$\frac{85}{78}$	$\frac{87}{82}$	$\frac{89}{86}$	$\frac{91}{91}$	$\frac{94}{95}$	$\frac{100}{100}$	—
Total (1976 and 1977)	28	19	43	42	17	44	30	9	8	10	9	15	274

^a Individual index routes are deceptively clumped during 1976 since the mark trees were being located prior to mid-July that year.

^b Not hiked that period.

Management implication.—Though demonstration of a non-random decline in marking was not achieved, a one-year 17% decline (or increase) in a bear population would be quite large. Consequently some potential as a population monitor does exist. However, a longer, more intensive study correlating marking levels and population levels would be necessary before marking could be used as a population monitor. The cost of such a study, when compared against the chances of success, would be prohibitive unless solid information concerning the motivation and function of bear marking indicated a definite probability of success. In contrast to the high cost of initiating a study, the addition of a marking study to an ongoing population study would be relatively inexpensive. If conducted concurrent with an intensive telemetry study of the resident population, more detailed information on the function(s) of mark trees would result.

The declines in both fresh marks and freshly marked trees were 17%; consequently, the mark trees would not have to be checked every 2 weeks. Two other factors would be important when considering the length of time between checks. First, no marks should be completely faded. Second, the check periods should be spaced so they also monitor fluctuations in fresh marks within the year. Marking may involve several different behaviors; the ability to observe marking from these behaviors separately may be necessary to monitor the population since population changes could selectively affect the different behaviors. Experience indicates that 5 hiking periods on or about 1 May, 15 June, 1 August, 15 September, and 1 November would be sufficient in the GSMNP. With 6 well-selected 20-25 km trails, enough mark trees could be

monitored to insure an adequate sample size. Expenses would be limited to 30 man-days of labor, transportation and a limited amount of supplies annually.

Periodicity.—Fresh marks were found every index route period but 1 (Table 10); the distribution was not random (one sided K-S test, $P = 0.01$ for the value 18). During 1976, the number of fresh marks declined after 1 August; a similar decline occurred 2 weeks earlier in 1977 (Table 10). In 1977 the number of fresh marks after 2 August did not differ from the number prior to that date (one-sided Z-test, Hays 1973: 724, $P > 0.05$). However, the number of fresh marks found between 20 May and 2 August (inclusive) was greater than the number found before and after that period ($P < 0.05$). Aruns above and below the median test over time for all trails indicated that the marking was clustered prior to mid-July during 1977 ($P = 0.002$).

Individual index routes with greater than 15 fresh marks per year exhibited a slightly different pattern; the marking frequency was low every index route weekend but 1, (sometimes 2) (Table 10). When marking frequency peaked on 2 weekends, the peaks were smaller and consecutive. Peaks occurred at different times on different routes. Bears in different areas apparently respond to different levels of factors initiating marking, or the levels or factors themselves vary.

Form and Function

Mechanics of marking.—Marking is primarily associated with glandular scent deposition. Consequently, the apparent lack of external

scent glands should be of paramount importance in the development of marking behaviors in bears. The ability to perceive and distinguish non-chemical signals should also be important. These ideas are important in the conceptualization of a combined visual and chemical marking system.

Obviously, mark trees contain both visual and chemical signalling capacities. Bacon (1973) reported that black bears possess excellent visual acuity of both hue and shape. Rogers (1977) reported that he could distinguish the odor of bear on a recently marked mark tree, and Tschanz et al. (1970) noted that captive brown bears sniffed each others marks. It then seems likely that (1) bears are well equipped to perceive both chemical and visual signals, and (2) both types of signals are present at mark trees.

Why are there 2 signals? Ewer (1973: 242) suggested that visual and chemical signals used together may complement each other. Rogers (1977) suggested that the elevated mark would help disperse the scent and that the tree's sap may help in retention of scent. It is also possible that 1 signal (potentially either, but most likely the visual one) simply designates the location of the other signal. Regardless of the specific information available at a mark tree, 2 modes (chemical and visual) of information transmission are available and perceptible to the bear; consequently, both modes are likely to be in use.

In order to leave a signal on a mark tree, bears assume specific postures and engage in specific behaviors, i.e., rubbing, biting, and clawing (Tschanz et al. 1970, Rogers 1977). These postures and behaviors have special significance in the development of marking. Ewer (1968)

stated that marking glands should develop in areas already having contact with the environment. The dorsum of the body is the most difficult for a bear to reach with its paws and mouth and is the most likely to be rubbed on other objects as a form of allogrooming (Jordan 1979). This portion would then be the most likely to be used in marking. Tschanz et al. (1970) reported just that; however, most portions of the body were rubbed at times. The apparent absence of a marking gland should again be emphasized, and it should also be noted that in the process of biting and clawing trees, saliva or an unfound inter-digitary gland (Jordan 1979) may come into function.

Function.—Though most authors now refer to behaviors associated with bear mark trees (or some artificial substitute) as marking behaviors (Meyer-Holsapfel 1957, Tschanz et al. 1970, Rogers 1977, and Jordan 1979), some skeptics may remain. Rogers (1977) stated that proposed non-marking functions failed to account for sex- and age-related differences in the frequency of the behavior. A more convincing case can be made by comparing characteristics of bear marking with pattern of marking in species with identified scent glands and well known marking repertoires.

Thiessen and Rice (1976) noted 8 characteristics of marking in 12 diverse species. Table 11 demonstrates that bears are not known to violate any of the characteristics and satisfy most of them. (Only one of the 12 species satisfied all 8 characteristics.) Such strong agreement should silence the most stubborn skeptics without evidence to the contrary.

Table 11. A comparison of the characteristics of bear marking with the marking characteristics of other mammalian species.

Characteristic of marking reported in several mammals	Agreement	Source and discussion
Sexually dimorphic	yes	Tschanz et al. 1970, Rogers 1977.
Age dependent	yes	Tschanz et al. 1970, Rogers 1977.
Seasonal development	yes	Tschanz et al. 1970, Rogers 1977, this paper.
Circadian	no information	
Dominance related	possibly	Rogers 1977; scant positive data, but no negative data.
Stimulated by aggression	yes	Rogers 1977, Jane Tate-Eager 1979 (per communication).
Stimulated by sex	no positive information	Lack of positive information could be construed as negative data.
Androgen dependent in males	probably	No laboratory data, but Rogers (1977) reported that male black bears marked most during the time that serum testosterone levels were the highest.

Given that bear marking is a form of social communication, a wide range of possible functions remain. Ewer (1968: 104-105) describes how an animal's own scent scattered throughout its home range can become a signal of ownership, reassuring the owner and even threatening transients and neighbors. Hornocker (1967) reported a mutual avoidance system in mountain lions (Felis concolor) probably involving the use of scrapes. Eaton (1970) demonstrated the use of a "moving territory" demarcated by urine scent marks in the cheetah (Acinonyx jubatus). Rogers (1977), noting Hornocker, Eaton, and other authors, proposed that dominant male bears in aggressive moods mark trees so that other males could better avoid mutually damaging conflicts.

While an avoidance system may be present in black bear populations, it seems unlikely that the primary function is reduction of conflicts; other factors must be considered. Hornocker (1967) and Eaton (1970) both noted that mutual avoidance would decrease the chance of interfering with other group's or individual's hunting and vice versa. Peters and Mech (1975) stated that marking and mutual avoidance by individuals from a wolf pack during the summer while pack members are frequently separated would increase the hunting efficiency of the pack and of individuals. This would also be true for species with overlapping home ranges such as the bear, cheetah, and mountain lion. One bear following another would most likely have a reduced foraging efficiency as would the whole population. The improved population foraging strategy resulting from mutual avoidance would allow a greater population reserve of immatures and transients, and it would increase the interspecific fitness (competitive ability) of the species in the consumption of scarce

resources. Obviously, mutual avoidance has more benefits than the reduction of conflict.

If an avoidance system is present in black bear populations, and some type of avoidance must be present in solitary species, the avoidance system does not operate near estrus females, garbage dumps, or other scarce desiderata. At these resources, contest and dominance determine access (Rogers 1977). It was near these resources that Rogers (1977) reported the most conflict and marking. It seems contradictory that the proposed mechanism of avoidance (marking trees) should increase where it is not operating or, alternatively, simply does not function properly.

Despite the somewhat theoretical arguments given above, it must be noted that there are no data to indicate that bear marking does not reduce conflict in a population. There are some data to indicate that other factors may be important, particularly prior to and during the breeding season.

This study, Tschanz et al. (1970), and Rogers (1977) have all shown that marking frequency is greatest prior to and during the breeding season. Tschanz et al. (1970) and Rogers (1977) both demonstrated that marking was done by adult male bears. Rogers (1977) speculated that the natural selection for the scent (presumably at mark trees) of mature male bears to promote estrus, thus synchronizing it with the male's presence, should be strong. This may well be happening; however, data are scant and the evidence is circumstantial.

First, the above hypothesis would better explain the high marking frequency several weeks prior to the breeding season. Second, in the GSMNP marking within 1 km (along the trail) of capture sites of estrus

females (based on swollen vulva) occurred several weeks prior to estrus (capture data). This was true for 4 females captured in 1976 and 1977. (For 1 of these females, only 1 mark tree had been marked by a bear within 1 km, but someone had blazed 13 trees along the trail in the vicinity of her capture site 1 month prior to her capture. Mark trees slightly greater than 1 km from the capture site had also been marked several weeks prior to the female's capture.) No further intensive marking occurred along index routes near any of the capture sites.

Female marking and late season marking remain unexplained.

Tschanz et al. (1970) found that female marking peaked at the end of the moult. Rogers (1977) only observed 3 incidents of female marking, all in late summer or early fall. Widespread movement by black bears in the GSMNP occurs in late summer and early fall in response to the mast crop (Beeman 1975, Garshelis 1978). Marking is known to increase in several species upon introduction into novel areas (Ralls 1971). Marking may be of use in orientation during visits to novel or rarely visited areas. While it is unlikely than an animal with the homing ability of black bears (Payne 1975, Beeman and Pelton 1976) would be lost, the use of the trees for orientation could increase the bears' orienting ability in new areas. Tschanz et al. (1970) reported that captive brown bears used their marks as part of a spacial relations system. Perhaps future studies can associate high fall marking with low fall food availability. Though mast was relatively abundant over most of East Tennessee in both 1976 and 1977, mast, particularly from white oaks, was more abundant in 1977 (Tennessee Wildlife Resources Agency 1977). Marking after mid-September was greater in 1976 even though some index routes were hiked an extra time in December 1977.

Though obviously inconclusive, the arguments presented above demonstrate that alternative hypotheses are plausible, and that hypotheses primarily based on assumed aggression are not necessarily valid. Similar arguments and implications can be made regarding marking by other carnivores.

As a final note, 4 hypotheses regarding the function of bear marking were discussed above; others, either modifications of the above or completely new, could be construed. Any, all, or several could eventually be demonstrated as close to fact.

Multivariate and Multiple Regression Analyses

Physiognomic parameters measured around mark trees were extremely variable (Table 22, Appendix). Individual logical analysis of the parameters was not successful; multivariate analysis was then attempted.

Factor analysis.—Initially, factor analysis reduced the 22 selected variables to 9 factors (Table 12); however, several factors were uninterpretable due to the unlikely combinations of variables most strongly correlated with the various factors. Removal of 5 variables (noted with the subscript a in Table 12) reduced the number of factors to 6 and allowed limited interpretation of the factors (Tables 13 and 14).

Factor 1, consisting largely of vegetation parameters, accounted for 34.5% of the variation. Factor 2, essentially elevation, accounted for an additional 21.7% of the variation. Factor 3, vegetation density, accounted for 14% of the variation. The first 3 factors combined accounted for 70.2% of the variation. Factor 4, consisting of

Table 12. Factor pattern matrix giving correlations between variables and factors after nearly orthogonal rotation of the factor axis.

Factor/Variable	1	2	3	4	5	6	7	8	9
DISTANCE	-0.18	0.14	0.15	-0.05	0.73	0.25	0.02	-0.07	0.03
ELEVATION	0.26	-0.77	-0.17	0.24	-0.05	0.12	-0.08	-0.02	-0.18
DISTANCE TO RIDGE TOP	-0.01	-0.00	0.15	-0.10	0.29	-0.51	-0.16	0.05	-0.08
SPECIES	0.46	0.62	-0.13	0.14	0.01	0.01	0.01	-0.04	0.08
WIDTR	0.33	-0.20	0.09	0.09	0.16	0.38	0.07	-0.02	-0.20
GENUS	-0.72	-0.42	0.03	-0.10	-0.06	-0.14	0.17	0.13	0.11
LIVE	-0.10	-0.01	0.28	0.31	-0.16	0.33	-0.05	0.22	0.01
HIKER VALUE	0.21	-0.02	-0.03	-0.10	0.22	0.39	0.09	-0.12	0.01
DOMINANCE	-0.05	0.32	0.29	0.65	-0.14	0.10	0.10	0.23	-0.09
STEM COUNT OF SMALL GYMNOSPERMS	0.30	-0.29	0.07	-0.17	-0.18	0.02	0.31	-0.22	-0.04
STEM COUNT OF ANGIOSPERMS	0.03	0.11	-0.69	0.56	-0.03	-0.08	0.03	-0.11	0.21
BASAL AREA OF GYMNOSPERMS	0.38	-0.12	0.14	-0.02	-0.01	0.10	0.57	-0.23	-0.11
BASAL AREA OF ANGIOSPERMS	-0.29	-0.10	0.03	-0.18	0.08	0.15	-0.32	0.23	0.26

Table 12 (continued)

Factor/Variable	1	2	3	4	5	6	7	8	9
SLOPE OF TRAIL ^a	-0.08	-0.04	-0.03	0.33	0.15	-0.05	0.27	-0.05	0.17
STEM COUNT OF SMALL ANGIOSPERMS	0.00	0.56	-0.12	-0.37	-0.22	0.16	0.20	0.18	0.12
STEM COUNT OF LARGE GYMnosperms	0.02	0.08	-0.13	-0.05	0.15	0.18	0.59	0.02	-0.18
STEM COUNT OF LARGE ANGIOSPERMS ^a	-0.05	0.01	-0.31	0.03	0.15	-0.10	-0.15	0.31	-0.05
STEM COUNT OF GYMNOSPERMS ^a	0.11	0.04	0.23	-0.00	-0.13	-0.02	0.21	-0.12	-0.25
UPDOWN ^a	0.13	-0.02	0.15	0.07	-0.02	0.03	0.05	0.45	0.11
ASPECT ^a	0.11	-0.03	0.04	-0.01	0.02	0.05	-0.02	-0.07	0.61
SLOPE OF GROUND	0.22	-0.13	0.20	0.01	0.36	-0.44	0.16	0.46	0.19
DBH	0.09	0.22	0.69	0.20	-0.03	-0.05	-0.00	-0.19	0.06

^aThese variables were removed for later factor analysis.

Table 13. Factor pattern matrix giving correlations between variables and factors after nearly orthogonal rotation of the factor axis.

Variable/Factor	1	2	3	4	5	6
DISTANCE	-0.23	0.09	0.13	-0.04	0.26	0.54
ELEVATION	0.21	-0.79	-0.18	0.04	-0.11	0.05
DISTANCE TO RIDGE TOP	0.05	0.00	0.10	-0.22	0.68	-0.10
SPECIES	0.39	0.63	-0.24	0.19	0.05	0.15
WIDTH OF TRAIL	0.20	-0.27	0.07	0.16	-0.14	0.47
GENUS	-0.48	-0.34	0.10	-0.16	0.04	-0.24
LIVE	-0.23	-0.10	0.09	0.56	-0.12	0.05
HIKER VALUE	0.03	0.00	-0.01	-0.04	-0.17	0.55
DOMINANCE	0.10	0.12	0.05	0.82	0.05	-0.10
STEM COUNT OF SMALL GYMNOSPERMS	0.49	-0.23	0.20	-0.20	-0.31	0.01
STEM COUNT OF ANGIOSPERMS	0.09	0.02	-0.82	0.20	0.10	-0.04
BASAL AREA OF GYMNOSPERMS	0.68	-0.13	0.22	-0.01	-0.23	0.27
BASAL AREA OF ANGIOSPERMS	-0.63	-0.01	0.01	-0.07	0.08	-0.01
STEM COUNT OF SMALL ANGIOSPERMS	-0.08	0.64	0.06	-0.10	0.32	-0.01
STEM COUNT OF LARGE GYMNOSPERMS	0.25	0.04	0.00	-0.04	-0.14	0.36
SLOPE OF GROUND	0.04	-0.04	0.12	0.02	0.54	0.06
DBH	0.24	0.17	0.49	0.39	0.10	-0.07

Table 14. Eigenvalues^a and percentage of variation explained by the factors resulting from factor analysis of 17 selected variables measured around the 78 intensively sampled mark trees.

Factor	Eigenvalue	Percentage of variation	Cumulative percentage of variation
1	3.09	34.5	34.5
2	1.94	21.7	56.2
3	1.25	14.0	70.2
4	1.17	13.1	83.3
5	0.78	8.7	92.0
6	0.72	8.0	100.0

^aThe eigenvalue may be interpreted as the variance of the factor.

measurements of the mark tree itself, accounted for 13.1% of the variation. Factor 5, the topographic position of the mark tree, accounted for 8.7% of the variation. Factor 6, either visitor or bear use, accounted for the remaining 8% of the variation.

Prediction of time of marking.—Since trees were marked every index route weekend but 1, it would be interesting to delineate what determined when the trees were marked. In an attempt to measure the extent to which the environment affected the index period marked, stepwise regression was attempted.

Stepwise multiple regression of 31 marking incidents with TIME OF MARKING as the dependent variable indicates that the time of marking for a tree can be predicted using the parameters measured around the set of intensively sampled trees as the independent variables.

The combination of 11 variables given in Table 15 was judged "best" based on the r^2 value (0.68) and the probability of no linear relationship (0.0064). Using more variables slightly increased r^2 to 0.71 for 22 variables, but the probability of no linear relationship increased with each additional variable.

If fewer variables to be measured are desired, the next "best" model used only the 5 variables given in Table 16. The r^2 value was 0.58 and the probability of no linear relationship was 0.0003.

While a relationship between environmental parameters and the time of marking does exist, it may be an indirect one which actually predicts which sites best fulfill a marking bear's environmental requirements at a specific time during the active season. Though the

Table 15. The best 11 variables, their b values, and the probability of no linear relationship for each variable, as ascertained by stepwise regression for the time of marking.

Variable	b value	Prob > F
INTERCEPT	16.26	—
BASAL AREA OF ANGIOSPERMS	-0.36	0.07
DISTANCE TO RIDGE TOP	0.03	0.01
SLOPE OF GROUND	-0.22	0.01
ASPECT	0.91	0.01
GENUS	-0.10	0.25
DOMINANCE	-0.60	0.10
WIDTH OF TRAIL	-0.04	0.00
SLOPE OF TRAIL	-0.95	0.01
LIVE	-2.78	0.15
STEM COUNT OF LARGE ANGIOSPERMS	0.31	0.17
UPDOWN	0.89	0.32

Table 16. The best 5 variables, their b values, and the probability of no linear relationship for each variable, as ascertained by stepwise regression for the time of marking.

Variable	b value	Prob > F
INTERCEPT	15.05	—
STEM COUNT OF ANGIOSPERMS	-0.03	0.02
SLOPE OF GROUND	-0.12	0.03
GENUS	-0.18	0.01
WIDTH OF TRAIL	-0.04	0.00
SLOPE OF TRAIL	-0.27	0.12

indirect relationship is more logical than proposing a direct relationship between the time of marking and site characteristics, the actual parameters used in the regression do not support the proposition (Tables 15 and 16). The best 5-variable model has only 1 site parameter. The first 2 variables entered in the stepwise regression were the width and slope of the trail. Still, it is hard to understand how the characteristics of a mark tree and its site directly affect the time of year that a particular tree is marked.

Discrimination between current and old trees.—During late summer of 1975, 51 mark trees were located along Sugarland Mountain Index Route, and all recent marking activity was noted. Two of the trees fell prior to 1977. Consequently 3 years' marking activity was collected for 49 previously marked trees. During 1975, 13 of these trees were marked. During 1976, 11 of the original 49 trees were marked; 6 of these 11 had not been marked during 1975. During 1977, 13 of the original 49 trees were marked; 3 of these 13 had not been marked during 1975 or 1976. By linear extrapolation, all non-new mark trees in current use should be located in 4 or possibly 5 years with approximately 50% of the trees being used. This is assuming that values of the factors and the factors controlling which trees are marked will remain constant. Since 50% of the trees were not being used, the assumption may not always be valid. However the data indicated that the factors remained stable for the 3 years the trees were observed.

Stepwise multiple regression and discriminant function analysis were used to distinguish between "current" and "old" mark trees within

the set of intensively sampled trees based upon the parameters measured around them.

Stepwise regression yielded questionable results. Using all 22 variables, the maximum r^2 value obtained was only 0.36 (Table 17). The probability of no linear relationship was 0.18. However, discriminant function analysis was still attempted using 3, 4, 6, 9, 10, 11, 12, 17, 19, and 22 variables on 13 attempts. Discrimination was much more successful than one would have predicted from stepwise regression.

Using all 22 variables, only 2 of 77 trees were misclassified (Table 18). Reduction of the number of variables used resulted in an increase in misclassified trees. Using only 3 variables (BASAL AREA OF GYMNOSPERMS, DISTANCE, WIDTH OF TRAIL) 29 of 78 trees were misclassified (Table 19). Intermediate numbers of variables resulted in intermediate numbers of mistakes (Figure 9). Most mistakes were from placing un-re-marked trees into the re-marked group. This was expected since most of the intensively samples trees were observed for only 2 years.

Tschanz et al. (1970) found that some rubbing places remained the same throughout the study while others were used for only a day or some intermediate time. The captive bears had a strong attraction for certain well used rubbing places and attempted to use them even when changes in the pit prevented rubbing in the old places. Similar results occurred from the experimental moving of spotted hyena (Crocuta crocuta) and civit (Civetictis civetta) defecation marking sites (Bearden and Randall 1978). In this study some trees were marked every year observed some were marked once and others which had obviously been marked many times were not marked during the study (Table 22, Appendix). Bearden

Table 17. Stepwise regression model for discriminant function analysis of current and old mark trees using 22 variables.

Variable	b value	Prob > F
INTERCEPT	0.347	—
STEM COUNT OF GYMNOSPERMS	-0.032	0.12
BASAL AREA OF GYMNOSPERMS	-0.045	0.10
STEM COUNT OF ANGIOSPERMS	-0.002	0.12
BASAL AREA OF ANGIOSPERMS	-0.007	0.69
DBH	0.002	0.92
DISTANCE	-0.001	0.11
DISTANCE TO RIDGE TOP	-0.001	0.43
ELEVATION	-0.000	0.87
SLOPE OF GROUND	-0.004	0.42
ASPECT	0.030	0.29
GENUS	0.011	0.43
SPECIES	0.001	0.67
DOMINANCE	0.026	0.64
WIDTH OF TRAIL	0.003	0.17
SLOPE OF TRAIL	0.015	0.47
LIVE	0.163	0.32
HIKER VALUE	-0.014	0.82
STEM COUNT OF SMALL ANGIOSPERMS	-0.001	0.35
STEM COUNT OF SMALL GYMNOSPERMS	0.039	0.29
STEM COUNT OF LARGE GYMNOSPERMS	-0.022	0.57
STEM COUNT OF LARGE ANGIOSPERMS	-0.005	0.77
UPDOWN	0.053	0.54

Table 18. Number of trees classified as re-marked and not re-marked based upon field observations and discriminant function analysis using 22 variables.

		Predicted group		Total
		Not re-marked	Re-marked	
Actual group	Not re-marked	44	1	45
	Re-marked	1	31	32

Table 19. Number of trees classified as re-marked and not re-marked based upon field observations and a discriminant function analysis using 3 variables.

		Predicted group		Total
		Not re-marked	Re-marked	
Actual group	Not re-marked	23	22	45
	Re-marked	7	26	33

Figure 9. Comparison of number of variables and number of mistakes in discriminant function analysis of current and old mark trees.

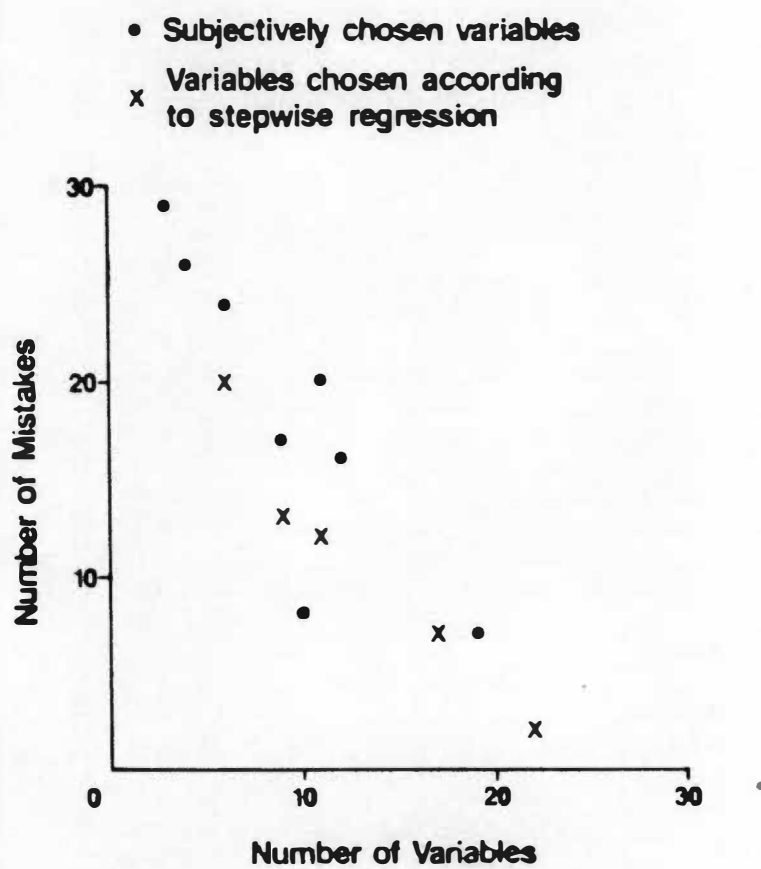


Figure 9

and Randall (1978) also reported different marking rates at different sites.

Changes in the members of a bear population are the most likely factor causing changes in the trees marked. However, there is no logical reason for those changes to be consistently reflected in the parameters around mark trees over a large area.

Changes in the vegetation will also occur around and to a mark tree. The first factor extracted in the 17 variable factor analysis most strongly correlated with vegetation parameters. Vegetation parameters were also the first variables chosen during stepwise regression analysis of current and old trees. Three of the first 4 and 5 of the first 7 variables chosen were vegetation variables.

Synthesis of the multivariate analyses.—The combined results of the multivariate and multiple regression analyses demonstrate that the environment significantly affects marking behavior and that we can predict the extend of that effect to a known degree. However, the analyses have only slightly elucidated which environmental factors are responsible. First, no 1 or 2 variables explained a large amount of variation in the analyses. Secondly, the analyses differ as to which variables were more important. That is, variables with higher b values in the stepwise regressions are most strongly correlated with the latter factors extracted in the factor analysis (Tables 12 and 13, pages 48 and 50; Tables 15-17, pages 53, 54, and 57). And third, no group of variables such as site, vegetation, trail, or mark tree variables tended to be disproportionately used in the analyses although vegetation variables were implicated somewhat more than the other groups.

V. SUMMARY AND CONCLUSIONS

Within the GSMNP, 691 mark trees were located; 8 different coniferous and 26 different hardwood species were marked. Preference and availability apparently determined the species marked.

The marks were centered at approximately 1.6-1.7 m above the ground, and they generally faced the trail and up the slope. The size of the mark varied with the age and intensity of the mark and the size and species of the mark tree. The use of an optical mark in addition to a scent mark would aid in the location of the mark by the bears.

All mark trees were found adjacent or near some type of trail. Abandoned manmade trails and ridge tops had more mark trees per km searched than any other type of trail. This corresponds to the high scat incidence found along abandoned trails (Matthews 1977). The location of mark trees along trails would increase the efficiency of a communication system involving mark trees. The distribution of mark trees along trails appeared clumped, but this could not be statistically substantiated.

Mark trees were also located around panhandler bear sites along Park roads. Sites along older roads yielded many more mark trees than those along newer roads. Most fresh marks were on previously marked trees, and track-like depressions in the duff frequently lead up to mark trees in areas undisturbed by man. In addition, some mark trees had obviously been marked for many years. It appears that marking sites are traditional and are slow to change.

Thirty-one percent and 23% of the mark trees along index routes were marked fresh during 1976 and 1977, respectively. Though the difference was not significant, a potential as a population monitor does exist, and a study could be incorporated into an ongoing populations study at minimal additional cost.

Fresh marks were found during every index route period but one; most marking occurred between 1 May and 2 August. Marking on individual index routes peaked on 1 or 2 (consecutive) periods. Peaks occurred at different times on different routes. Bears in different areas apparently respond to different levels of the factors initiating marking, or the levels or factors themselves vary over space and/or time. Fall marking patterns were nebulous, but a small increase in marking did occur. It was asserted that marking prior to and during the breeding season could help synchronize estrus with the presence of adult males and that fall marking could be the result of widespread black bear movements during the fall.

Stepwise regression and discriminant function analysis indicated that physiognomic parameters on and around mark trees affect both which mark trees are re-marked and the time of year that the trees are marked. The function of such a relationship was undetermined.



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APPENDIX

Table 20. The mean, standard deviation, minimum measurement, maximum measurement (cm), and sample size of mark tree and mark parameters by species in the Great Smoky Mountains National Park.

	Height to scar (cm)	Length of scar (cm)	Width of scar (cm)	Percentage circumference	Dbh	Dominance
<u>Eastern hemlock</u>						
$\bar{X}$	107	118	49	46	37	2.3
$S_{\bar{x}}$	31.7	47.1	28.8	21	20.2	1.5
Min	0	32	8	3	5	0
Max	150	279	154	100	106	4
n	58	58	58	57	60	59
<u>Table mountain pine</u>						
$\bar{X}$	121	52	26	63	17	2.4
$S_{\bar{x}}$	33.3	28.2	13.7	31.9	11.6	1.6
Min	36	11	6	7	4	0
Max	160	135	57	100	51	4
n	32	32	32	32	31	32
<u>Fraser fir</u>						
$\bar{X}$	115	99	36	47	27.1	2.1
$S_{\bar{x}}$	32.8	63	19.3	27.5	13.5	1.4
Min	29	27	5	8	9	0
Max	221	245	73	100	62	4
n	29	29	29	29	28	29
<u>Red spruce</u>						
$\bar{X}$	109	120	42	51	30	2.7
$S_{\bar{x}}$	27.7	43.8	22.8	25.5	17.4	1.4
Min	67	47	8	17	8	0
Max	183	187	102	100	80	4
n	22	22	21	21	23	23
<u>Pitch pine</u>						
$\bar{X}$	147	47	29	36	26	3.4
$S_{\bar{x}}$	14	27.2	18	20.2	7.8	0.7
Min	103	4	4	3	12	2
Max	168	122	78	87	44	4
n	22	22	22	22	22	22

Table 20 (continued)

	Height to scar (cm)	Length of scar (cm)	Width of scar (cm)	Percentage circumference	Dbh	Dominance
<u>Virginia pine</u>						
$\bar{X}$	142	49	32	41	24	3.3
$S_{\bar{X}}$	11.9	20.7	15.4	16.2	8.3	0.7
Min	107	15	15	13	16	2
Max	156	90	66	68	44	4
n	12	12	12	12	12	12
<u>White pine</u>						
$\bar{X}$	141	54	17	27	19	1.9
$S_{\bar{X}}$	24	35	8.7	14.9	11.6	1.2
Min	106	10	3	11	6	1
Max	189	124	32	51	46	4
n	11	11	11	11	10	11
<u>All gymnosperms</u>						
$\bar{X}$	121	84	37	49	28	2.5
$S_{\bar{X}}$	31.2	51.8	23.2	26.3	16.5	1.4
Min	0	4	3	3	4	0
Max	221	279	154	100	106	4
n	205	205	203	202	204	206
<u>Sweet birch</u>						
$\bar{X}$	149	27	22	44	15	2.3
$S_{\bar{X}}$	14.9	18.1	13.5	24.4	5.5	1.2
Min	94	4	4	7	5	0
Max	170	84	70	100	29	4
n	44	44	44	44	43	44
<u>Red maple</u>						
$\bar{X}$	134	62	15	32	15	2.3
$S_{\bar{X}}$	24	31.3	11.4	18.6	9.7	1.3
Min	90	14	3	6	4	0
Max	169	116	52	77	50	4
n	29	29	29	29	29	28
<u>Yellow birch</u>						
$\bar{X}$	146	33	17	46	9	2.2
$S_{\bar{X}}$	13.6	17.7	12.2	25.3	4.7	1.2
Min	115	10	3	13	4	1
Max	167	58	36	78	19	4
n	11	10	11	11	18	18

Table 20 (continued)

	Height to scar (cm)	Length of scar (cm)	Width of scar (cm)	Percentage Circumference	Dbh	Dominance
<u>American beech</u>						
$\bar{X}$	147	29	17	38	15	1
$S_{\bar{X}}$	19.9	23.4	13.2	32	7.2	0.6
Min	108	5	6	9	6	0
Max	167	68	44	100	24	2
n	7	6	7	7	7	7
<u>Fire cherry</u>						
$\bar{X}$	142	32	25	47	17	2.4
$S_{\bar{X}}$	17.1	23.7	8.8	26.9	8.8	1.7
Min	108	6	11	21	4	0
Max	165	86	42	100	31	4
n	12	12	12	12	14	15
<u>Silverbell</u>						
$\bar{X}$	152	33	17	32	15	1.9
$S_{\bar{X}}$	16.4	16.2	11.2	20.5	5.6	1.1
Min	114	15	4	7	7	1
Max	175	62	40	75	26	4
n	13	12	12	12	13	13
<u>Sugar maple</u>						
$\bar{X}$	147	32	14	26	15	1.4
$S_{\bar{X}}$	25.9	16.1	13.3	15	10.7	0.7
Min	83	7	2	6	2	1
Max	177	53	44	49	31	3
n	10	10	8	8	10	10
<u>Sourwood</u>						
$\bar{X}$	144	36	21	57	12	1.4
$S_{\bar{X}}$	20.7	14.1	7.5	22.7	6.8	1
Min	101	15	5	31	5	0
Max	172	55	32	100	22	3
n	9	9	9	9	7	9
<u>All angiosperms</u>						
$\bar{X}$	143	41	19	41	15	2.1
$S_{\bar{X}}$	20.4	27.8	12.4	24.2	8.1	1.3
Min	75	4	2	6	2	0
Max	177	142	70	100	50	4
n	181	176	176	176	187	191

Table 20 (continued)

	Height to scar (cm)	Length of scar (cm)	Width of scar (cm)	Percentage circumference	Dbh	Dominance
	<u>All mark trees</u>					
$\bar{X}$	131	64	29	45	21	2.3
S_x	28.7	47.5	20.9	25.6	14.7	1.4
Min	0	4	2	3	2	0
Max	221	279	154	100	106	4
n	386	381	379	378	391	397

Table 21. Frequency of mark trees and fresh marks by species for 1975, 1976, and 1977 along index routes in the Great Smoky Mountains National Park.

Species or group	Frequency of species or group, 1977	Frequency of species or group, 1976	Frequency of species or group, 1975	# fresh any 2 years
	# fresh marked, 1977	# fresh marked, 1976	# fresh marked, 1975	
Eastern hemlock (<u>Tsuga canadensis</u>)	60/7	59/13	20/1	4
Table mountain pine (<u>Pinus pungens</u>)	32/10	32/13	1/1	9
Fraser fir (<u>Abies fraseri</u>)	29/2	28/1	9/1	1
Red spruce (<u>Picea rubens</u>)	25/8	22/7	5/1	6
Dead spruce or fir	3/0	3/0	1/0	0
Pitch pine (<u>Pinus rigida</u>)	23/5	21/8	7/4	5
Virginia pine (<u>Pinus virginiana</u>)	16/1	10/0	0	0
<u>Pinus</u> sp. (unidentified yellow pine)	13/1	17/4	5/2	2
White pine (<u>Pinus strobus</u>)	11/2	10/1	0	0
Shortleaf pine (<u>Pinus echinata</u>)	1/0	1/0	0	0
All pines combined	96/19	91/26	13/7	16
All gymnosperms	213/36	203/47	48/10	27
Sweet birch (<u>Betula lenta</u>)	46/9	48/23	4/0	5

Table 21 (continued)

Species or group	Frequency of species or group, 1977	Frequency of species or group, 1976	Frequency of species or group, 1975	# fresh any 2 years
	# fresh marked, 1977	# fresh marked, 1976	# fresh marked, 1975	
Red maple (<u>Acer rubrum</u>)	36/10	31/8	14/1	5
Yellow birch (<u>Betula allegheniensis</u>)	28/11	17/7	0	4
American beech (<u>Fagus grandifolia</u>)	17/5	8/5	0	1
Fire cherry (<u>Prunus pennsylvanica</u>)	16/3	14/2	1/1	2
Silverbell (<u>Halesia carolina</u>)	15/6	13/8	1/0	4
Sugar maple (<u>Acer saccharum</u>)	13/4	10/4	1/0	1
Sourwood (<u>Oxydendrum aboreum</u>)	10/1	9/0	1/0	0
Striped maple (<u>Acer pennsylvanicum</u>)	8/6	5/4	0	3
Fraser magnolia (<u>Magnolia fraseri</u>)	7/1	7/2	0	1
Northern red oak (<u>Quercus rubra</u>)	6/2	4/2	2/2	1
Yellow buckeye (<u>Aesculus octandra</u>)	6/10	5/3	0	0
<u>Sumac</u> sp.	5/3	4/4	0	2

Table 21 (continued)

Species or group	Frequency of species or group, 1977	Frequency of species or group, 1976	Frequency of species or group, 1975	# fresh any 2 years
	# fresh marked, 1977	# fresh marked, 1976	# fresh marked, 1975	
Black locust (<u>Robinia pseudoacacia</u>)	3/2	3/2	0	2
Yellow poplar (<u>Liriodendron tulipifera</u>)	3/1	3/0	0	0
Chestnut oak (<u>Quercus prinus</u>)	2/0	2/0	1/0	0
Sassafras (<u>Sassafras albidum</u>)	2/0	2/0	0	0
<u>Amelanchier</u> sp.	3/0	2/0	0	0
Black cherry (<u>Prunus serotina</u>)	1/1	1/1	0	1
Devil's walking stick (<u>Aralia spinosa</u>)	1/1	1/0	0	0
Nine bark (<u>Physocarpus opulifolius</u>)	1/1	0	0	1
Scarlet oak (<u>Quercus coccinea</u>)	1/1	0	0	0
Big leafed magnolia (<u>Magnolia macrophylla</u>)	1/0	1/0	0	0
Mountain maple (<u>Acer spicatum</u>)	1/0	1/0	0	0
<u>Fraxinus</u> sp.	1/0	1/1	0	0
Unidentified hardwood	2/0	2/0	0	0

Table 21 (continued)

Species or group	Frequency of species or group, 1977 # fresh marked, 1977	Frequency of species or group, 1976 # fresh marked, 1976	Frequency of species or group, 1975 # fresh marked, 1975	# fresh any 2 years
All angiosperms	235/68	196/77	26/4	33
Total	448/104	399/124	74/14	60

Table 22. The mean, standard deviation, minimum measurement, maximum measurement, and sample size of parameters at mark trees in the Great Smoky Mountains National Park.

	ELEVATION (m)	SLOPE OF GROUND (degree)	ASPECT (degree)	DISTANCE (m)
<u>Eastern hemlock</u>				
$\bar{X}$	1251	21	197	183
$S_{\bar{x}}$	221.9	10.5	85.5	242.3
Min	610	0	0	3
Max	1539	41	346	999
n	60	56	57	59
<u>Table mountain pine</u>				
$\bar{X}$	1108	14	141	58
$S_{\bar{x}}$	215.8	12.6	133.6	127.7
Min	549	0	0	1
Max	1396	40	360	600
n	32	32	31	32
<u>Fraser fir</u>				
$\bar{X}$	1704	17	213	38
$S_{\bar{x}}$	43	8.7	107.2	43.9
Min	1615	0	0	2
Max	1798	35	355	200
n	30	28	28	28
<u>Red spruce</u>				
$\bar{X}$	1620	20	213	98
$S_{\bar{x}}$	107.	8.2	95.1	163.5
Min	1341	2	0	0
Max	1795	34	355	800
n	25	23	23	25
<u>Pitch pine</u>				
$\bar{X}$	935	20	191	109
$S_{\bar{x}}$	150.6	9.1	62.2	207.9
Min	549	5	76	1
Max	1189	40	348	999
n	23	22	22	23
<u>Virginia pine</u>				
$\bar{X}$	667	17	92	183
$S_{\bar{x}}$	115.5	14.6	98.5	334
Min	549	0	0	5
Max	1067	36	277	999
n	16	12	11	16

Table 22 (continued)

	ELEVATION (m)	SLOPE OF GROUND (degree)	ASPECT (degree)	DISTANCE (m)
<u>White pine</u>				
$\bar{X}$	739	15	213	111
$S_{\bar{x}}$	153.9	10.3	103	119.2
Min	533	0	2	5
Max	884	29	357	400
n	11	11	11	11
<u>All gymnosperms</u>				
$\bar{X}$	1217	18	186	124
$S_{\bar{x}}$	366.1	10.5	104	215.3
Min	533	0	0	0
Max	1798	41	360	999
n	217	206	201	214
<u>Sweet birch</u>				
$\bar{X}$	1184	26	182	73
$S_{\bar{x}}$	167.9	13.6	94.7	147.6
Min	960	4	2	1
Max	1539	90	354	999
n	48	43	42	48
<u>Red maple</u>				
$\bar{X}$	1279	19	164	44
$S_{\bar{x}}$	159.4	10.3	92.3	44.6
Min	869	0	0	0
Max	1585	40	351	200
n	36	30	29	36
<u>Yellow birch</u>				
$\bar{X}$	1420	13	147	65
$S_{\bar{x}}$	216	10	64.6	133.7
Min	805	2	45	5
Max	1646	34	251	600
n	28	18	18	27
<u>American beech</u>				
$\bar{X}$	1376	20	147	77
$S_{\bar{x}}$	123	8	142.8	75.1
Min	1082	11	7	3
Max	1494	32	312	200
n	17	7	7	17

Table 22 (continued)

	ELEVATION (m)	SLOPE OF GROUND (degree)	ASPECT (degree)	DISTANCE (m)
<u>Fire cherry</u>				
$\bar{X}$	1364	23	205	95
$S_{\bar{x}}$	147.5	10.1	114.1	106.9
Min	1097	0	0	2
Max	1641	38	342	400
n	16	14	14	16
<u>Silverbell</u>				
$\bar{X}$	1189	23	152	85
$S_{\bar{x}}$	166.4	7.5	94.6	107.5
Min	991	12	20	3
Max	1494	36	349	400
n	15	13	13	15
<u>Sugar maple</u>				
$\bar{X}$	1212	20	160	75
$S_{\bar{x}}$	177.7	12.4	117.1	111.5
Min	914	3	10	2
Max	1433	35	354	400
n	13	10	10	13
<u>Sourwood</u>				
$\bar{X}$	1126	24	146	54
$S_{\bar{x}}$	106.1	13.9	114.3	28.1
Min	975	1	9	25
Max	1311	38	337	100
n	10	9	8	10
<u>All angiosperms</u>				
$\bar{X}$	1259	21	170	85
$S_{\bar{x}}$	188.7	11.7	103.3	162.2
Min	805	0	0	0
Max	1646	90	359	999
n	237	191	187	235
<u>All mark trees</u>				
$\bar{X}$	1239	20	178	104
$S_{\bar{x}}$	288	11.2	103.8	190.2
Min	533	0	0	0
Max	1798	90	360	999
n	454	397	388	449

VITA

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