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IMPROVING ACCURACY AND REDUCING
COSTS OF ENVIRONMENTAL BENEFIT ASSESSMENTS

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VALUATION OF VISUAL FOREST DAMAGES FROM OZONE

by

Donald C. Peterson
Robert D. Rowe

Energy and Resource Consultants
(RCG/Hagler Bailly)
P.O. Drawer 0
Boulder, Colorado 80306

William D. Schulze
Glenn W. Russell
Rebecca R. Boyce
Steven R. Elliott
Brian Hurd

Center for Economic Analysis
Department of Economics
University of Colorado
Boulder, Colorado 80309

PROJECT OFFICER

DR. ALAN CARLIN
Office of Policy, Planning and Evaluation
U.S. Environmental Protection Agency
Washington, D.C. 20460

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TABLE OF CONTENTS

	Page
1.0 INTRODUCTION	1-1
2.0 PREVIOUS ECONOMIC STUDIES ON THE VALUE OF FOREST VISUAL AESTHETICS	2-1
2.1 Crocker and Vaux	2-1
2.2 Brown, King and Daniel	2-8
2.3 Walsh and Olienyk	2-8
2.4 Other Studies	2-12
2.5 Research Needs	2-13
3.0 OZONE CAUSED PHYSICAL INJURY, FOREST RESOURCES, AND SITE CHARACTERIZATION	
3.1 Ozone-Caused Visible Forest Injury	3-1
3.2 Characterization of U.S. Forest Resources	3-5
3.2.1 The Northern Forests	3-9
3.2.2 The Southern Forests	3-14
3.2.3 The Great Plains and Rocky Mountain Forests	3-17
3.2.4 The Pacific Coast Forests	3-19
3.3 Case Study Site Selection and Characterization	3-27
3.3.1 San Bernardino and Angeles National Forest	3-29
3.3.1.1 The Angeles National Forest	3-29
3.3.1.2 San Bernardino National Forest	3-35
3.3.2 Shenandoah National Park	3-38
3.3.2.1 Shenandoah National Park's Forest Resources	3-43
3.3.2.2 Reported Ozone Caused Foliar Injury in Shenandoah National Park	3-46
3.3.3 Acadia National Park	3-49
3.3.3.1 Acadia National Park's Forest Resources	3-52
3.3.3.2 Reported Ozone Caused Foliar Injury in Acadia National Park	3-57
3.4 Conclusion	3-60
4.0 PERCEPTION OF FOREST SCENIC BEAUTY	4-1
4.1 Introduction	4-1
4.2 Development and Applications of Scenic Beauty Research	4-2
4.3 Procedures for Scenic Beauty Evaluation	4-4
4.3.1 General Alternatives	4-4
4.3.2 Forest Scene Representations	4-5
4.3.3 General Questioning and Presentation Procedures	4-7
4.4 Findings and Results From Scenic Beauty Research	4-9
4.4.1 Analysis Methods and Models	4-9
4.4.2 Scenic Beauty Characteristics	4-11
4.4.3 Issues	4-14
4.5 Considerations for the Application of Valuing Ozone Induced Aesthetic Damages	4-18

5.0 SURVEY DESIGN AND IMPLEMENTATION . . . . , ... 5-l
5.1 Introduction 5-l
5.2 Survey Design 5-2
5.3 Sample and Mailing List 5-2
5.4 Slide Selection 5-3
5.5 Map 5-6
5.6 The Survey 5-7
5.6.1 Non-resident (recreator) survey 5-7
5.6.2 Property Owner Survey 5-9
5.7 Survey Response 5-11

6.0 SURVEY RESULTS 6-1
6.1 Introduction 6-l
6.2 Recreator Survey 6-l
6.3 Property Survey 6-3
6.4 Telephone Survey 6-25

7.0 PROPERTY VALUE ANALYSIS 7-l
7.1 Introduction 7-l
7.2 The Hedonic Property Value Approach 7-1
7.3 The Data and Modeling Approach 7-4
7.4 Results 7-29

8.0 CONTINGENT VALUE DATA ANALYSIS AND FOREST DAMAGE ASSESSMENT . . 8-1
8.1 Analysis of the Contingent Value Responses 8-l
8.2 Damage Calculations for the Angeles and
San Bernardino National Forests 8-18

1.0 INTRODUCTION

This document reports on an EPA funded study of the value of visual aesthetic damages to forests from ozone air pollution. The study is a cooperative effort between the Center for Economic Analysis at the University of Colorado and Energy and Resource Consultants, Inc. This version of the study is a preliminary draft report provided for internal EPA use. All conclusions and estimates provided in this document are preliminary and may be substantially revised by the authors in the draft final report which will be submitted in January of 1988.

Estimation of economic values of environmental impacts for benefit cost analysis requires three steps. First, ‘credible and defensible estimates of physical injury must be established. If economic valuation lacks a credible physical science foundation the resulting benefit cost analysis becomes indefensible. This foundation is provided in Chapter 3 of the report which also provides the rationale for choosing the study area. Second, since economic damage results from the human perception of physical injury, a careful understanding of the psychology of perception must be developed. Individuals can only value what they perceive. To provide a basis for economic valuation we review the literature on the perception of forest scenic beauty in Chapter 4 and conduct a perception study as part of the valuation methodology which is described in Chapter 5. The valuation study itself uses a mail survey approach to obtain both information on perception of forest quality for the Angeles and San Bernardino National Forests (chosen as the study area) and to develop value measures using two approaches. These approaches are (1) the property value method and (2) the contingent valuation method. The raw survey results are reported in Chapter 6. The property value analysis is reported in Chapter 7. Chapter 8 presents both an analysis of the contingent valuation approach and develops aggregate measures of visual aesthetic forest damage attributable to air pollution in the Los Angeles area.

2.0 PREVIOUS ECONOMIC STUDIES ON THE VALUE OF FOREST VISUAL AESTHETICS

There are few economic studies addressing the issue of valuing changes in visual forest aesthetics. The most directly applicable effort was by Crocker and Vaux (1983, See also Crocker, 1986) which examined ozone damage to trees in the San Bernardino National Forest. An ongoing effort by Brown, King and Daniel is attempting to link scenic beauty measurement and economic values for changes in many aesthetic forest attributes. Walsh and Olienyk (1981) conducted a Contingent Valuations Method (CVM) study of recreator values for forested areas in Colorado affected by the mountain pine bettle. Each of these studies identifies research issues in conjunction with a forest aesthetic valuation study and gives information about the order of magnitude of values one might find for ozone induced aesthetic forest damages. Other studies have also been conducted looking at the effects of tree density on recreation demand and tree characteristics on property values. These are also briefly discussed. Due to the length of this review, a summary of implications for the current analysis is found in Section 2.5.

2.1 <u>Crocker and Vaux</u>

<u>Application</u>

Crocker and Vaux (C&V) used a contingent valuation method (CVM) survey to estimate economic measures of visual ozone damage to ponderosa and Jeffrey pine forests in the San Bernardino National Forest. Interviews were conducted in June and July of 1983 at unstated locations with 36 weekday and 64 weekend respondents. However, there is Some indication within the text which implies that the intervies were conduced at campgrounds.

Respondents were shown three representative photographs which represented of distinct levels of visible ozone caused damage to ponderosa and Jeffrey pine trees. Respondents were asked which site most resembled the site typically visited, asked to rank the alternatives in terms of preferences, asked CVM bidding questions, and asked questions about congestion and substitution and other related variables. Photograph A was characteristic of no ozone injury or very slight ozone injury to Jeffrey and ponderosa pines. Photograph B depicted very severe ozone injury, and photograph C depicted moderate ozone injury. The degree of injury was assigned by Dr. Paul Miller of the Pacific Southwest Forest and Range Experiment Station. Presentation order of the photographs was not coincident with the order of magnitude of physical damages to reduce induced order effects in the responses.

The questionnaire length was kept short to limit interference with the respondents' recreational experience. Important to note is that respondents were told at the beginning of the interview that many scientists believe air pollution is damaging to the health of the forest. The CVM question asked:

> Suppose that the only way you can enter any environment like the one you most prefer is by paying a daily fee additional to any you are now paying. This additional fee will be used to finance special programs designed to protect this forest. Would you be willing to pay an additional $3.00 to assure entrance today to the environment you most prefer?

An iterative bidding procedure was used to obtain the maximum bid. Subsequently a one bid procedure was used for the bid to enter the next most preferred and the least preferred environment. Assuming nothing else changes in the environment but the quality, the differences in the bids (the bid for environment A minus the bid for environment B) are assumed by C&V to equal the compensating surplus measure of changes in visual tree quality. The questions obtained use value estimates only.

Results

Results were reported for weekend and weekday visitors, but for simplicity, generally only aggregate results are reported for the 100 total respondents. Fifty-seven of the respondents indicated they typically recreate in environments represented by picture A (referred to hereafter as environment A and so forth), 9 said no environment was typical of where they recreated, 27 chose environment C and 7 chose environment B. Seventy-six respondents picked environment A as most preferred, 18 had no preference and 6 most preferred either B or C. When A was most preferred, the next most preferred environment was almost equally split between B and C, with 10 having no preference between either B or C.

C&V report mean incremental bids to recreate in each environment, as reported in Table 2.1. Implied per party difference in value for recreating in different environments are also presented in Table 2.1 and range from $1.35 to recreate in A rather than B, to not being statistically different from zero to recreate in C rather than B. The bids for C and B are not statistically different, but it is not stated whether any of the reported or implied values are statistically different from zero. Crocker (1986) subsequently notes that all zero bids by individuals who preferred environment A were eliminated on zero bid evaluation criteria. Apparently those who bid a positive number for A but not for other environments were retained. Also, that 5 bidders were substantially higher than the others with bids between $10 and $20. Neither C&V (1983) nor Crocker (1986)

Table 2.1

Crocker and Vaux Mean Bids for

Aesthetic Forest Quality*

I. Actual Bids

	Injury Level		
	Slight (A)	Moderate (C)	Severe (B)
Injury Score mid-point	4.5	18	32
Mean of Bids (x)	$2.09	$0.66	$0.74
Standard Deviation of X	$2.80	$0.78	$1.00

II. Implied Bids

Mean Bid for a move from Environment B to Environment A	$1.35
Mean Bid for a move from Environment C to Environment A	$1.43
Mean Bid for a move from Environment C to Environment B	$-.08

* Mean for weekend and weekday recreators. Taken from Crocker (1986)

report the number of zero bids, or the total number of bids that are retained in the statistical analysis. This is an omission that makes it impossible to evaluate the statistical hypotheses.

The authors use the results of the mean bids to imply that “non-convexities” exist in the value function. This is to say that increases in forest quality have increasing positive marginal value. This would be a finding of interest as traditional economic theory typically assumes decreasing marginal utility of goods and services. However, as we will discuss below, the C&V procedures may have been a significant factor causing, rather than revealing, the non-convexity finding.

Crocker (1986) also reports results of a regression relating the bid measure to forest visual aesthetics and other variables. While this bid is not related to underlying utility theory, it appears that the functional form would require a utility function specification that forces the marginal utility of forest aesthetics to be "non-convex". It also appears that zero bids previously deleted are included in the regression analysis, this seems unwarranted. In this analysis visual aesthetic damage is statistically significant.

Respondents were asked to consider the importance of crowding in subsequent questions. Seventy-seven percent of respondents would have been willing to go from their most preferred to their least preferred environment if the former were perceived to be crowded. As Crocker indicates (page 252), “It seems that the compensation respondents would demand for crowding exceeds that which they would demand for air pollution damages," as 70 of the 77 were individuals who most preferred environment A.

The questionnaire also asked for the current number of visits per year to the San Bernardino National Forest and the number that would be taken if all the forest were similar to their least preferred environment. Respondents indicated that visitation would fall off by 10 to 20 percent if all of the forest were similar to their least preferred environment.

Finally, C&V attempt to aggregate the individual findings to infer values for aesthetic changes on a per acre basis and for the forest as a whole (this work is not carried forward into the Crocker, 1986 paper). Unfortunately, the assumptions used have important flaws leading to a potential bias in estimated values. The reasons for this determination include :

* In their computations, C&V assume the sample (presumably of campers) is representative of all recreation use days in the San Bernardino National Forest; however, values are likely to differ by use type, with campers potentially being among those with the highest values for forest aesthetics.

* The bids by individual by day are applied to all recreation days, although the bids probably may best be interpreted as visitor party bids.

* C&V assume that part of each of the over 6 million recreation visitor days took place within those portions of the 161,000 acre area surveyed by Miller for oxidant damage to Jeffrey and ponderosa pine. This seems unrealistic as there are nearly 2 million acres in the San Bernardino National Forest with diverse vegetation cover and recreational use, although making alternative assumptions is equally difficult.

* The photos used in the survey present alternative forest conditions for stands that are predominately Jeffrey or ponderosa pine, while in those areas with these species, the percent of all trees of these species range from very small (10-20 percent) to very high (80-100 percent). The value (and certainly the value per acre) of injured ponderosa and Jeffrey pine may be less in those stands where they comprise a small portion of the trees in the stand.

* An offsetting potential problem is that values for changes in conditions may be understated due to the exclusion of negative bids (see next section).

The aggregate results C&V report range from $21 to $68 per acre of injured stand. They calculate the total forest-wide value for having environment A rather than environment C at about $9 million/year (or about $90 million present value at a 10% discount rate).

Issues and Use of the Results

The main issues surrounding the use of the C&V work in policy application are: whether the "non-convexity" finding is meaningful; and whether the estimates of values per visitor party and the aggregate estimates are reasonable, and what they imply.

The non-convexity finding may be more related to the structure of the questionnaire than to the underlying values the researchers attempted to reveal. In particular, the questionnaire asked for the WTP of an additional amount above current fees to guarantee admission to the most preferred, next most preferred, and least preferred environment. As indicated by the visitation and congestion questions, many respondents would rather not take the trip to the San Bernardino National Forest if their preferred environment is not available. Therefore, C&V should have allowed respondents to state negative WTP (require reduced fees or compensation) to visit less preferred sites, rather than limiting WTP to a lower bound of zero. By limiting the lower bound of the bids to zero, the questionnaire truncates the difference between the value of visits to the most and the least preferred environments. This is evidenced by the substantial number of apparent zero bids for least preferred environments resulting in means less than $1.00. If negative bids were allowed, the non-convexity may have likely, although not necessarily, disappeared. More importantly, the calculated use values for changes in forest quality, calculated as the difference in the maximum WTP entrance fee for each environment type and which are limited to zero, are likely to be understated.

Other questionnaire design factors affecting the responses may well be sequencing and starting bids. The bid for the preferred environment was first, and respondents were given a starting bid of $3. The resultant mean bid of just under $3 suggests the starting bid may have had a strong influence on the responses. Further, the bids for the next most preferred and least preferred environment followed but did not have a starting bid. If this sequencing had been reversed, beginning with the least preferred environment and a starting bid of $3, followed by single bids for the more preferred environments, it is possible the non-convexities would again have disappeared. These sequencing and starting bid issues are perceived as less significant than the previous comments.

Turning to the value estimates, it is noticeable how relatively small they are: on the order of $1.35 per visitor party per day for changes from environment C or B (moderately to severely injured) to environment A (very slight injury). However, as noted above due to limits on negative values, the structure of the questionnaire artifically limits the estimates of the appropriate consumer surplus measure. Therefore, it is likely an improved use value estimate might be several times this magnitude, but not an order of magnitude larger. This is because questions on congestion and number of trips taken indicate that most trips would still be taken even if conditions worsened at the sites. On the other had, it is possible that the reported values would have been even lower if the questionnaire had not identified the damage as probably air pollution induced. (See the discussion in Section 4.4.3 on the effect of information on scenic beauty evaluations).

Therefore the aggregate estimates are suspect. As noted above, there are many substantial upward biases. However, these biases may be largely offset by. the probable understatements in the average value per visitor party, and by the fact that only use values are estimated. The exclusion of option and non-use values may be substantial. As a result, use value estimates on the order of $5 to $15 million per year appear plausible.

2.2 Brown, King and Daniel

This ongoing study has examined use values for many forest characteristics, which from previous SBE work would help identify order of magnitude estimates for ozone injury. Results have not yet been released, but are expected in early 1988.

2.3 Walsh and Olienyk

Applicaton

The purpose of this study was to develop measures of the effect of mountain pine beetle damages to ponderosa pine trees on demand for recreation use of forest resources in the front range of the Colorado Rocky Mountains. As a result of pine beetles, about 15 percent of the trees have been killed in the National Forests of this area, about 5,000 square miles. The damage per acre however, ranges from 0 to almost 30 percent depending upon the National Forest area being considered.

When mountain pine beetles attach to ponderosa pine trees, discoloration of needles first occurs, then trees die and fall down. This then reducesg the density of trees.

Walsh and Olienyk (W&O) interviewed 435 recreator users on-site throughout the front range national forests during 1980, primarily at elevations between 6,000 and 8,000 where ponderosa pines grow. In these areas Ponderosa pines are common in stands of, on average, 160 trees per acre with dbh of six inches or more.

The W&O questionnaire asked respondents about the characteristics of the current trip including activities, expenditures and perceptions of on-site conditions. They also asked the importance of: congestion, tree density at the site and in the distant view, tree size, discolored needles and dead trees. About two dozen willingness to pay questions were also asked about these issues as were several contingent travel cost questions.

The questionnaire used six photographs representing different densities of healthy trees ranging from 0 to 300 per acre. No pictures of alternative levels of discoloration or standing or downed dead trees were included.

Among the important elements in the questionnaire design is that the WTP and contingent visitation questions are not always consistent or clear as to whether the proposed change is to occur at one site or throughout the entire forest. If the responses are applicable to impacts at only one site, they may misrepresent the values if the entire forest experiences similar impacts. Another element is that the questionnaire focuses most heavily upon tree density as if the standing dead trees are removed without a trace and there are no discolored trees.

Results

Unfortunately W&O do not report the means or variances of individual WTP or contingent travel demand questions, but rather regressions examining responses to selected WTP or travel demand questions. As a result, determining changes in consumer's surplus from the analysis is a difficult task. They also do not report any results for many of the questions, including the congestion analysis.

Forest quality characteristics were uniformly found to be significant to recreation experience. About half of the respondents rated trees as being more important than views of mountains or rock outcroppings. Slightly less than half rated trees more important than topography or nearness of streams and lakes.

Tree density was found to have a significant effect on the demand for site visits. However, the relationship between tree density and demand for site visits varied greatly depending upon recreation use type (for example, fewer trees are preferred for off-road vehicle recreation). The relationship between tree density and visits increases up to 150 to 200 trees per acre (depending upon use type), levels off for the addition of 0 to 100 trees/acre, then declines. The interesting implication is that in moderate or densely forested areas, decreases in tree density may have negligable or positive effects on site demand. On average, across use types, and at the average density of 165 trees/acre, a 10 percent decline in tree density was associated with a 3.5 percent decrease in demand. This is comparable to estimates by Leuschner and Young (1978), who found an elasticity of .64 to .68 for trees at campgrounds located at reservoirs in

Texas, and estimates of Michaelson (1975), who found an elasticity of .27 for trees at camping sites in Idaho forests.

The effects of visible discoloration (living but significantly discolored) and of standing dead trees (trees lacking needles) were found to be about the same. They are 6 to 7 times greater than that of tree density, with an elasticity of demand of 2.3, on average, across activities, at a medium tree density, in the range of 1 to 15 percent of trees damaged.

Using a travel cost model, the authors report changes in consumer surplus for changes in tree density. With these estimates and the above elasticity of demand, one can infer a guess of what the change in consumer surplus might be for changes in fully discolored and dead trees. From W&O's figures (Table 42 in their text) a 10-15 percent change in tree density, at the mean density and averaged across use types, in an average loss of consumer surplus of $5.42 to $8.59 per year ($1982) occurs. If the change in consumer surplus for dead or dying trees is 6 times as important, 10 to 15 percent of dead or dying trees would result in values of $32 to $50 per year. The comparable per trip estimate for 10 to 15 percent dead and dying trees (using O&W Table 43) would be about $8 to $11 dollars per year.

Issues and Use of Results

The major issues for the current study is that no presentation of discolored and dead trees was made with visual graphics in the questionnaire. As as a result quantifications of the degree of injury inferred by the respondent cannot be ascertained or compared to the types of damage experiences. However, mountain pine beetle damage quickly discolors entire trees in groups which is generally a much more substantial effect than the effects of ozone damage alone. In addition, the issue of how respondents perceived the effects throughout the forests of the front range is unclear and clouds the interpretation of the results.

Another issue is the tranferability of results of recreators in Colorado to others areas throughout the country. However this is less severe if one treats the values as order of magnitude estimates.

The results and issues identified suggest that the consumer surplus estimates of $8 to $11 ($1980) per recreation trip for 10 to 15 percent of all trees totally discolored or dead would overstate the effects from ozone in isolation of other confounding or subsequent effects (such as a resulting pest infestation due to predisposition by ozone;. These estimates applied to trips of, on average, 6 hours. How the estimates should be adjusted to reflect that some costs are incurred by everyone in the group, yet the reported willingness to pay, may apply to the group as a whole, is unclear.

2.4 Other Studies

Other studies have been completed addressing how trees and tree quality affects recreational value and property prices. These studies are not as directly applicable as those mentioned above for estimating the benefits of ozone control.

Recreational studies have included those by Michaelson (1975) addressing mountain pine beetle damage to ponderosa pine on the demand for recreation at campgrounds in the Targhee National Forest in Idaho. It was found that the degree of infestation significantly affects campsite demand. Leuscher and Young (1978) addressed southern pine beetle damage to ponderosa pine on the demand for campground recreation at two reservoirs in Texas. Again, reduced demand occurred at damaged sites. The damage to those still recreating at those sites was not considered.

Property value impacts have been assessed through appraisals (Peters 1971, Morales 1976, Paige 1964 Payne et al. 1973, Payne and Strom 1975 Neely 1979 and others) and through willingness to pay surveys (Coursey and Brookshire 1985). These efforts have uniformly addressed issues of tree density and size on property values. They have not addressed characteristics of tree injury. usually these studies look at the planting of trees in urban or suburban areas rather than within national forest areas. Interestingly, these studies do suggest that properties with an abundance of trees are often on the order of 20 to 30 percent more valuable than lots with few or no trees.

2.5 Research Needs

The results of the most comparable studies suggest that use values for recreational impacts of forest damage are likely to be on the order of a few dollars per visit day per visitor party. Option and non-use values are unknown and more information on this topic may be of importance. Given the importance of forests to other ecologic systems, there may be substantial value beyond immediate recreational impacts.

Limited information exists for values by user types, especially for those who are not campers, but rather day hikers, picnickers and other less intensive user groups. The recreational use of forests by these groups often substantially exceeds that of overnight campers. Therefore estimates of values for these groups are of interest.

Property values represent an important method to reveal values, yet only limited or outdated information is available for residences within or adjacent to national forest areas. More information on these values will extend the understanding of forest injury values.

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3.0 OZONE CAUSED PHYSICAL INJURY, FOREST RESOURCES, AND SITE CHARACTERIZATION

This chapter reviews ozone caused tree injury with an emphasis on the description of visible foliar and stand effects. Section 3.1 briefly describes ozone injury mechanisms, establishing a linkage between elevated ozone exposures and the expression of visible injury by sensitive trees. Section 3.2 characterizes the Nation's forest resources, and describes in some detail available data relating elevated ozone exposures to physical injury. Section 3.3 describes the criteria used in selecting the San Bernardino and Angeles National Forests as the site for this study. Two potential, alternative, sites are also discussed.

3.1 Ozone-Caused Visible Forest Injury.

Ozone effects on forest ecosystems range from the potentially insignificant to fundamental alterations in ecosystem relationships and processes, and are determined through: the genetically controlled resistance of individual ecosystem members; the influence of environmental conditions; and ozone-caused changes in inter and intraspecific relationships. The complexity of these ozone-forest ecosystem interactions prevents a simple characterization of ozone-caused forest injury in general and visible foliar or stand injury in particular. Readers interested in a comprehensive discussion of forest response to air pollution are referrerd to McLaughlin (1985), specific treatments of ozone-caused injury are found in Guderian et al., (1985) and U.S. EPA (1986).

This section introduces a number of visible ecosystem and forest tree effects that have been associated with elevated ozone concentrations. The focus of this discussion will be on the description of visible foliar injury and predicted changes in forest stand composition resulting from ozone exposure. Section 3.2 describes regional forest damage caused by ozone.

Ozone is absorbed by plants directly from the atmosphere. Uptake is practically limited to plant leaf structures and its rate is a function of the chemical and physical properties of the plant and the environment (see Tingey and Taylor, 1982; Guderian, et al., 1985). Once ozone has been absorbed by plants, effects at the cellular level are initially expressed through the altered permeability of membranes, resulting in changes in cellular compartmentalization, and' water and mineral relations. These effects, as well as alterations in enzyme activity, plant metabolism, cellular structure and organization cause cellular perturbations and may result in cell death.

Ozone-induced cellular alterations can reduce photosynthesis rates, elevate plant respiration, and distrupt plant water relations. Numerous studies have described the effects of photochemical oxidants and ozone on plant photosynthesis (Guderian, et al., 1985). Under chronic ozone exposures, ozone has been reported to reduce soluble sugars and starch, leading to decreased plant growth and yield. Associated with reduced photosynthate production is the altering of photosynthate partitioning, causing a reduction in root growth and root processes (Miller, 1973). While photosynthesis is reduced shortly after elevated ozone exposures, the net photosynthetic rate has been shown to return to its original level when ozone exposures are ended. Photosynthesis can be reduced without the appearance of visible foliar injury, but the appearance of visible symptoms is always associated with measurable reductions in photosynthesis (Guderian, et al. 1985).

Foliar injury results from biochemical and physiological changes caused by the disruption of cell membranes. Four types of visible ozone injury have been identified on leaves: pigmented leisons (stipple), bleaching, chlorosis, and bifacial necrosis (Hill, et al., 1970; Guderian, et al., 1983). The first three types generally result Prom chronic ozone exposures, while bifacial necrosis results from acute exposures.

Pigmentation is the most common visible foliar injury on deciduous trees, shrubs, and herbaceous plants. It occurs mainly on the upper leaf surface as sharply defined small dots or flecks resulting Prom the pigmentation or death of groups of leaf palisade cells. Depending on the plant species, lesions may be dark drown, black, red, or purple.

Bleaching also occurs principally on the upper surface of deciduous and herbaceous species. Numerous small necrotic, unpigminted leisons resulting from injured palisade cells impart a mottled appearance to the leaf.

Chlorosis occurs mainly on the upper surfaces of leaves, with the primary injury usually being limited to small groups of palisade cells. The leisons range in size from only a few cells to flecks approximately 1 mm in diameter. With chronic or repeated acute exposure, injured areas may coalesce imparting a mottled appearance to the leaf. Chlorosis is a common symptom on pines, but occurs less frequently on other species than either pigmentat ion or bleaching.

Bifacial necrosis occurs when the mesophyll tissue between the upper and lower leaf epidermis is destroyed. As a result, the upper and lower epidermis is drawn closer together, creating a thin papery leison that may range in color from white to red-orange.

Visible injury to conifers has been widely discussed in the literature (Guderian, et al., 1985: U.S. EPA, 1986). Because welfare estimates developed in this report measure economic values associated with visible injury to conifer trees and stands, the following material introduces three classic expressions of ozone injury to conifers.

The term “ozone injury” was first used by Sinclair and Costonia (1967), to describe symptoms previously identified as “emergence tipburn,” “white pine blight,” or “white pine die-back,” of eastern white pine. Ozone injury to eastern white pine is widespread in the eastern United States, and is eXpreSSed through tip die-back of young developing needles. The partially mature tissue is the most severely injured. In general, ozone injury develops from chlorotic flecks into pink leisons and bands, followed by a spreading red-orange necrosis of the needle tip. The injury may reduce needle retention from three years to one on healthy trees; on sensitive trees, the needles senesce prematurely, leaving only current year needles by mid-summer. In both cases, shoot, radial, and root growth are reduced in affected trees.

“Ozone injury” and the "chlorotic dwarf syndrome” are both visible injury symptoms occurring on eastern white pine. "Chlorotic dwarf” is characterized by stunted root and shoot growth, mottled needles, and the premature needle sensescence (Dochinger, et al., 1970). Needles on genetically sensitive trees begin to develop normally, but chlorotic flecks soon develop. Older needles turn prematurely yellow and are shed before younger needles reach full development. In the final stages, needles develop a tip-burn. Severely injured or sensitive individuals tend to die within a 15 year period.

"Chlorotic decline” has been used to refer to ozone-induced injury on ponderosa and Jeffrey pine in California. Chronic ozone exposures in the mountains adjacent to the Los Angeles Basin induce chlorotic mottle symptoms that develop from the needle tip to base, eventually followed by necrotic tip die-back. The older needles sensescence prematurely, with chlorotic areas coalescing and turning a tan color. Because of premature needle drop, severely affected trees retain only one year old needles, while uninjured trees maintain needles for three to five years. Premature needle drop results in a characteristic "thinness" in the tree canopy very evident to forest visitors. Variation in genetic susceptibility to chlorotic decline results in dead and dying trees growing alongside visibly unaffected trees.

Other visible effects accompanying elevated ozone exposures are associated with responses of forest communities to changes in competitive interactions resulting from the death or suppressed growth rates of sensitive individuals. In the San Bernardino National Forest, stands of ponderosa and Jeffrey pine are being gradually replaced with the less sensitive white fir (Miller, 1987). While not currently evident to recreational forest users, this successional change could result in a dramatically different forest cover type in areas heavily impacted by ozone pollution. In addition, the heavy reported mortality of ponderosa and Jeffrey Pine has increased the volume of standing and fallen dead wood in the forests, potentially increasing the frequency and/or intensity of forest fires. The increased volume of dead timber increases the potential of greater injury to plants and soil organisms and encourages the succession of fire tolerant species.

3.2 Characterization of U.S. Forest Resources

This section contains information on the area and selected characteristics of the Nation's forests. The Nation's 736 million acres of forested land are widely distributed across the United States and encompass a wide variety of characteristics, ownerships, and uses. Table 3-1

TABLE 3-1

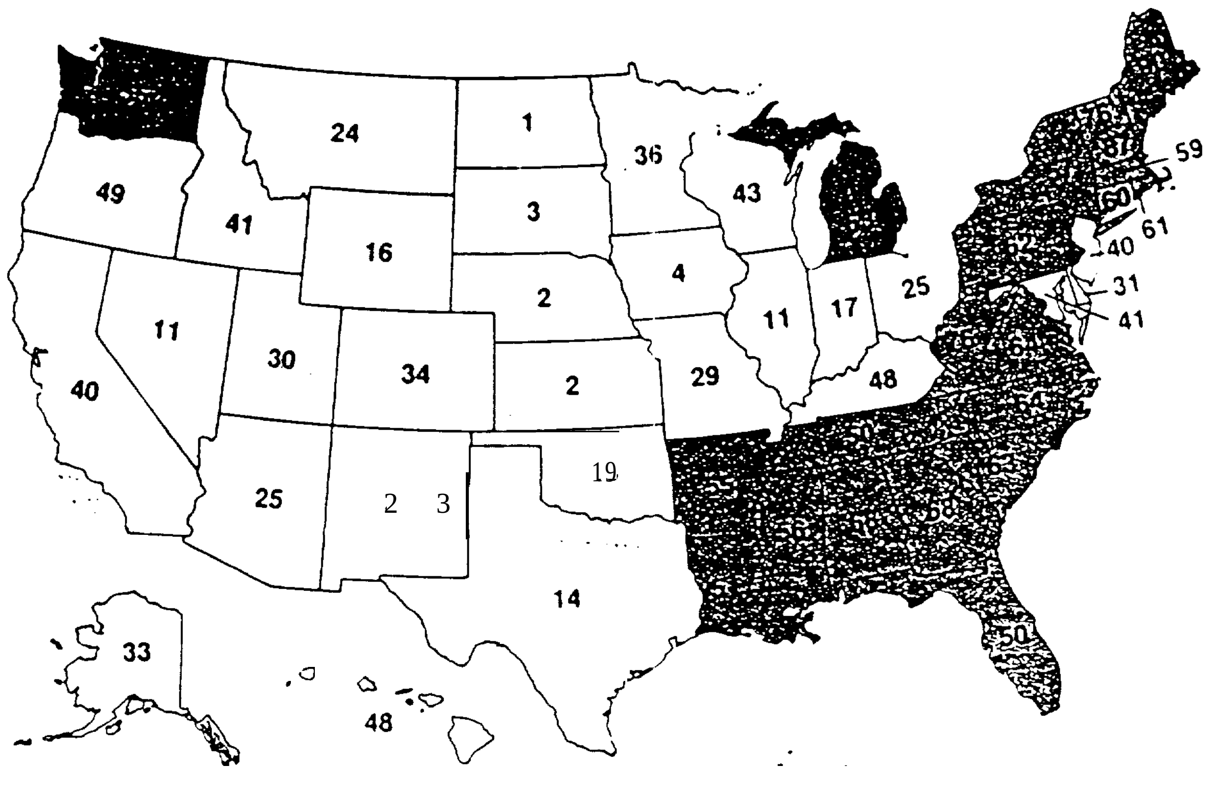
Area and Ownership of U.S. Forested Land

Region	Land Area in Forest (000 Acres)	Percent Ownership of Forested Land: Forest Service	Bureau of Land Mgmt.	Other Federal	Other Non-Federal
Northeast	83,147.1	3.0	0	1.0	96.1
Northcentral	79,224.5	14.3	0	1.9	87.0
Total North:	162,371.6	7.0	0	1.4	92.0
Southeast	91,005.8	5.8	0	3.7	90.5
Southcentral	128,030.2	5.4	0	1.4	93.1
Total South:	219,036.0	5.6	0	2.3	92.0
Rocky Mountains	136,379.6	49.2	14.1	5.6	31.1
Great Plains	4,497.3	22.8	1.0	3.9	72.3
Total Rocky Mtns. and Great Plains	140,876.9	48.4	13.6	5.5	32.4
Pacific Northwest	172,135.9	19.9	54.6	7.3	18.4
Pacific Southwest	42,138.0	37.6	2.2	4.9	55.3
*Cal/Oreg/Wash	93,143.0	40.8	6.1	3.5	49.5
Total Pacific Coast :	214,273.9	23.4	44.3	6.6	25.7
Total U.S.	736,558.4	19.3	15.5	4.0	61.2

Source: An Assessment of the Forest and Range Land Situation in the United States. USDA Forest Service Forest Resource Report No. 22. October 1981.

TABLE 3-1

Forest Land as a Percentage of Total Land Area



Source: <u>An assessment of the Forest and Range Land Situation in the United States</u>. USDA Forest Service Resource Report No. 22. October 1981.

TABLE 3-2

Ecosystem Composition of U.S. Forest Regions

(% Composition)

	(000) Acres All Ecosystem	White Red Jack Pine	Fir Spruce	Long Leaf Ash	Loblolly-Short Leaf	Oak-Pine	Oak-Hickory	Oak-Gum-Cypress	Elm-Ash-Cottonwood	Maple-Beech-Birch	Aspen-Birch	Non-Stocked	Other
Northeast	83,147.1	9.0	14.2	0	2.5	2.6	23.4	0.3	11.5	29.4	4.6	2.4	0
North Central	79,224.5	5.4	11.8	0	0.7	1.4	30.4	0.3	10.5	15.7	20.8	3.0	0
Total North	162,371.6	7.3	13.1	0	1.6	2.1	26.8	0.4	11.0	22.7	12.5	2.7	0
Southeast	91,005.8	0.4	0	14.6	23.8	13.2	28.0	13.2	1.8	0.4	0	4.6	0
South Central	128,030.2	0.1	0	3.0	20.3	15.4	34.2	13.0	2.0	1.2	0	0.8	9.9
Total South	219,036.0	0.2	0	7.8	21.8	14.5	31.6	13.1	1.9	0.8	0	2.4	5.8
Total East	383,738.7	3.2	5.5	4.4	13.1	9.1	29.6	7.6	6.1	10.1	5.3	2.5	3.3

	(000) Acres All Ecosystems	Douglas Fir	Ponderosa Pine	Western White Pine	Fir Spruce	Hemlock-Sitka Spruce	Larch	Lodgepole Pine	Redwood	Other Western Soft Woods	Western Hard Woods	Non-Stocked	Chapparal	Pinyon Juniper	Other
Rocky Mountains	136,379.6	12.8	12.1	0.3	12.1	1.0	1.5	12.3	0	3.3	5.6	1.9	5.8	30.9	0.5
Great Plains[1]	4,497.3	0	32.8	0	0.6	0	0	0	0	0	1.9	12.7	0	0	0
Total Rocky Mountains and Great Plains	140,876.9	12.4	12.8	0.2	11.7	1.0	1.5	11.9	0	3.2	5.5	2.2	5.6	29.9	0.5
Pacific Northwest	172,135.9	10.3	4.6	0.1	53.0	10.6	0.4	2.0	0	0	15.9	1.3	0	1.4	0.3
Pacific Southwest	42,138.0	7.7	18.5	0.3	13.5	0.4	0	2.5	1.8	0	10.9	4.2	17.9	6.4	15.9
Cal/Oreg/Wash	93,143.0	22.6	16.9	0.2	14.5	6.1	0.8	4.5	0.8	0	9.6	3.5	8.2	5.5	6.8
Total Pacific Coast:	214,273.9	9.8	7.4	0.1	45.2	8.6	0.3	2.1	0.4	0	14.9	1.7	3.6	2.4	3.4
Total West:	355,150.8	10.8	9.5	0.2	31.9	5.6	0.8	6.0	0.2	1.3	11.2	2.0	4.4	13.3	2.2

[1] Ecosystem totals may not add to region totals. Kansas, Nebraska, North Dakota and South Dakota contain species not included in the above catagories

Source: An Assessment of the Forest and Rangeland Situation in the United States. USDA Forest Service Forest Resource Report No. 22. October 1981.

summarizes the amount of forested land in the United States by region and ownership. While the Pacific Coast region contains the largest number of forested acres in the Nation, Figure 3-1 indicates that the Eastern Region of the U.S. contains a very high percentage of it's total land area in forest. Similarly, humid portions of the Pacific Coast and higher elevation areas in the West that receive sufficient precipitation are also forested. As summarized in Table 3-1, the Eastern States account for slightly more than half of the Nation's forest land. The vast majority of this land is in non-federal ownership. The Rocky Mountain and Pacific Coast States account for most of the remainder of U.S. forested land. Unlike the east, the majority of forested acres are owned by the Federal Government in the west. The Great Plains States have relatively little forested land.

3.2.1 The Northern Forests

The northern region represented in Table 3-1 includes 20 States from the Atlantic seaboard west of Minnesota, Iowa, and Missouri, and south to the Ohio River, including West Virginia and Maryland. The northern fraction of the region has generally low relief with rolling hills and low mountain elevations in the Northeast. Much of this area has been glaciated, with typically strongly leached acid soils. The southern portion is characterized by rolling or flat terrain, with the exception of the Appalachian Mountains that reach elevations up to 3,000 feet.

Table 3-2 summarizes the forest ecosystem type, by percent composition, across land regions as defined by the USDA Forest Service. In the northern region, the most prevalent ecosystems are the oak-hickory, the maple-beech birch, and the spruce-fir. These ecosystems respectively account for 26.8%, 22.7%, and 13.1% of the total forested land in this region.

Oak-hickory. The oak-hickory ecosystem covers more than 43 million acres, and contains eight separate associations in the northern region. The ecosystem's composition is highly variable, and depends mainly on location. Although dominants vary, numerous species are commonly found including white oak, red oak, black oak, post oak, blackjack oak and others. Common associates in this forest ecosystem include numerous pines, yellow poplar, elms, maples, and black walnut. The commercial value of this ecosystem is variable, and limited by the abscence of strong markets for the less desirable hardwood species that are a part of these stands.

Insect and pathogen mortality is important in this forest ecosystem. There is no apparent relation between these natural pests and anthropogenic air pollution or ozone. Of these pests, the gypsy moth (Porthetria dispar L.) is very destructive. The most important disease-causing pathogen on oaks is the oak wilt fungal pathogen [Ceratocystis fagacearum (Bretz) Hunt], responsible for widespread mortality in both white and red oaks.

Hepting (1971) has reported oak declines in Pennsylvania, Virginia, South Carolina, and Texas. Davis and Gerhold (1976) have reported oaks to be variably sensitive to ozone. White oak (Quercus alba) and Gambells oak (Q. gambelli) were classified as sensitive species, while scarlet (Q. coccinea), pin (Q. palustris), and black (Q. velutina) were classified as being intermediate. Three species were classified as being resistant, shingle (Q. imbricaria), bur (Q. macrocarpa), northern red (Q. rubra). In a recent survey (Sanchini, 1985) populations of white oak, red maple, and yellow poplar were evaluated for signs of ozone injury in Shenandoah National Park. As reported, 3% of the yellow poplar sample, 5% of the oak sample, and 9% of the red maple had foliar injury attributable to ozone.

On trees exhibiting ozone injury, very little leaf area was affected. For example, it was reported that .l% of the sampled white oak leaf surface was damaged. Sanchini further reported that insect and fungal diseases caused “much greater damage" to leaves than ozone. The most important causes of leaf injury were listed as leaf cutting insects, skeletonizing insects, leaf mining insects, and leaf spot fungus.

Maple-beech-birch. Covering 37 million acres, this ecosystem contains some of the most commercially and aesthetically important hardwood species in the Nation. Sugar maples, yellow birch, white birch, and basswood are all important to the wood products industry. The variety of hardwood species is responsible for the fall foliage display in the north, a highly valued recreational asset to millions of Americans. The common dominants are sugar maple, American beech, and yellow birch. Associates in the maple-beech-birch forest include yellow poplar, hemlock, elm, white ash, black cherry, red and white oak, white pine, sweet birch, and basswood.

The beech scale (*Cryptococcus fagi* Baer.) and beech bark disease (*Nectria coccinea* var. *faginata* Loh., Wats & Ay) have been causing extensive mortality of beech throughout New England and New York since the 1950s. This disease has not been related to air pollutants.

Numerous regional maple declines have been reported in the northeastern U.S. over the past 40 years. Yellow birch experienced widespread mortality throughout New England and New York from 1940-1965. No satisfactory explanation for this decline has been provided, and the birch have subsequently recovered. Numerous trees in the maple-beech-birch ecosystem have been evaluated for sensitivity to ozone and classified as (Davis and Wilhour, 1976, and Sanchini 1985):

Sensitive

white ash	_Fraxinum americana_
white oak	_Quercus alba_
basswood	_Tilia americana_
yellow poplar	_Liriodendron tulipifera_

Intermediate

sugar maple	_Acer saccharum_
black cherry	_Prunus serotina_
red maple	_Acer rebrum_
black locust	_Robinia psedoacacia_
elm	_Ulmus americana_

Resistant

hemlock	_Tsuga canadensis_
red oak	_Quercus rubra_

While Davis and Wilhour (1976) ranked eastern white pine (_Pinus strobus_) as “intermediate" in its sensitivity to ozone, numerous reports suggest that individual eastern white pine genotypes may be very sensitive to ozone. Foliar injury to eastern white pine has been observed in Laboratory fumigations at ozone levels as low as .03 ppm for 48 hours (Costonis and Sinclair 1969). Evidence of foliar injury on eastern white pine that may be attributable to ozone has been reported from Maine south to Georgia and Tennessee (Bennett et al., 1986 and Anderson et al., 1986). Visible foliar injury to white pine was evident in both the Shenandoah and Acadia National Parks during field visits made in September of 1986.

Spruce-fir. The spruce-fir ecosystem covers more than 21 million acres in the north, or slightly more than 13% of the total forested area in the northern U.S.. This forest is the primary source for the area’s woodpulp industry, and the more remote, higher elevation stands are popular recreation sites. Common associates in the spruce-fir ecosystem include yellow birch, mountain ash, eastern hemlock, beech, sugar maple, red maple, mountain maple, tamarack, and northern white cedar.

The spruce-fir ecosystem has been frequently disturbed by fire, wind, and logging. Wind damage is very prevalent throughout spruce-fir stands. Severe wind damage can result in even age stands and resulting cyclic reproduction at higher elevations or exposed sites. Spruce budworm (Choristoneura fumiferana Clemens) and the balsam woolly adelgid (Adelges picea Ratz.) are very destructive insect pests in the spruce-fir ecosystem. There is little or no indication that the rate of budworm or adelgid infestation is affected by air pollutants or ozone.

Very little is known regarding the ozone tolerance of red spruce (Picea rubens), Balsam fir (Abies balsamea) and, in the south, Fraser fir (A. fraseri). There have been numerous reports that red spruce has been experiencing decreasing growth rates and significantly increased mortality since the early 1960s at sites throughout the northern and southern Appalachian Mountains (Johnson and Siccama 1983; Bruck 1984). Preliminary hypothesis development focused on potential causal roles for acidic deposition. However, in the recent NAS (1986) report, Johnson and McLaughlin discounted the potential link between red spruce decline and air pollution and suggested that changes in climate were more likely causes of the widespread mortality and apparent growth decline. Mortality of Fraser fir in the south has been largely explained by the balsam woolly adelgid. There is not sufficient evidence to indicate that the fir is predisposed to successful adelgid attack by higher levels of air pollutants, specifically ozone.

Remaining Ecosystems. The remaining area within the northern region is comprised of a number of less common ecosystems. Two are of particular interest in this review because of their potential sensitivity to ozone: white-red-jackpine and aspen-birch. As previously mentioned, the sensitivity of eastern white pine (Pinus strobus) has been extensively studied. Estern white pine is apparently especially sensitive to ozone. As referenced in Table 3-2, the white pine-eastern hemlock association comprises 9% of the forest area in the northeastern U.S. The aspen-birch ecosystem may also be sensitive to ozone based on Treshow (1970) and Treshow and Stewart (1973). Treshow and Stewart exposed aspen (Populus tremuloides) to a single 2-hr exposure of ozone at 0.15 ppm. This exposure caused severe foliar injury over 30% of the foliage.

3.2.2 The Southern Forests

The southern forest region described in Tables 3-l and 3-2 extends from Virginia and Kentucky along the South Atlanticand Gulf Coast, including Taxes and Oklahoma at it's western boundary. The nature and significance of forest ecosystems vary across the 13 states in this region. In the southeastern states, comprised of the 5 states along the Atlantic seaboard, slightly more than 91 million acres are forested. As shown in Figure 3-l the percentage of forested land area is approximately 60% in the southeastern states. In the remaining Gulf Coast and interior states approximately one third of the total land area is forested. Ownership of the southern forests is largely private, with the majority of forest volume available to the timber industry (Table 3-l). The two most prevalent southern forest ecosystems are the oak-hickory and the loblolly-shortlead pine, comprising 32% and 22% of the total forested area (see Table 3-2).

Oak-hickory. The oak-hickory ecosystem covers 69 million acres in the south. As in the north, this ecosystem is comprised of a wide variety of species in many different associations. Eastern white pine is an important component of this ecosystem. Recently, air pollution symptoms were desribed on about 23% of sample white pine stands in the southern range of the species in Virginia, North and South Carolina, Georgia, Tennessee, and Kentucky (Anderson et al., 1986). Results of this study indicated that the highest incidence of foliar injury was in Kentucky, where 77% of the trees exhibited air pollution injury symptoms. The lowest incidence occurred in Georgia, where 10% of the sampled trees exhibited injury. Symptomatic trees tended to occur near pollution sources, and the plantation samples exhibited greater injury than natural stands. This is significant, as the' authors reported that symptomatic trees in sampled stands were growing 49% less volume than healthy trees.

Loblolly-shortleaf pine. Covering almost 48 million acres, the loblolly-shortleaf pine ecosystem is the source For more than 25% of the Nation's timber harvest (USDA Forest Service, 1976). In 1976, southern pine production produced 71% of the south's timber volume (USDA Forest Service 1983). Loblolly pine is the most important commercial tree species in the south. Except in Florida, where slash pine is common, loblolly is the dominant pine species in each of the Atlantic and Gulf Costa1 states south of New Jersey.

The longleaf-slash pine and loblolly-shortleaf pine forests are the two major yellow pine types. Although the standing inventory of shortleaf pine is only about half that of loblolly pine, shortleaf is still much more abundant than longleaf and slash pines combined. Other pines that may be important components or associates of the loblolly-shortleaf ecosystems are

Virginia pine, pond pine, white pine, sand pine, Table Mountain pine, and pitch pine. Common deciduous associates in the loblolly-shortleaf ecosystem include: dogwood, sweetgum, oak, black gum, sassaras, yellow poplar, sourwood, hickories, maples, and elm.

Bark beetles cause important mortality in loblolly-shortleaf pine. Epidemics of beetle in stands experiencing stresses associated with competition, flooding, and fungal disease. While this infestation may perhaps be linked to ozone concentrations, as in the San Bernardino National Forest, this has not been established. The two most destructive diseases of loblolly and slash pines are fusiform rust (Cronartium fusiforme Hedge. and Hunt) and pitch canker (Fusarium lateritium f. pini Hepting). Little leaf disease in shortleaf pine has occurred in wide areas of the Piedmont of North and South Carolina, Georgia, and parts of Alabama since the 1940s (Manion 1981). The disease is associated with abused or eroded soils, and not air pollution.

Recently, Forest Investory and Analysis (FIA) surveys have suggested that growth declines may be occurring in loblolly pine stands in the Piedmont region (Sheffield et al., 1985). FIA data indicate that the average annual radial growth rate of most yellow pines under 16 inches in diameter has declined by 30% to 50% throughout the Piedmont and mountain areas of the southeast since the third survey cycle, which measured growth between the years 1957-l966. Increased pine mortality was also recorded. The survey indicated that 15% of the annual growth of yellow pine is lost to mortality, compared with 9% in 1975. Sheffield et al. indicate a 77% increase in the annual mortality of pine over previous surveys. Loblolly pine has been generally considered to be intermediate in its sensitivity to ozone injury (Kress and Skelly, 1976). Growth effects may be caused by ozone without the expression of visible foliar injury.

To evaluate the potential for ozone caused stress in loblolly pine stands in Georgia, South Carolina, and North Caroline, Chevone et al. (1986) surveyed ozone sensitive plants that occur in association with loblolly pine during the first two weeks of September, 1985. These included yellow poplar (Liriodendron tulipifera L.), white and green ash (Fraxinum americana L. and F. pennsylvanica Marsh), black cherry (Prunus serotina), common milkweed (Asclepias sp.), poison ivy (Rhus toxicodendron L.), wild grape (Vitas sp.), and blackberry (Rubus sp.). The results indicate "typical foliar injury symptoms prevalent throughout the survey area." Approximately 50% of the yellow poplar trees were injured, with roughly 30% of their leaves showing visible injury. All surveyed species had more than 20% of their surveyed individuals injured. The authors concluded that this survey "demonstrated that ambient concentrations of air pollutants (ozone) are affecting native, sensitive plant species and may be impacting growth of commercial timber such as loblolly pine."

3.2.3 The Great Plains and Rocky Mountain Forests

The Rocky Mountain area extends from Canada to the Mexican border, including 8 states. The neighboring Great Plains area includes 4 states to the east. These 2 regions contain approximately one-third of the land area in the U.S., with almost 141 million acres in forest. The majority of forested land in the Rocky Mountains 'is owned by the Federal Government. Forest resources in the Great Plains states are relatively scarce and won't be further considered in this report. Rocky Mountain Forests total over 136 million acres, or more than 94% of the total forested area in the Great Plains and Rocky Mountains. The most heavily forested states in the Rocky Mountains are Idaho, Colorado, and Utah. The most common forest ecosystems are pinyon-juniper, douglas-fir, ponderosa pine, and fir-spruce.

Pinyon-juniper covers more than 42 million acres in the region. It is the dominant forest ecosystem in Arizona and New Mexico. Occurring in arid regions of the remaining Rocky Mountain states, the pinyon-juniper ecosystem does not appear to be sensitive to current ozone concentrations in the region.

Rocky Mountain Douglas-Fir (Pseudotsuga menziesii var. glauca), while commercially less important than the Pacific coast variety, menziesii, is second only to ponderosa pine in commercial importance in the Rocky Mountains. Over 12 million of the total 17.5 million acres of Douglas-fir are located in Idaho and Montana. Douglas-fir associates with western larch, lodgepole pine, ponderosa pine, western hemlock, Engleman spruce, supalpine fir, aspen, Gambel oak, limber pine, and blue spruce. Douglas-fir dwarf mistletoe (Arceuthobium douglasii), the Douglas-fir beetle (Dendroctonus pseudotsugae), and the spruce budworm (Choristoneura fumiferana) have all caused serious disease epidemics. Douglas-fir has been ranked as insensitive to ozone by David and Wilhour (1976). On the other hand, aspen, a component of the ecosystem, has been noted to be especially sensitive to ozone damage in Utah by Treshow and Stewart (1973).

The ponderosa pine ecosystem covers approximately 16.5 million acres in the Rocky Mountains. This is the most important commercial forest ecosystem in the west, with pure stands occurring in Arizona, New Mexico, and in the Plains state of South Dakota. Over 108 species of pests. attack ponderosa pine. The most important tree-killing insects are several species of pine beetle (Dendroctonus). The western pine beetle (D. brevicomis) is a common cause of mortality in over-mature, decadent trees, but it can also kill apparently healthy trees of all age classes. It has been reported to cause increased mortality on ozone injured ponderosa pine trees in the San Bernardino National Forest in California (Miller, 1983). Another important pathogen is the root rot Fomes Annosus. It attacks pines of all ages, and has been shown to more aggressively colonize ozone injured ponderosa pine trees in the San Bernardino National Forest (Miller, 1983). Ozone injury has not been reported on Rocky Mountain ponderosa pine stands.

3.2.4 The Pacific Coast Forests

Covering the 3 Pacific seaboard states and Alaska and Hawaii, the Pacific Coast forests include almost one third of the forest land in the United States, see Table 3-l. Forests cover 93 million acres, or 46% of the land area in California, Oregon, and Washington. This report does not consider the forest resources of Alaska and Hawaii. Forests in the remaining Pacific states can be divided into two regions: the more humid coastal area and the interior forests to the east.

The area of western Washington, western Oregon, and northwestern California has three major forest ecosystems: redwood, Douglas-fir, and hemlock-sitka spruce. These forests, which receive heavy rainfall and mild winter temperatures, are recognized as being among the most productive in the world. The redwood ecosystem along the California Coast covers only 80,000 acres, but is important for its timer products and scenic and recreational values. Douglas-fir, western hemlock, grand-fir, and western red cedar are important conifer associates in this ecosystem.

The Douglas-fir ecosystem (menziesii) is the most important timber producing ecosystem in this area, dominating the majority of the forested area in Washington, western Oregon, and northern California sites east of the Pacific Coast. Important associates include western hemlock, western redcedar, tanoak, live oaks, and pacific madrone. Hemlock-sitka spruce, found along the Washington-Oregon coastline, is limited to humid sites, covering approximately 6 million acres.

In contrast to the coastal forests, the climate of interior Oregon, Washington, and California is characterized by hot, dry summers and cold winters. The forests of this region are very similar to the Rocky Mountain region. Nine forest ecosystems are found mostly in these interior areas. The most important is the ponderosa pine ecosystem, which covers almost 16 million acres. Approximately one half of this area is in California where ponderosa and Jeffrey pine are found along the west and east slopes of the Sierra Nevada. Stand composition varies, but associates include: western larch, Douglas-fir, sugarpine, true firs, lodgepole pine, and incense-cedar. Ponderosa pine forests are favored for camping, hunting, and ‘hiking because of the open nature of mature stands.

Important non-air pollutant threats to Pacific Coast forests include fire, insects, and diseases. In California, forest inventory data indicate that 3% of the total interior timber volume is lost to fire caused mortality annually (Bolsinger, 1980). Insect mortality is also important. In California, insect caused tree mortality has been estimated at 107 million board feet per year during a period of normal infestation (Bolsinger 1980). Three common root diseases attach and weaken a number of important tree species, including ponderosa pine: Fomes Annosus, Armillaria mellea, and Verticicladiella wagnerii.

In southern California, the coastal chaparral ecosystem, dominated by chamise and manzanita or woodland species, and the coniferous forest ecosystem have received severe exposure to oxidants, while the desert ecosystems in the vicinity of mountain passes connecting the coastal and desert regions have also been exposed to elevated ozone concentrations. Oxidant injury has been extensively documented in the mixed-conifer ecosystem of the San Bernardino Mountains (Kickert, et al., Miller, et al., 1977; 1980, and 1982). Early symptoms of injury in coniferous species were reported in 1970 by Miller and Millecan (1971). In the southern Sierra Nevada USDA Forest Service surveys conducted in 1974 detected increased injury in ponderosa pine at many locations in the Sequoia National Forest. Ozone symptoms have also been reported in Sequoia, Kings Canyon and Yosemite National Parks (Duriscoe 1986a and b, Bennett 1986, Peterson, et al., 1986).

Forest Service surveys conducted in Sierra and Sequoia National Forests indicate that oxidant injury symptoms are now widespread (Pronos, et al., 1978; Pronos and Vogler, 1981). A survey conducted between 1980 and 1982 in Sequoia and Kings Canyon National Parks indicates that 36% of the sampled ponderosa and Jeffrey pine trees had foliar ozone injury symptoms (Wallner and Fong, 1982).

According to Bennett (1986), in 1980-1982, 48% of 280 sampled Ponderosa pine trees expressed foliar injury in Sequoia National Park. By 1985, 58% of 300 sampled ponderosa pine trees in Yosemite National Park expressed foliar injury symptoms attributed to ozone. While numerous trees were reported to exhibit foliar ozone symptoms, the foliar area of ozone injury was very small. For example, Duriscoe (1986b) reported that of the foliar symptoms observed in Yosemite National Park, 2.8%, 10.2%, and 14.6% of the total leaf area were recorded for ozone mottle, other abiotic injury and biotic injury respectively. It should be noted that this level of ozone foliar injury is not likely to be evident to park visitors.

A survey conducted in the Stanislaus National Forest indicates that ozone symptoms occur in the Stanislaus National forest, with at least 10% of the trees on 83% of the surveyed plots exhibiting foliar effects of oxidant exposure (Allison, 1982). While there is growing concern because of oxidant damage occurring to ponderosa pine and associated species at numerous locations in the Sierra Nevada foothills east of the San Joaquin Valley, the majority of evidence relating ozone exposure to forest ecosystem effects has been developed in the San Bernardino Mountains.

The mixed conifer forests in the San Gabriel and San Bernardino Mountain ranges east of Los Angeles have been exposed to oxidant air pollution since the 1950s (Miller, et al., 1982). Most oxidants in the South Coast Air Basin are generated in the Los Angeles Valley. During the summer, a combination of weather patterns and topography contribute to average 24-hour ozone concentrations in the San Bernardino Forest that range from a background of 3 to 4 pphm up to a maximum of 10 to 12 pphm (Miller, et al., 1977). The San Bernardino National Forest forms the principal northern and eastern barrier to the movement of oxidants out of the Los Angeles Basin, and reported oxidant concentrations at San Bernardino National Forest monitoring stations range up to 40% higher than at lower elevation windward urban monitoring stations (Miller, et al., 1977).

In 1971 Miller and Millecan utilized methods developed by Wert (1969) to determine the extent of oxidant injury to ponderosa and Jeffrey pines in diameter classes larger than 30 cm in the San Bernardino National Forest. Pine injury was categorized as heavy, moderate, light or negligible. Ozone injury is identified by a complex of symptoms beginning with a distinct chlorotic mottle occurring on progressively younger needles, followed by reduced needle retention and length, excessive branch mortality, and reduced radial and vertical growth. In extreme cases ozone injury may result in tree mortality (Wallner and Fong, 1982). Miller (1971) estimated that of 1,298,000 affected trees, 82% were moderately affected, 15% severely, and 3% were dead. Miller (1973) subsuquently ranked common tree species for decreasing sensitivity to ozone following laboratory fumigation experiments, see Table 3-3.

The results of the San Bernardino National Forest Research Project (SBNF) conducted by the U.S. EPA from 1973 to 1978 in the pine and mixed conifer forests of the San Bernardino Mountains confirm the relative ozone sensitivities established by Miller (1973). Ponderosa pine was very ozone sensitive, with foliar injury occurring at 24-hour average May-September concentrations of 5 to 6 pphm (Kickert, et al., 1980; Miller, et al., 1982). Jeffrey pine was also sensitive followed by, in decreasing order of sensitivity, white fir, black oak, incense cedar, and sugar pine (Miller, et al., 1982).

The SBNF research project (Miller, et al., 1977; 1982; Kickert, et al., 1980) examined oxidant stress along a gradient of decreasing oxidant concentrations from west to east. As the elevation increases, this gradient is paralleled by a gradient of decreasing precipitation and air temperatures.

Sensitivity to ozone in the SBNF study was defined by the average number of annual needle whorls retained by the trees. Pines exposed to hourly average ozone concentrations ranging from 6 to 12 pphm had their number of annual needle whorls decrease from 2.5 to 2.0 from 1973 to 1978 (Miller, et al., 1982). On the other hand, pines at plots with lower oxidant doses maintained the same number of annual needle whorls or showed

TABLE 3-3

Sensitivity of Selected California Trees to Ozone Fumigation Experiments

Most Sensitive	Intermediate Sensitivity	Tolerant Species
ponderosa pine	Coulter pine	Incense cedar
Jeffrey pine x	Douglas Fir	sugar pine
Coulter pine hybrid Monterey x	Jeffrey pine white fir	giant sequoia
Knobcone pine	bigcone Douglas Fir	
Western white pine		

Source: Miller, 1973

slight increases in retention. The average number of annual needles retained by white fir remained approximately the same during the 1973 to 1978 period, while California black oaks showed a sensitive leaf injury response to ozone each year. Incense cedar and sugar pines evidenced little foliar injury (Miller, et al., 1982).

Chlorotic mottle symptoms appeared on current ponderosa pine needles before they were fully grown following an accumulated ozone dose ranging between 1.0 and 2.0 x 105 ug/m3 excluding background ozone (Miller, et al., 1982). The results for 1973 to 1975 indicated that visible injury symptoms increased in seven pine populations, while five remained the same, and six decreased (Miller, et al., 1977). The diminished photosynthetic capacity resulted in decreased stem diameter and height growth in affected trees. Needle shoot and main stem growth of ponderosa pine and Jeffrey pine saplings maintained in a carbon-filtering greenhouse compared with pine growth in an unfiltered greenhouse was much greater following an exposure period lasting from 1968 to 1973. (Miller, et al., 1977).

The severity of ozone symptoms noted in the SBNF study was clearly related to increased tree mortality. Between 1973 and 1975, the accumulated mortality of ponderosa and Jeffrey pines on the eighteen research sites ranged from 0 to 8.9%, and averaged 2.9% in plots categorized as having slight, moderate, and severe injury. Mortality was less than 0.3% in the remaining plots rated as having very slight or no visible injury. The increase in timber volume from low to high risk management categories was very large at two Forest Service plots between 1952 to 1972. The removal of high risk trees from oxidant damage stands on the San Bernardino National Forest is considered an oxidant related mortality factor (Miller, et al., 1977).

Ozone damage contributes to pine mortality by predisposing pines to insect and pathogen invasion. Air pollution injured ponderosa and Jeffrey pines are more subject to invasion by *Fomes annosus* root disease and western pine bettles (*Dendroctonus brevisomis*). *Fomes annosus* colonizes freshly cut stump surfaces of weakened trees and consequently accelerates the contact between stumps to proximate living root systems (Miller, et al., 1977). In addition, the fungus appears to spread more rapidly in weakened trees than in healthy trees (Miller, et al., 1977). Because *F. annosus* is involved in a significant proportion of both the fir and pine pest mortality in Southern California Forests, the predisposition of stressed trees to *F. annosus* may lead to significantly increased ponderosa and Jeffrey pine mortality. As fewer western beetles are required to kill weakened trees, a given population of western pine beetles can be expected to kill more oxidant weakened trees and propagate at an accelerated rate (Miller, et al., 1977). *F. annosus* and the western pine bettle were commonly noted to be present in the same tree in the San Bernardino National Forest.

The advanced mortality and differential sensitivity of ponderosa and Jeffrey pine on the western slopes of the San Bernardino National Forest have led some investigators to suggest that changes in stand successional development will result in simplification of the forest ecosystem (Miller, et al., 1982). In sites significantly affected by ozone damage, pine needle litter accumulation and a heavy layer of combustible litter accumulation following the pine mortality may contribute to crown fires, eliminating the majority of pines (Miller, et al., 1982). Even without catastrophic crown fires, pine succession has been hindered by the lower seed production of the injured trees and the predisposition of ozone stressed trees to pest infestation.

3.3 Case Study Site Selection and Characterization

To select the valuation study site, three principal criteria were used:

* the site must have experienced ozone caused visible foliar injury to prominent forest tree species;

* the site must have documented ozone and vegetation response data, however sparse or inconclusive; and

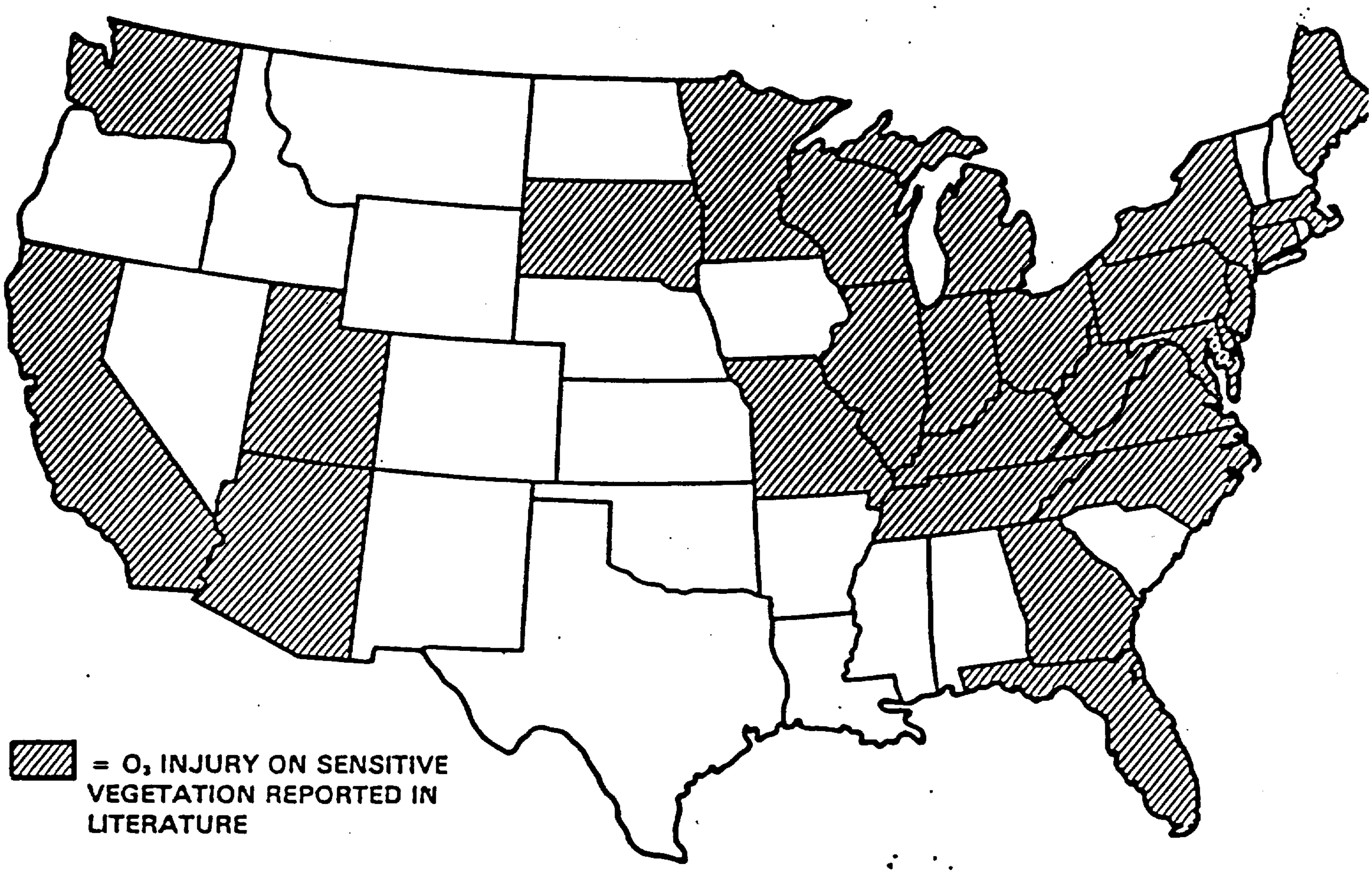
* the site must have important recreational and aesthetic attributes that may be potentially sensitive to ozone caused vegetation injury.

Ozone injury to vegetation has been reported in 27 states, see Figure 3-2 (U.S EPA 1986). As identified in the previous section, injury to natural vegetation is apparently most severe in the San Bernardino National Forest in southern California. Injury to ponderosa and Jeffrey pine, as well as sensitive associated species has been reported at a number of other southern California sites. While recent reports have suggested that Jeffrey and ponderosa pine as well as California black oak have been injured in Sequoia, Kings, and Yosemite National Parks (see Duriscoe 1986a and b), this injury is considerably less severe and less visible to the average visitor than in the San Bernardino National Forest. The San Bernardino National Forest, and the adjacent Angeles National Forest were selected as a potential site.

Consideration of an alternative eastern site focused on those eastern National Park Service lands for which the literature indicated ozone injury to prominent natural vegetation. Ozone injury to sensitive eastern white pine has been widely reported. Injury has been reported from the southern

FIGURE 3-2

States in which some injury to vegetation has occured as reported in the published literature



Source: U.S. EPA Draft Ozone Criteria Document. Chapter 7.

range of the species in Virginia, North and South Caroline, Georgia, Tennessee, and Kentucky north to Maine (Skelly et al., 1983); Anderson et al., 1986; Bennett et al., 1986). Much of the original work reporting white pine field sensitivity was reported in the Shenandoah National Park along the Blue Ridge Parkway (Skelly, and Will 1974; Hayes and Skelly 1977; and Skelly et al., 1977). More recently, Dawson (1985) and Sanchini (1986) have reported ozone injury within Shenandoah National Park.

In addition to Shenandoah National Park, white pine trees in Acadia National Park in Maine have been reported to exhibit ozone caused foliar symptoms (Treshow 1985) and Bennett et al., (1986). Both Shenandoah and Acadia National Parks were evaluated as potential valuation sites for this project and are discussed below, along with the San Bernardino and Angeles National Forests.

3.3.1 San Bernardino and Angeles National Forest

Oxidant injury has been extensively documented in the mixed-conifer ecosystem in the San Bernardino Mountains and, to a leser extent, in the San Gabriel Mountains in the Angeles National Forest, see section 3.2.4. Within a 2-hour drive of approximately 14 million people, the San Bernardino and Angeles National Forests are two of the most important National Forests for recreation purposes in the United States (USDA Forest Service, 1986). The combination of reported high ozone concentrations, documented ozone injury, and the importance of these forests as recreation sites for southern Californians suggests that a substantial fraction of the Nation's ozone related visible foliar damages may be measured at this site.

3.3.1.1 The Angeles National Forest

The Angeles National Forest administers 640,584 acres of National Forest Land in Los Angeles County California. The forest consists of the

San Gabriel and Sierra Pelona Mountains, which are part of the Transverse Range of Southern California. Composed of steep, rugged mountains with vegetation ranging from chaparral to conifers, the forest provides 71% of the available open space in Los Angeles County. Because of the rugged terrain (over two thirds of the forest has slopes steeper than 6O%, with only 4% of the land base having slopes less than 20%) travel is concentrated on a limited number of highways, principally the Angeles Crest Highway. The steep eroded slopes are generally covered with shallow, coarse and infertile soils. Recreational access to much of the forest is limited by the combination of decomposing granitic soils and steep terrain. The forest is exposed to a Mediterranean climate with mild winters and hot, dry summers. Approximately 95% of the average precipitation occurs from November to April, with total amounts ranging from 15 inches on the desert slopes to 40 inches at higher elevations.

The forest supports a variety of plant community types, summarized in Table 3.4. Chaparral is the most common plant community type in the forest, covering approximately 78% of the forest. Of the 503,243 acres covered by chaparral, roughly 65% is comprised of the coastal sage scrub/chamise chaparral type composed of an open association of grasses, sagebrush, ‘and other low-growing species occurring at lower elevations and chamise chaparral, which generally occurs at lower elevations on hot, dry exposures. Mixed and semi-desert chaparral cover roughly 177,595 acres. This community is comprised of a number of species including toyon, hollyleaf cherry, manzanita, mountain mahogany, and scrub oak.

Table 3-4
Vegetation Cover in the Angeles National Forest

Type	Acres	Percent of ANF
Coastal Sage Scrub & Chamise Chaparral	325,148	50
Mixed and Semi-desert Chaparral	177,595	28
Conifer	104,798	17
Oak Wood land	22,033	3
Pinyon-Juniper	10,510	2

The conifer type covers approximately 17% of the forest, and is comprised of a number of different species often occurring in mixed stands, including digger pine, Coulter pine, bigcone douglas fir, ponderosa pine, Jeffrey pine, sugar pine, white fir, and incense cedar. Ponderosa and Jeffrey pine are the most sensitive conifers to ozone injury. Ponderosa pine occurs in relatively pure stands at the lower limit of its elevational range, but with increasing elevation and precipitation, sugar pine, white fir, and incense cedar become common associates. Jeffrey pine grows in relatively pure stands above 6,000 feet, particularly on south and west facing slopes. A great deal of recreational use takes place in the conifer type and ponderosa/Jeffrey pine stands in the Angeles National forest. This is primarily due to the relatively gentle topography on which these stands grow and the development of campgrounds, picnic areas, and other recreational facilities in these areas. Most of the productive conifer habitat with slopes less than 20% has been developed with recreation sites and special uses. Thus, the potential economic damages due to visible foliar injury is greatest in these areas.

Oak woodlands comprise approximately 3% of the forest. Found

TABLE 3-5

Recreation by Activity in Each Ranger District -
Angeles National Forest - 1985
Recreation Visitor Days (in thousands)
(percent of ranger district total recreation visitor days in parentheses)

	Ranger Districts				
Activity	**Arroyo Seco**	**Mt. Baldy**	**Saogus**	**Valyermo**	**Tujunga**
Motor Vehicle Use[1]	497.9 (38.0)	573.4 (32.2)	511.6 (45.0)	238.1 (22.9)	200.9 (25.8)
Camping[2]	273.2 (20.8)	153.3 (8.6)	145.7 (12.8)	161.7 (15.6)	82.2 (10.6)
Organization Camping[3]	156.2 (11.9)	42.8 (2.4)	43.4 (3.8)	207.9 (20.1)	(0.9)
Non-Motorized Travel[4]	107.8 (8.2)	76.1 (4.3)	13.7 (1.2)	52.0 (5.0)	24.1 (3.1)
Picnicking	55.6 (4.3)	209.5 (11.8)	141.0 (12.4)	(0.9)	89.3 (11.5)
Recreation Cabin Use	48.0 (3.7)	329.9 (18.6)	84.2 (7.4)	(0.9)	168.6 (21.7)
Tours, Interpretive Hikes, Etc.[5]	62.0 (4.7)	11.3 (0.6)	(0.2)	10.9 (1.0)	23.3 (3.2)
Swimming and Water Play[6]	26.4 (2.0)	38.6 (2.2)	57.4 (5.1)	74.5 (7.2)	94.3 (12.1)
Winter Sports[7]	27.2 (2.1)	36.6 (2.1)	(0.0)	192.1 (18.5)	-- --
Nature Study[8]	30.1 (2.3)	15.0 (0.8)	(0.0)	(0.1)	(0.1)
Viewing Activities	(0.7)	126.7 (7.2)	11.3 (1.0)	17.9 (1.7)	12.1 (1.5)
Hunting, Big and Small Game	(0.4)	(0.3)	(0.4)	(0.3)	(0.0)
Resort Lodging	(0.3)	68.2 (3.9)	11.4 (1.0)	39.6 (3.8)	-- --

TABLE 3-5 (Continued)

Recreation by Activity in Each Ranger District -
Angeles National Forest - 1985
Recreation Visitor Days (in thousands)
(percent of ranger district total recreation visitor days in parentheses)

Activity	**Ranger Districts** Arroyo Seco	Mt. Baldy	Saogus	Valyermo	Tujunga
Team and Individual Sports	2.4 (0.2)	33.6 (1.9)	44.6 (3.9)	4.2 (0.4)	65.7 (8.5)
Fishing, Warm and Cold Water	1.5 (0.1)	58.3 (3.3)	66.1 (5.8)	13.8 (1.3)	8.8 (1.1)
TOTAL :	1,307.9 (100)	1,776.90 (100)	1,138.l (100)	1,035.3 (100)	777.5 (100)
GRAND TOTAL:					6,035.7

NOTES:

[1] Motor Vehicle Use includes automobile travel, motorcycle and scooter travel, train and bus touring, and aerial trans and lifts.
[2] Camping includes general day camping, auto, trailer, and tent camping.
[3] Organization Camping includes general day and night camping.
[4] Non-Motorized Travel includes hiking and walking, bicycling, and horseback riding.
[5] Tours, Interpretive Hikes, Etc. includes viewing interpretive exhibits, attending talks and programs, unguided touring, guided and unguided walking, viewing interpretive signs, and general information.
[6] Swimming and Water Play includes swimming, canoeing and sailing.
[7] Winter Sports include downhill and cross-country skiing, snow play, snowshoeing, ice skating, sledding and tobogganning.
[8] Nature Study includes nature study, mountain climbing, and gathering forest products.

principally along drainage bottoms and at middle elevations on northern exposures, dominant species include scrub oak, canyon live oak, interior live oak, California live oak, and California black oak. Oak woodlands are an important source of recreational and wildlife values on the Angeles National Forest. There is, however, little information regarding the sensitivity of oaks to ozone. In some stands, the heavy dispersed and developed recreation has resulted in the loss of understory oak trees, the loss of litter under the trees, the breaking of branches for firewood, and vandalism. Approximately 20% of the 3,000 cords of firewood produced annually on the forest come from dead oak trees.

Roughly 2% of the forest is comprised of pinyon/juniper pine, which occurs primarily on the north slopes of the San Gabriel Mountains between 3,000 and 5,000 feet. Little is known about the sensitivity of these species to ozone.

Recreation

In 1985 over 6 million recreation visitor days were reported on the Angeles National Forest, Table 3-5. USDA Forest Service data indicate that recreational use increased at a 13% annual average between 1980 and 1985. Over the past five years dispersed day use recreation has increased significantly. Automobile travel has increased by 38%, motorcycle use by 29%, recreational cabin use by 25%, picnicking by 26%, and swimming and waterplay by 24%. In 1985, 53% of forest recreation was dispersed, e.g., hiking, picniking, driving for pleasure, and off road vehicle use. Forty two percent was developed, camping, boating, etc. Only 1% of the total recreation took place within designated wilderness within the Angeles National Forest. In 1985, motor vehicle use accounted for 38% of all recretion on the forest, Table 3-5. Motor vehicle use, camping, and non-motorized travel comprised approximately 80% of recreation use in 1985. The USDA Forest Service anticipates that recreational demand will increase by approximately 30% by the year 2000. The forest currently has 773 recreational residences, 35 organizational camps, and 10 resorts and lodges under permit.

3.3.1.2 San Bernardino National Forest

The mixed conifer forests in the San Bernardino Mountain ranges east of Los Angeles have been exposed to oxidant air pollution since the early 1950's. Foliar symptoms of chronic ozone injury to ponderosa and Jeffrey pine are visible as far as 120 km east of central Los Angeles (Miller, 1983). Extensive visible injury and a concern for possible adverse effects on forest ecosystem stability has led to extensive investigation and documentation of foliar injury associated with oxidant exposures. This literature has been discussed above. For a review of this work, see Miller (1983).

The San Bernardino National Forest covers 818,999 acres within San Bernardino and Riverside Counties. The San Gabriel and San Bernardino Mountains, which constitute the northern part of the forest, are part of the Transverse Ranges, and lie in an east to west direction. The forest is bounded on the west by the Angeles National Forest. On their southern boundary these mountains adjoin the Los Angeles Basin and are characterized by deep canyons and steep slopes that rise to broad flat ridges and occasional high peaks. To the north and east they slope more gradually into the Mojave Desert. The southern portion of the forest includes the San Jacinto Mountains, which as part of the Penninsular ranges, extend southward for twenty-five miles to the Santa Rosa Mountains at the southern boundary of the forest. Approximately 90% of the soils on the forest granitic. Most soils are coarse, well drained, and have low water holding capacities. As almost half of the forest exceeds 50 percent slope, soils are often shal1ow and erodible. Deeper soils are generally found on the flatter regions of the forest to the north. Precicipation varies dramatically across the forest. Annual rainfall ranges from 2 to 4 inches on the desert side of the forest to 30 inches at the higher elevations.

Wide variation in elevation, aspect, topography, and climatic contribute to a large diversity in plant species and communities in the San Bernardino National Forest. Recent vegetation classifications have divided forest plant and species communities into 6 categories: chamise chapparal, woodland chapparal, coniferous forest, and pinyon juniper woodland.

Table 3.6

Vegetation Zones in the San Bernardino National Forest

Vegetation Zone	Area (Acres)	Percentage of SBNF
Chamise and Soft Chaparral	122,850	15
Chaparral	163,000	20
Hard woods	188,370	23
Conifer	171,990	21
Pinyon-Juniper	163,800	20

On the south and west facing slopes of the forest, the alluvial fans and slopes below 5,500 feet are covered with a dense, impenetrable chaparral. These lands comprise a major part of the forest resources. Chaparral often covers steep nutrient poor soils. At lower elevations, dominant species include California sagebrush and black sage; at intermediate elevations, ceanothus and redshanks: and scrub oak and manzanita at higher elevations. Scattered residences, ranches, and small communities are located on private lands in the chaparral zone. The growth of urban centers in the lower foothills and valleys adjacent to the erodible, steep slopes combined with the climate and accumulated fuels in the chaparral contributes to the high risk of wildfires.

Above the chaparral, roughly 23% of the forest is covered with hardwoods between approximately 5,000 to 6,000 feet. Hardwoods also extend into the chaparral zone along stream courses, providing a dense canopy with little understory vegetation. Dominant hardwood species are canyon live oak and interior live oak.

The conifer zone extends from approximately 5,500 to 11,000 feet. Miller, et al., (1977) used aerial photography to map the coniferous zone, and identified five forest types. These were the ponderosa pine type, ponderosa pine-white fir type, the ponderosa-Jeffrey pine type, Jeffrey pine-white fir type, and the Jeffrey pine type. Incense cedar is frequently found in the ponderosa pine types. Sugar pine and California black oak are important components of all five conifer types. A west to east transect through the forest shows that the ponderosa pine types dominate the conifer zone until the higher elevations are reac ed near Butler Peak, where they give way to Jeffrey pine. The popular recreation areas, Lake Arrowhead and Big Bear Lake, are in different conifer zones. To the west, Lake Arrowhead is in a ponderosa pine dominated type. This area is at a lower elevation and recieves more annual precipitation than the Jeffrey pine dominated conifer forest enar Big Bear Lake.

The eastern, desert facing, slopes of the forest are comprised of pinyon and juniper pines, interspersed with shrub communities. Dominant species include one-needle pinyon, Parry pinyon pine, western Juniper, California juniper, and joshua tree. Ozone concentrations in this area of the forest are typically much lower than those fund further to the west, and foliar response to ozone has not been rigorously surveyed or tested.

Recreation

The San Bernardino National Forest is one of the most heavily used in the nation. In 1985, approximately 5.5 million recreation visitor days were recorded on the forest, Table 3-7. The majority of this use occurred within the Big Bear and San Gorgonio Range Districts, which accounted for a combined total of 64% of the recreation on the forest. Motor vehicle use was the most popular recreational activity, accounting for a total of 43% of all recreation. Developed recreational facilities are generally located in oak woodlands and conifer stands. Summer home use, lodges, resorts, private camps, and clubs accounted for over 1 million recreation visitor days in 1982. Dispersed recreation has been increasing moderately across the forest, in 1982 it accounted for 61% of all recreation. Off Road Vehicle use and demand for additional recreational opportunities has grown significantly, but is unimportant in the conifer zone due to access limitations.

3.3.2 Shenandoah National Park

Shenandoah National Park is the northernmost of 3 National Parks located along the Appalachian Mountains. The 305 square mile park straddles the Blue Ridge Mountains and is known for its rolling hills and elevated vistas. It is the Nation's first "recycled park", as most of the Park's biological resources were severely depleted due to previous

TABLE 3-7

Recreation by Activity in Bach Ranger District -
San Bernardino National Forest - 1985
Recreation Visitor Days (in thousands)
(percent of Ranger District total recreation visitor days in parentheses)

	Ranger Districts				
Activity	**Arrowhead**	**Big Bear**	**Cajon**	**San Gorgonia**	**San Jacinto**
Motor Vehicle Use[1]	601.3 (60.8	956.7 (50.7)	161.6 (37.0)	473.9 (29.5)	156.5 (28.9)
Camping[2]	80.6 (8.2)	138.7 (7.5)	143.2 (32.7)	250.9 (15.7)	130.1 (24.0)
Organization Camping[3]	48.3 (4.9)	- - - -	- - - -	308.6 (19.3)	(1.0)
Non-Motorized Travel[4]	18.8 (2.0)	133.9 (7.1)	26.2 (5.9)	213.3 (13.2)	82.5 (15.3)
Picnicking	24.4 (2.5)	61.6 (3.3)	10.5 (2.4)	36.3 (2.3)	35.3 (6.5)
Recreation Cabin Use	20.9 (2.1)	230.1 (12.2)	31.8 (7.3)	116.9 (7.3)	(1.2)
Tours, Interpretive Hikes, Etc.[5]	21.9 (2.2)	(0.5)	(0.0)	28.0 (1.7)	(1.0)
Swimming and Water Play[6]	17.9 (1.8)	(0.0)	37.4 (8.6)	37.5 (2.3)	(1.2)
Winter Sports[7]	124.5 (12.5)	303.1 (16.1)	(0.5)	15.2 (0.9)	16.2 (3.0)
Nature Study[8]	(0.5)	12.9 (0.6)	(0.4)	65.4 (4.1)	20.7 (3.8)
Viewing Activities	12.1 (1.2)	(0.4)	- - - -	16.2 (1.0)	53.7 (9.9)
Hunting, Big and Small Game	(0.2)	4.7 (0.2)	(0.6)	(0.2)	(1.0)
Resort Lodging	- - - -	21.4 (1.1)	- - - -	(0.1)	- - - -

TABLE 3-7 (Continued)

Recreation by Activity in Each Ranger District -
San Bernardino National Forest - 1985
Recreation Visitor Days (in thousands)
(percent of ranger district total recreation visitor days in parentheses)

	Ranger Districts				
Activity	**Arrowhead**	**Big Bear**	**Cajon**	**San Gorgonia**	**San Jacinto**
Team and Individual Sports	8.1 (0.8)	0.4 (0.0)	17.3 (4.0)	16.1 (1.0)	3.0 (0.5)
Fishing, Warm and Cold Water	3.0 (0.3)	3.2 (0.2)	2.4 (0.5)	20.7 (1.3)	14.5 (2.7)
TOTAL :	989.3 (100)	1,883.0 (100)	437.4 (100)	1,605.1 (100)	541.8 (100)
GRAND TOTAL:					5,456.6

NOTES:

[1]Motor Vehicle Use includes automobile travel, motorcycle and scooter travel, train and bus touring, and aerial trans and lifts.

[2] Camping includes general day camping, auto, trailer, and tent camping.

[3] Organization Camping includes general day and night camping.

[4] Non-Motorized Travel includes hiking and walking, bicycling, and horseback riding.

[5] Tours, Interpretive Hikes, Etc. includes viewing interpretive exhibits, attending talks and programs, unguided touring, guided and unguided walking, viewing interpretive signs, and general information.

[6] Swimming and Water Play includes swimming, canoeing and sailing.

[7] Winter Sports include downhill and cross-country skiing, snow play, snowshoeing, ice skating, sledding and tobogganning.

[8] Nature Study includes nature study, mountain climbing, and gathering forest products.

TABLE 3-8

Top 10 States of Origin for 1984 SNP Visitors

State	% of Total Visitors
Virginia	37.9%
Maryland	13.9
Pennsylvania	7.2
New ,Jersey	5.1
New York	4.5
Florida	3.6
North Carolina	2.2
Connecticut	1.9
California	1.5
0ther	19.1

Source: 1984 Shenandoah National Park Point-of-Origin Survey

TABLE 3-9

Total Visits to Shenandoah National Park by Month
1984-1986

	1984	1985	1986
January	24,063	18,097	33,433
February	42,134	30,863	21,280
March	62,564	74,612	80,498
April	129,729	129,036	121,782
May	193,863	187,216	192,088
June	212,397	234,165	193,112
July	269,090	271,826	266,141
August	266,238	250,990	283,224
September	218,196	248,904	
October	390,867	386,852	
November	94,892	91,440	
December	40,120	36,965	
Total :	1,944,153	1,960,966	

Source : National Park Service Monthly Public Use Reports.

agricultural and timber exploitation. Shenandoah is a readily accessible mountain park with close proximity to the large population centers of Baltimore, Washington, and Richmond. Within the Park there are over 400 miles of trails, campgrounds, and lodges. The Appalachian Trail runs along the crest of the Blue Ridge, adjacent to Skyline Drive. Skyline Drive, a 105 mile long highway that twists through the center of the Park, is its most prominent feature. Most of the major features of the Park can be observed or reached from this roadway.

A 1981 survey of Shenandoah visitor preferences (Popino 1981) showed that 55.6% of those surveyed were just driving through the Park, without planning any stops. Two-thirds of those surveyed travelled less than 100 miles to reach the Park. Results of a 1984 point-of-origin survey conducted by the National Park Service showed that the majority of visitors were from Virginia and Maryland, see Table 3-8.

As suggested above, most recreational activity in the Park is oriented towards scenic driving (Popino 1981). Popino's survey Pound the 5 most preferred and participated in activities to be: driving on Skyline Drive, scenic viewing, walking and hiking, camping, and photography. Other popular activities are picnicking, backpacking, rockclimbing, horseback riding, and bicycling. Table 5-9 summarizes total visitation data for Shenandoah National Park by month Prom January 1984 through August 1986.

3.3.2.1 Shenandoah National Park's Forest Resources

The forest in Shenandoah National Park is extremely diverse and the broad distribution of species creates numerous complex interactions among its' various plant communities. Comprehensive vegetation mapping of the Park's forested resources has not been completed. However, a recent survey (Sanchini, 1986b).

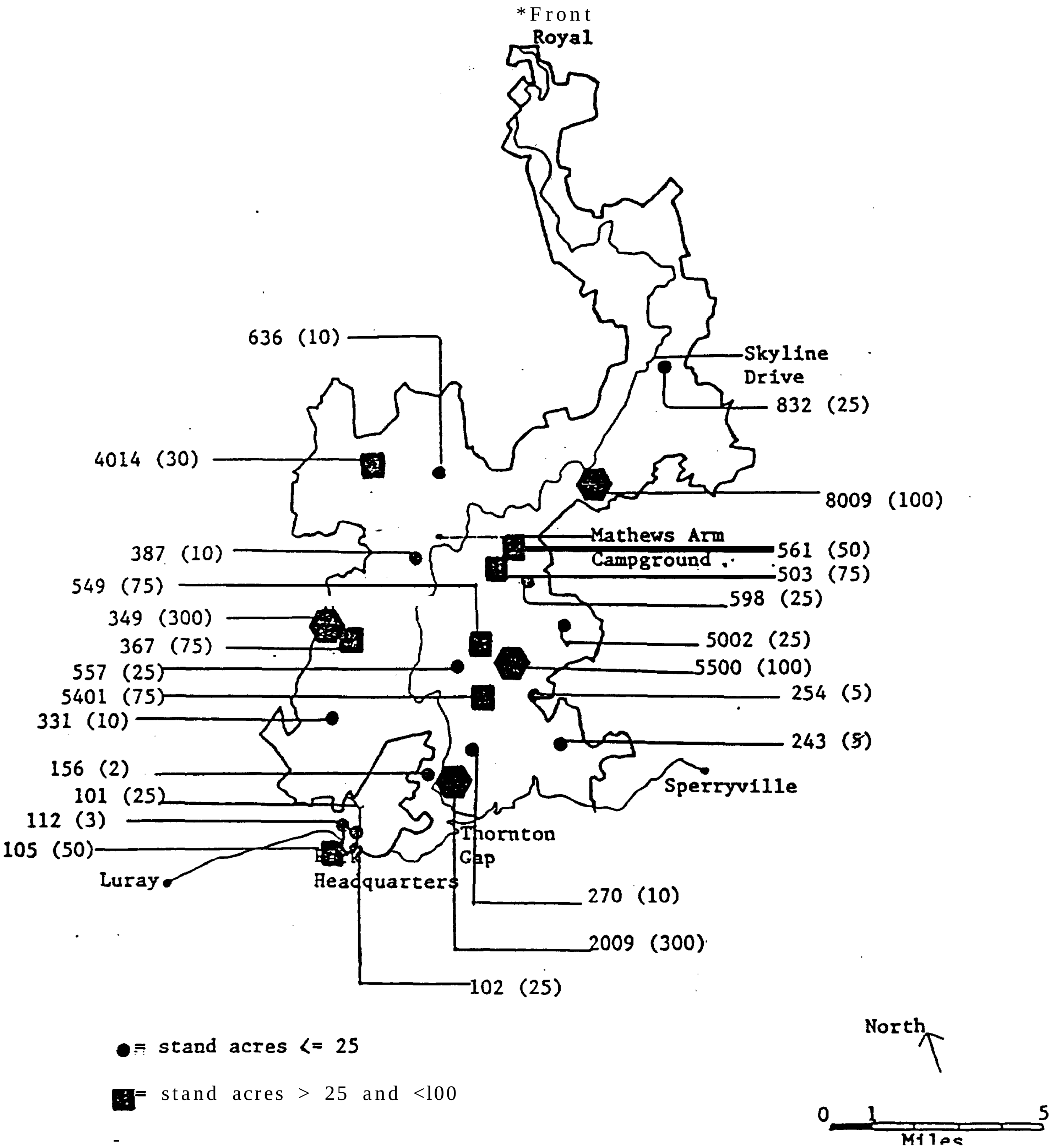
of the Park's Northern District, encompassing 55,000 acres of the Park from Front Royal south to highway U.S. 211, provides useful information on the distribution and density of forest species in the Park (Teetor, 1986). Fifty-five different forest types were identified during the survey, of these Teetor identified 7 major cover types. The most common forest cover type in the Northern Region is chestnut oak, comprising 32% of the forest cover. Red oak, red oak/basswood/ash, yellow poplar, black locust, pine, and hemlock comprised respectively 11%, 26%, 16%, 7%, 6%, and les than 1% of the forested area.

The location of eastern white pine stands in the Northern Region of the Park is shown in Figure 3-3. The Blue Ridge Parkway can be seen as the continuous line drawn on a vertical axis through the map. As shown, the majority of eastern white pine stands are located some distance from the parkway. According to Teetor, only 50 plots out of the sample of 787 in the North District contain white pine, or 6.4% of the sample. In only 6 of those stands does white pine make up greater than 50% of the canopy. The survey indicated that white pine comprised less than 5% of the canopy in 10 stands, greater than 5%, but less than 25% in 24 stands, and between 50% and 75% in 8 stands (Teeter, 1986b). The Central Region has approximately the same density of white pine as the North, however, the Southern Region has less eastern white pine (Teeter, 1986b). White pine is an associate in other cover types, and is present in the chestnut oak and red oakbasswood/ash ecosystems as well as the pine. However, white pine is not common outside of the isolated stands described above. One biologist familiar with white pine in Shenandoah National Park estimated that there are 10-l2 white pine per linear mile outside of the stands described above (Sanchini, 1986b).

FIGURE 3-3

Location of stands containing white pine in the North District ‘Shenandoah National. Park, VA 1986

(Numbers in parenthesis indicates approximate acres of stand. Number to left of parenthesis is the stand reference number)



3.3.2.2 Reported Ozone Caused Foliar Injury in Shenandoah National Park

Ozone injury has been widely reported for diverse plant species in Shenandoah National Park. Skelly, et al., (1983) reported results from nearly 12 years of research on the effects of ozone on natural vegetation along the Blue Ridge Parkway. In addition to eastern white pine, ozone symptoms were noted on tuplip poplar (Liriodendron tulipfera L.), green ash (Fraxinum Pennsylvania, Marsh), hickory (Carya spp.), black locust (Robinia pseudoacia L.) table mountain (Pinus pungens, Lamb), Virginia (P. virginiana, Mill.), and pitch pines (P. rigida, Mill), hemlock (Tsuga canadensis L.), wild graphe (Vitis spp.), and Milkweed (Asclepias syriaca L.).

Ozone injury to eastern white pine was evaluated by Skelly and Johnston (1978) at 32 plots along the Blue Ridge Parkway. Skelly (1979) reported varying injury levels in nine surveys during the period 1977-1979. Tolerant trees comprised from between l-38%, intermediate 58-76%, and sensitive l-21% of the sampled eastern white pines. Average values were 22%, 67%, and 1%. Trees were assigned to sensitivity categories based on subjective appraisals of the percent of total foliar injury. Very high ozone levels were recorded during July 14 to 24, 1977, when peak hourly ozone concentrations reached 0.166 ppm. Hayes and Skelly (1977) reported that by late August, senstitive eastern white pines had 80% necrotic leaf tissue, with the remainder being mottled.

Dawson (1985) performed a series of studies in Shenandoah National Park in 1983 to evaluate the possible effects of ozone on 23 stands in the cove hardwood forest, red oak, forest, oak pine forest and eastern white pine stands. While a thorough search for ozone caused air pollution injury was only conducted for eastern white pine, populations of 3 sensitive tree species -- eastern white pine, white oak and sugar maple -- appeared to be normal, with sufficient regeneration and normal mortalty. Visible foliar injury on eastern white pine was reported for only 5 of 511 sample trees. Trees were assigned injury scores and to sensitivity classes using the same system as Skelly (1979). According to Dawson, sensitivity values were 51.5% tolerant, 48.5% intermediate, and 1% sensitive. Using 3 higher elevation sites, Dawson reported eastern white pine percentages in the three sensitivity classes as 36%, 62.5%, and 1.5%. Unlike the results reported by Hayes and Skelly (1977) no tree was reported to have more than 10% foliar necrosis. This level of injury, unlike the reported 80% necrosis is unlikely to be evident to Shenandoah National Park visitors for 2 reasons. First, this damage is visually very slight and appears to be within bounds of normal forest variation. Second, damaged trees -- when they occur -- appear as individuals and not stands creating a large area of visible foliar injury.

Sanchini established biomonitoring plots near ozone monitoring stations in the Park in 1985. Yellow poplar, white oak, and red maple were evaluated. According to Sanchini (1986a) all of the trees were reasonably healthy. Foliar ozone injury in July 1985 averaged .1% overall, and was observed on 3% of the yellow poplar, 6% of the white oak, and 9% of the red maple. However, even on trees with ozone injuries, the average percent leaf area affected was very low, varying from 1.8% for white oak to 3.1% for yellow poplar.

During August and September of 1986 Sanchini conducted a survey of eastern white pine trees in Shenandoah National Park. Preliminary results suggest that no single tree exhibits foliar injury greater than 30%.

The majority of foliar injury symptoms are located along the Blue Ridge Parkway. This result is similar to Dawson's 1985 findings.

During September 15 and 16, 1986, a field visit was conducted to record the visible foliar injury on senstitive tree species. Pine and deciduous trees were viewed throughout the Northern and Central Sections of the Park. There was widespread evidence of ozone mottle on common milkweed. Injury was also noted on white ash, poison ivy, and tulip poplar. However, because of the beginning of the fall foliage dis play, these symptoms could only be distinguished from normal fall senescence with close inspection. It seems improbable that the foliar injury levels expressed on deciduous foliage in Shenandoah National Park during this visit would be perceptable to most visitors, and therefore would be likely to have only a limited affect on park visitors.

Careful attention was paid to the foliar condition of eastern white pine along the Blue Ridge Parkway. Sites were visited with a contractor performing a survey of eastern white pine injury for the National Park Service. No tree sampled exhibited greater than 30% foliar injury. While numerous pine trees, including Table Mountain and Virginia pines, exhibited chlorosis on older needle worls, this damage was attributed either to the drought or normal variabiity in needle condition. In many cases, second year needles on eastern white pine exhibited chlorosis that was attributed to natural fall sensecence or drought. In all cases, purported ozone injury to eastern white pine was difficult to perceive from the Blue Ridge Parkway.

In summary, the forest in Shenandoah National Park is apparently healthy from the perspective of the lay visitor or vacationer. Ozone caused injuries during the fall of 1986 were very subtle on eastern white pine and other sensitive species. It seems likely that the Gypsy Moth infestation will cause both more visible injury and inconvenience to park visitors. There is no evidence that ozone levels are influencing the sensitivity of tree foliage to the gypsy moth. It should be noted that ozone levels recorded during 1986 at Shenandoah National Park Monitoring stations were considerably below those noted in previous studies, see Skelly, et al. (1983). Reduced ozone levels in the park may be related to the level of symptom epression observed in the fall of 1986. In addition, the drought conditions experienced over much of the east coast may have influenced the expression of ozone foliar symptoms.

3.3.3 Acadia National Park

Acadia National Park is the only designated natural area administered by the U.S. Park Service in New England. Located on the Maine cost, which reaches approximately 350 miles from Kittery to Eastport, Acadia comprise 25% of the publicly owned coastline in Maine. Comprising 34,573 acres, the park is travered by a range of granitic mountains with elevations ranging up to 1,500 feet. Glacial erosion has left the northern slopes of these mountains rounded, but the southeast slopes are steeper, often being broken into a series of cliff-like steps. The tops of these mountains are generally bare, except for low-growing vegetation. The lower slopes are covered with red spruce and balsam fir forests. The glacial valleys between the mountains contain deep, elongated lakes and ponds, and irregularly rolling hills interspersed with bogs. The vegetation on these hills conssits primarily of a mixture of eastern white pine, birch, beech, northern red oak, maple, and red and white spruce. Acadia's 40 miles of shoreline and 10-12 foot tidal range present visitors with a rich assemblage of marine plant and animal life.

Only 2% of the land in Maine is available for the general public for outdoor recreation purposes. Ninety percent of the wildlands in Maine are controlled by 16 corporations and 4 families. Acadia comprises approximately 8% of this available resource, and has a major impact on the tourism in the surrounding area. Visitation data for Acadia National Park indicate that there were approximately 3.9 million visits to Acadia in 1985, of these approximately .05%, or 183,000 were non recreational. The number of reported non-recreational visits has remained constant since 1983. Table 3-10 shows visitation data, by month, recorded by the Park Service for the years 1984, 1985, and 1986 through August. Summer visitation is considerably larger than winter, with the months of April, May, October, and November being roughly similar.

Preliminary results from a survey that is being conducted for the National Park Service (Manning, 1986) indicate that the majority of visitors to Acadia are from New York, with Maine and Massachusetts accounting for slightly less visitation, see Table 3-11. Over 52% of the respondents had visited Mt. Desert Island previously. Respondents reported that the most important factor in deciding the time to visit Acadia was their work schedule, however both weather conditions and children's school schdules were listed as being important. Respondents participated in a wide variety of activities with sightseeing being rated as the most commonly engaged in activity, see Table 3-12. Hiking and viewing the scenery were ranked as being the most important activities, see Table 3-13.

TABLE 3-10

Total Visits to Acadia National Park by Month
1984-1986

	1984	1985	1986
January	39,525	46,612	43,621
February	41,437	38,513	48,307
March	52,541	61,567	62,642
April	244,890	276,662	273,178
May	287,216	357,027	426,856
June	474,760	448,178	502,087
July	805,644	741,203	733,116
August	881,095	831,546	824,525
September	458,874	466,278	
October	377,125	388,289	
November	209,987	222,222	
December	45,293	50,497	
Total:	3,918,387	3,928,594	

Source: National Park Service Monthly Public Use Reports.

Survey respondents agreed that the environmental quality of the Park's resources were being well preserved and that the air quality in the Park is "very high." Seventy-four percent strongly agreed with the statement that "preserving the environmental quality of Acadia National Park is extremely important." Approximately 82% of the respondents strongly agreed with the statement that "I enjoyed my visit to Acadia National Park."

3.3.3.1 Acadia National Park's Forest Resources

Table 3-14 lists 14 different terrestrial ecosystem types found in Acadia National Park. As can be seen, Acadia's forests are relatively diverse, and unlike either Shenandoah National Park or the San Bernardino and Angeles National Forests. These ecosystems are strongly influenced by the sea, whose close proximity directly affects the composition of forest communities.

The dominant forest type in Acadia National Park is the spruce-fir forest. Dominant species include the red spruce, balsam fir, and white spruce. There are lesser numbers of red maple, white birch, and other species. The percenage of spruce-fir has been correlated with the intensity of the marine influence on the site. Consequently, spruce-fir is found at the borders of the island and on most of the smaller islands. In addition to the effects of the sea, fire and wind are also important environmental factors in the spruce-fir type on Acadia. The results of a 1947 forest fire are still highly visible, as much of the organic soil, as well as many spruce-fir trees were destroyed.

Further inland, eastern white pine and deciduous trees predominate. Known as the mixed hardwood-conifer forest, this forest has 2 different forms in Acadia: the northern hardwoods and the northern hardwood-spruce

TABLE 3-11

Residence of Survey Respondents

State/Country	Percent
New York	14.3
Maine	14.2
Massachusetts	12.5
New Jersey	8.3
Pennsylvania	7.3
Conneticut	6.5
Maryland	3.6
Michigan	3.6
Ohio	3.4
New Hampshire	2.6
Virginia	2.5
Florida	2.5
Illinois.	2.0
Rhode Island	1.3
Indiana	1.1
Other (20)	10.4
Canada	3.2
Other (England, West Germany, Sweden, Belgium, Switzerland)	.7

Source: Acadia National Park Visitor Use Project: Conducted by the National Park Service in Cooperation with the University of Vermont.

TABLE 3-12

Participation of Acadia National Park Survey Respondents in Selected Activities

Activity	Percent
Sightseeing	96
Viewing the Scenery	94
Walking	83
Hiking	72
Photography	71
Shopping	70
Picnicking	54
Nature Study	49
Camping	48
Boating	34
Bicycling	20
Tour Participant	19
Fishing	10
Horseback Riding	7
Skiing	3

Source : Acadia National Park Visitor Use Project: Conducted by the National Park Service in Cooperation with the University of Vermont.

TABLE 3-13

Most Important Recreational Activities
of Acadia National: Park Survey Respondents

Activity	Percent
Hiking	48
Viewing the Scenery	42
Camping	36
Sightseeing	26
Nature Study	24
Walking	20
Photography	15
Bicycling	14
Picnicking	9
Boating	9
Tour Participant	7
Shopping	4
Fishing	4
Skiing	3
Horseback Riding	3

Source: Acadia National Park Visitor Use Project: Conducted by the National Park Service in Cooperation with the University of Vermont.

TABLE 3-14

Major Plant Communities of Acadia NationaI Park

	Approximate Area in Acres
Spruce-Fir forest	10,000
White pine-birch-maple-spruce forest	7,000
Birch-Aspen-Blueberry forest	5,000
Northern Red Oak-Birch forest	3,500
Birch-Beech-Maple forest	2,000
Pitch Pine-Blueberry	1,000
Black spruce-Sphagnum bog	1,000
Sedge-Alder marsh	1,000
Cedar-Maple forest	400
Scrub Oak-Pitch Pine-Blueberry	200
Jack Pine-Blueberry	200
Water Lily-Water Shield (fresh water ponds)	100
Grass-Sedge marsh	100
Beach Grass-Beach Pea	3
Total:	31,503
Rockland or open water	3,000
Rockweed-Kelp (Intertidal Zone)	500
	35,003

Source: Acadia National Park Visitor Use Project: Conducted by the National Park Service in Cooperation with the University of Vermont.

forest types. In the northern hardwood forest, sugar maple, red maple, mountain maple, beech, and hemlock are the dominant species. Other components include striped maple, red maple, mountain maple, white ash, and eastern white pine. In the northern hardwood-spruce forest, the dominants include sugar maple, yellow birch, beech, red spurce, and hemlock. Associates are balsam fir, red maple, mountain maple, white birch, white pine, and red pine.

Roughly 10,000 acres of spruce-fir forest were destroyed by fire in 1947. As a result, large sections of mountains in Acadia have a sparse vegetation composed of stunted trees, shrubs, herbs, and grasses. Much of the granitic bedrock of Mt. Desert Island is still exposed, although pioneer species have established themselves over large areas. In some places successional tree species including birch, pin cherry, poplar, and sumac are establishing themselves.

3.3.3.2 Reported Ozone Caused Foliar Injury in Acadia National Park

Eastern white pine is one of the most prominent plant species in Acadia National Park. As noted by Treshow (1985) it is most commonly found in mixed stands of spruce and hardwood forests, where mature eastern white pine rise will above the forest canopy. Individual eastern white pine trees are prominent along the carriage paths, roads, and lake shores. This prominence gives eastern white pine a visual dominance and imparts a quality to the environment that far exceeds its numerical distribution in Acadia's forests (Treshow, 1985). Foliar injury on white pine on Acadia was first attributed to ozone by S.B. McLaughlin in 1983 (Bennett, et al., 1986).

In response to McLaughlin's 1983 statement, twenty white pine biomonitoring plots were established in Acadia by Treshow during August

TABLE 3-15

Frequency of Ozone Injuries on white pine (*pinus strobus*) in Permanent Pine Plots in Acadia National Park (1985)

	% with no Injuries	% with 0%<Inj<10%	% with lO%<Inj<30%	% with >30%
Total Ozone Injury	9.5	80.9	9.3	0.3
Chlorotic Mottle	44.9	52.0	3.1	0
Fleck	47.6	51.4	1.0	0
Tipburn	46.9	50.4	2.7	0

Chlorotic Mottle has been described by Jacobson and Hill 1970, Miller and Evans 1974, and Malhotra and Blauel 1980. Symptoms described as: yellow and tan blotches on the needle surface, margins of spots and blotches indistinct, translucence of leaf mesophyll often detectable.

Fleck has been described by Costonis and Sinclair 1969 and Costonis 1970, 1971. Symptoms described as: minute silvery flecks scattered over the stomata1 surfaces of needles. Host often found on middle third of needle. Also seen on the ridge of tissue between stomata1 surfaces. When dense flecks coalesce to produce elongated bleached areas or tan lesions on these surfaces.

Tipburn has been described by Costonis and Sinclair 1969, Evans and Miller 1972, Jacobson and Hill 1970, and Malhotra and Blauel 1980. Symptoms described as: reddish-brown banding of the needle tissue, most often progressing from the needle tip to the base. Trees sometimes show uniform amount of injury to all needles in whorls, but often only scattered needles are affected in whorls.

Source : Sanchini 1986 c.

through November in 1984. According to Treshow, necrosis and chlorosis symptoms attributed to ozone were located on eastern white pine in every biomonitoring plot. Foliar injury symptoms were' relatively uniform throughout the plots. Chlorotic mottle symptoms were found on 12%, 58%, and 22% of the 1984, 1983, and 1982 needles. Twelve percent, 9%, and 3% of the eastern white pine had needle necrosis on the 1984, 1983, and 1982 needles. While lichens and other plant species typically sensitive to elevated ozone concentrations showed no symptoms of ozone injury, Treshow concluded that the "symptoms on this species (pinus strobus) were definitive." (Treshow, 1985).

In August and September of 1985, 294 white pine were resampled on the 20 plots established in 1984. Roughly 90% of the sampled trees had ozone injury. However, only 0.3% had symptoms covering more than 30% of the sample tree's foliage. Although the relative incidence of injury was high, relatively little of the needle area was affected by injury symptoms, on average less than 5% of the sample's needle surface.

Chlorotic mottle accounted for approximately 35% of the total ozone injury on eastern white pine, but affected only an average of 1.8% of the total needle surface (Sanchini, 1986c). This result is similar to that reported by Treshow (1985), of 58% mottle on the 1983 needles. As shown in Table 3-15, 53% of the trees exhibited fleck injury, but only an average of 1.2% of the needle surface was affected. Similarly, 53% of the eastern white pine sample had tipburn, but again only over a very small fraction of the leaf surface, an average of 1.2% (Sanchini, 1986c).

Bennett, et al. (1986) report results of a workshop held to determine the cause of the injury no ted to eastern white pine in the previous studies. Workshop participants evaluated visible foliar injury on 10 severely injured white pine. They concluded that the severe needle tip necrosis occurring in Acadia National Park may be caused by either ozone or semi-mature tissue needle blight. Ozone may or may not be related to semi-mature tissue needle blight. Chorotic symptoms on white pine foliage, while much less visible than the tip necrosis, were regarded as being diagnostic of ozone injury.

During September 18 and 19 of 1986 a field visit was made to determine the extent of visible foliar injury to white pine in Acadia National Park. A number of the eastern white pine plots established by Treshow were visited. Foliar injury on white pine in these plots was visible. In some cases tree foliage appeared to be generally necrotic and severely injured: These levels of injury are clearly manifest to forest visitors. However, these heavily injured trees are widely dispersed and do not appear to be concentrated in a stand or particular area within the park. Consequently, visitors may see foliar damage expressed on one tree within an apparently healthy and diverse stand. As was the case in Shenandoah National Park, fall chlorosis due to natural senescence of the white pine needles was common and highly visible. There was no fully diagnostic evidence of ozone injury on other park vegetation.

3.4 Conclusion

In summary, three sites, (1) The Angeles and San Bernardino National Forest, (2) Shenandoah National Park and (3) Acadia National Park were considered for quantification of aesthetic forest damage from ozone air pollution. Although all three sites have clear documentation of physical injury, only the Angeles and San Bernardino National Forests have levels of visible injury which will likely affect lay perceptions of scenic beauty.

Perception of forest scenic beauty is discussed in the next chapter. Since economic use values depend on perception of physical injury, not on physical injury itself; use values can only be estimated for the Angeles and San Bernardino National Forests at this time. Thus, this site was chosen for detailed damage estimation.

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4.0 PERCEPTION OF FOREST SCENIC BEAUTY

4.1 Introduction

Considerable research on evaluating the scenic beauty of alternative combinations and levels of forest visual characteristics has been conducted and provides, at a minimum, evidence that changes in visual aesthetics of forests affect the perceived beauty, and presumably enjoyment, of forests. Scenic beauty estimation (SBE) research has tested and refined the use of photographic presentation of alternative visual aesthetic conditions of forests and provides information relevant to the design of the current study.

This chapter reviews forest aesthetic SBE research to provide information and guidance on:

The effectiveness of using photographs to represent alternative levels of scenic beauty.

Procedures to follow to generate accurate photographic representations of alternative forest resource conditions of interest.

How visual aesthetic damages, similar to those induced by ozone, may affect the perceived scenic beauty and enjoyment of forest resources. This may help in both the design of the alternatives to be presented and in the interpretation of the reasonableness (consistency with previous findings) of the results.

How other scene characteristics might affect scenic beauty, and which must be controlled for in the study design to ensure respondents are rating, and subsequently valuing, different scenarios due to changes in well identified conditions that are reasonably attributable to ozone, and not to other unintended changes in the presentations.

This chapter reviews the standard procedures of forest SBE research, SBE findings of relevance to this study, issues in the SBE research of concern to this study, and considerations of how SBE work should be incorporated into the current effort.

4.2 Development and Applications of Scenic Beauty Research

We all have a notion or sense of what has beauty and what does not. There is generally a prevailing "romantic" notion applied to the concept of scenic beauty that suggests beauty is entirely a subjective matter. Although that notion cannot be completely refuted, “beauty is neither inherent in the landscape nor purely in the eye of the beholder, it is the product of an encounter between an observer and the landscape” (Brown and Daniel 1984, p.2).

Psychologists have been studying the relationship between physical stimuli and human perceptions, sensations and judgments for nearly 150 years and have coined the term psychophysics to describe this field and approach to understanding human behavior and sensation. The works of Thurstone (1927, 1948), Torgerson (1958), Green and Swets (1966) and others in psychology have firmly established psychophysical concepts and methods for understanding human response to external stimuli. As an indicator of product appeal and consumer satisfaction, psychophysical studies have been well tested and extensively used in a wide array of contexts. We are, in fact, conditioned to this approach of assessing scenic beauty. Each time we see an advertisement, visit the supermarket, or test drive a new car, we are participating in a setting whose visual parameters have been defined, measured- and prescribed.

It has, however, only been within the last 15 years that the systematic modeling of environmental scenic beauty has received particular interest. When applied to environmental scenic beauty this approach requires comparisons of observers' perceptual responses to measures of landscape features for a set of differant landscapes. The typical format for psychophysical landscape studies suggested in Brown and Daniel (1984) include the following three steps:

1. Color slides or photographs are shown to observers who express their aesthetic judgment and preference by ranking, rating or choosing between pairs of scenes. Based on the observers' response the represented landscapes. are scaled from low to high scenic quality.

2. Physical characteristics and parameters of the landscape scene are measured. This includes both on-site as well as measurements taken from the photographs.

3. The final step relates the measures from physical and photographical assessments of scene features to the perceptual judgment indices of scenic beauty. This step usually requires the use of formal regression and statistical procedures.

Among the first to suggest the use of color photographs and psychological methods, Shafer (1964) and others established early on that: (1) individual observers can and do consistently evaluate the scenic beauty of different landscape scenes ; (2) scenic beauty judgments of color photographs do adequately reveal estimates of the actual landscapes; and (3) there is good agreement among different observers regarding the relative scenic beauty of landscapes.

Applications of the SBE method have covered a wide range of forest scenic quality assessment problems; for example:

1) The scenic consequences of alternative watershed treatments in Ponderosa pine forests (Daniel et. al. 1973, Daniel and Boster 1976).

2) The scenic effects of silvicultural methods, species composition, harvest techniques, roads and other management changes on Northeastern (Brush 1979) and northern Rocky Mountain (Benson and Ullrich 1981) forests have been analyzed.

3) Daniel et. al. (1977) developed a scenic beauty contour map of a ponderosa pine forest area by using the SBE scale to compute isoquants of scenic quality.

4) In 1981, Daniel et al. provided a comprehensive assessment of the scenic impact of mountain pine bettle damage to Ponderosa pine stands in the Colorado front Range.

5) The scenic effects of prescribed fires and wildfires in Ponderosa pine forests were observed by Anderson et al. (1982) and Taylor and Daniel (1.984).

6) Schroeder and Daniel (1980) used the SBE method to develop scenic beauty profiles for measuring the relative beauty of views offered by different forest road alignments.

These and other applications of the basic SBE methodology have demonstrated the utility of the method for assessing the visual quality of forest scenic resources (Brown and Daniel 1984).

4.3 Procedures For Scenic Beauty Evaluation

4.3.1 General Alternatives

There are three general mechanisms for conveying scenic preference information: choosing between pairs of scenes; ranking a set of scenes; and rating the scenes using a subjectively defined scale.

Choosing Between Scene Pairs - Often referred to as the Law of Comparative Judgment (LCJ) method, this method draws its name from the pioneer psychological work of Thurstone (1927) who developed a statistical procedure to establish interval measures from simple comparisons. Essentially, a pair of photographs depicting two landscapes with discernable differences are presented and the observer is asked to judge which one is more (or less) preferred. By pairing each possible combination of photographs a detailed metric of preferences can be formed from the information about the percentage of times each photograph was selected as being more visually pleasing than all others it was paired with. This produces an interval measure of scenic preferences and is usually used in the setting of a slide presentation (often exhibiting over 100 pairs of slides to a group of observers).

Ranking - Essentially identical to the scene-pair approach, this mechanism eliminates the need for an extensive scene-pair comparison to arrive at an ordinal measure of scenic beauty. This method asks observers to view a series of slides or photographs and rank them in order of increasing (or decreasing) preference. The drawback to this approach arises when the sample of scenes to be ranked becomes to large to be easily, mentally manipulated thus generating observer fatigue and interest loss. When the number of photographs is kept under about 10-12 this method should efficiently arrive at an interval measure comparable to one obtained if the LCJ paired comparison method were used.

Rating - Rating involves a user-defined scale (usually a 10 point scale) to rate the scenic quality of a series of photographs. The observer is asked to rate each scene on a scale of 1 (low) to 10 (high) with respect to scenic beauty. This results in a quasi-cardinal measure of scenic beauty but also gives a measure of the relative intensity of scenic preference for a group of observers. The Scenic Beauty Estimation (SBE) procedure developed by Daniel and Boster (1976) embodies this rating procedure and introduces statistical methods correcting for both differences in the criteria of the observers' judgment scales and for perceived differences in the properties of the presented landscapes.

Comparison studies conducted by Buhyoff and others (see Hull et al. 1984) have shown that the scenic beauty metrics obtained by these different measurement methods are highly correlated, thus, suggesting that the particular method used to convey scenic preference may not appreciably affect the outcome.

4.3.2 Forest Scene Representations

Forest scenes are generally represented in the form of color slides or photographs. The photographic process, in order to produce objective, realistic pictures involves a number of considerations. Control variables in photographic simulations include: season; type of camera lens; time of day; angle of view; film type; physiography; slope angle and direction; sky composition; and vegetative pat terns. The primary consideration for representing a variety of forest scenes through photographs is consistency. The procedures used to develop a series of photographs should be consistently applied to each scene with the same camera, film type, processing, etc. Photographs are meant to depict the actual forest characteristics in an objective manner and should not be of artistic intent. Although photographic procedures are not firmly established by the literature, there are common practices that can be adhered to if conditions are favorable. These practices include:

1) Film type: 64 ASA (slide or print depending on presentation)
2) Camera type: 35 mm single lens reflex
3) Camera lens: 50 mm or 55 mm

Photographs should be taken with as high a depth of field as lighting permits (f8 or greater) and distance to tree stands should be consistant (i.e., 30 feet). Photographs should be taken under similar lighting and cloud conditions, generally this refers to relatively cloudless conditions during the sunlit hours of the day between 9 AM and 3 PM. Consistency among photographs being compared should also be maintained for other conditions not relating to forest damage. This includes other vegetation forms, angle of view, slope angle and general physiography. Man-made objects, people and wildlife should, generally, not appear in photographs (see Hull, Buhyoff, and Cordell 1986). Again, consistency is the standard and variability of factors that are not of direct interest should be minimized. From the photographs, measurements can be made of the proportion of “seen area” and numbers of various visible patterns and characteristics (i.e., vegetation, trees, sky, downed wood, grass, etc.).

In another method of forest scene representation, Daniel and Boster (1976) have suggested techniques for simulating forest differences by physically manipulating photographs. There are a number of ways that this can be done including the use of computer imaging and photographic laboratory touch-up. Computer imaging has advanced greatly in recent years and essentially involves the digitation of photographs or other scenes which can then be manipulated electronically allowing various elements to be added, subtracted or moved within or between scenes. Laboratory touch-up is a common practice in general photography that allows for simple alterations in color and form. It is possible that the visible forest injury brought on by ozone could effectively be replicated through laboratory touch-up procedures that could mimic mottling, chlorosis, and needle drop. These techniques provide for the precise control over scene variation and can be quite useful in certain contexts. These contexts as well as several other advantages and disadvantages to photographic manipulation will be discussed in the Section 4.4.3.

4.3.3 General Questioning and Presentation Procedures

The majority of scenic beauty research conducted to date has utilized the format of slide presentations to groups of individuals. This format has general appeal for several reasons including the ability to review and analyze a relatively large sample of photographs, and the cost effectiveness of using groups of observers. This procedure assembles a group of observers, instructions are read and procedures explained. Before the actual ratings are begun, a trial showing of about 20 slides is given to show the range of scenic quality that will be exhibited. This trial run essentially allows the observers to calibrate their subjective judgment scales to the range of scenes expected. After the initial trial run, the survey monitor then announces:

"you are to begin rating the next set of slides. You should assign one rating

> number from zero to nine to each slide. Your rating should indicate your judgment of the scenic beauty represented by the slide. Please use the full range of numbers if you possibly can and please respond to each slide. Are there any questions before we start?" (Daniel and Boster 1976, p. 25).

Another procedure that has been successfully applied in assessing scenic beauty is the personal interview. In a current study by Daniel and King (1985), campers in the National Forests of Arizona were questioned about the scenic beauty and value of alternative camping sites depicted through photographs. Campers were asked a number of questions concerning their camping experience, costs and family background for use in developing a Travel Cost Model. Additionally, campers were asked to view a series of 35 photographs and rate each from l-VERY LOW SCENIC BEAUTY to 10-VERY HIGH SCENIC BEAUTY, in addition, they were asked to rate the scenic beauty of the forest campground that they were currently visiting to compare scenic beauty indices for the same site from both photographic representations and actual visitation. A Contingent Valuation question was also asked of the campers:

> This next question is hypothetical. One way that has been used to get an idea of the value people place on their recreation experiences is to ask what they would be willing to spend for the experience. For example, you have estimated that you will spend $__________(from travel cost questions) for this part of your trip. We are interested in knowing how much more you (household) would have been willing to spend on this trip before deciding not to come to this campground--that is, before deciding to do something else or to stay at home.
>
> HOW MUCH MORE do you think you would have been willing to spend?
>
> __________

Results from this study have not yet been released, but this example shows how scenic beauty and valuation work has been combined. Mail surveys have not been previously used in this type of research, however, there are not reasons suggesting that a mail survey approach could not be successfully used when comparing a limited number of alternatives.

4.4 Findings and Results From Scenic Beauty Research

This section will discuss relevant scenic beauty models and significant findings, especially with regard to research involving forests. Beginning with a review of the Scenic Beauty Estimation method developed by Daniel and Boster (1976) this section will also consider physical parameters that are relevant as well as other selected issues in scenic beauty research of potential importance to the current study.

4.4.1 Analysis Methods and Models

The Scenic Beauty Estimation (SBE) method, developed by Daniel and Boster (1976), provides the analytical framework that converts the ratings of a group of observers over a range of photographs into single numerical estimates of scenic quality. The assessment of scenic beauty involves two distinct components: the perceptual component and the judgment criterion component.

The perceptual component involves the visible landscape properties that combine to form a value on the observers' subjective scale. However, this value does not indicate the standards being applied to the judgment of the scene. In other words, what changes across scenes are most important and are liked or disliked.

The judgment criterion component of scenic beauty reflects the preference structure that the individual is applying to the depicted scenes. The judgment criterion depends upon the nature of the individual's past experience with settings similar to those depicted. For example, one observer may rate a scene as a 3 and another a 7, whereas another observer may give the same two scenes a 5 and 6 respectively. Does the 4-point difference indicated by the first observer indicate a greater difference in scenic beauty than the l-point difference in the second observer? This ambiguity can be eliminated through statistical normalization procedures that consider differences in distributional characteristics of ratings between scenes by the individual.

The measurement of physical characteristics and parameters of the landscape scene is an esential part of the SBE process. This involves the use of standard silvicultural and photographic measures and descriptons. The variety of physical parameters for on-site measurements includes: seedlings and saplings; crown canopy density; numbers of large and small trees; tree type and distribution; tree stories and groupings; herbage and ground cover (i.e., grasses and shrubery); tree height, estimated vegatative mass; percentages of ground cover in gravel, stone, bare soil, downed wood, herbage and trees as well as mechanically disturbed areas. All of these variables may not be relevant to any one site but consideration needs to be given to each of the characteristics present (Buhyoff 1978).

After the site characteristics and the perceived scenic beauty indices have been generated, the final step is the statistical determination of the relationship between forest characteristics and scenic beauty indices. This is done usually through the use of least squares regression procedures for estimating hypothesized relationships. Estimated equations usually take a nonlinear form consistent with the previous psychophysical research that suggests that constant increases in visual stimuli do not normally correlate with constant increases in subjective sensation. A majority of the evidence researched suggests this nonlinear form: however, Schroeder and Brown (1983) found that the nonlinear specification did not significantly increase the predictive ability of the model over linear specifications.

An important aspect of objective scientific inquiry is the verification of experimental design and results. The reliabilty of scenic beauty studies has been demonstrated. In 1980; Buhyoff et al. replicated his earier work (Buhyoff and Leuschner, 1978) on the ability to measure visual landscape preferences as a function of insect infestation intensity. His results indicated that the original 1978 prediction model was statistically identical to the one generated in 1980 with a separate sample, and thus had predictive validity. Again, Lien and Buyhoff (1986) showed that the same regression model (as originally reported in Buhyoff et al 1984) for the prediction of urban forest scenic beauty as derived from resample data from the original population. This demonstrates that landscape preferences can be reliably measured and valid prediction models can be developed.

4.4.2 Scenic Beauty Characteristics

In the study of specific characteristics that contribute to scenic beauty, several studies have identified (often incidentally) a number of scenic attributes that apparently contribute or detract from the scenic quality of a forest scene. It should be made clear that only general effects of these characteristics can be stated and that both the composition of the individual characteristics can be stated and that both the composition of the individual scene as well as the context of the series of scenes being viewed can have a strong impact on the sign, significance and magnitude of the effect of any one characteristic. Many of the attributes listed below exhibit a non-monotonic relationship to scenic beauty that confounds the attempt to strictly define the impact of any one attribute (see, for example, Hull and Buhyoff, 1986). For example, increasing tree density will (depending on the tree diameter) generally increase scenic beauty estimates up to a point and then further density increases begin to have a negative effect on scenic beauty. These complexities must be considered when interpreting the figures in Table 4-1, which is

Table 4-l

GENERAL AFFECT OF FOREST SCENE CHARACTERISTICS UPON SCENIC BEAUTY ESTIMATES

Attributes Generally Enhancing Scenic Beauty

STRONG EFFECT

The Presence of Snow
Sharp Peaked Mountains
Forest Density (Depending on Average Tree Diameter)

MODERATE EFFECT

Average Tree Diameter
Tree Stand Age
Expansive Distance Views

WEAK EFFECT

Amount of Shadow
Density of Crown-Cover Views
Presence of Cumulus Clouds

Attributes Generally Decreasing Scenic Beauty

STRONG EFFECT

Size and Area of Downed Wood

MODERATE EFFECT

Distribution of Downed Wood
Tree Crowns damaged by Insents
Area of Rocks and Base Ground
Area of Visible Tree Injury and/or Mortality

WEAK EFFECT

Number of Tree Stumps
Area of Sky

based upon the results in Daniel and Boster (1976), Buhyoff et al. (1982) Brown and Daniel (1984).

The ability of statistical models to detect the effects of forest injury on scenic beauty has been demonstrated in a number of studies. Of particular consequence to our efforts, Buhyoff et al. (1982), in a study of 64 forest vistas in the Colorado Front Range, found that chlorotic faders, one characteristic associated with direct and indirect ozone damage, significantly decrease forest scenic beauty. The estimated scenic beauty model and corresponding results are presented below for a model describing the behavior of untrained observers.

Equation 4.1.

$$SBI = 127.12 + \underset{(.OOOl)}{10.32SHRP} - \underset{(.OOOl)}{0.57SHRP^2} + \underset{(.01)}{1.79BVF} - \underset{(.04)}{6.77MDAM} - \underset{(.02)}{61.07FORDEN} + \underset{(.004)}{0.93FLT}$$

significance levels are in parentheses

$R^2 = 0.55$

SBI = Scenic beauty index
SHRP = Area in square inches of sharp peaked mountains
BVF = Area in square inches of background and distant forest
MDAM = Area in square inches of insect damage in the middle ground including all fader (yellowish crown), red top (crown), and black top (crown) damage
FORDEN = Ratio of area in square inches of bare (nonvegetated ground and rocks) divided by the area of forest in square inches
FLT = Area in square inches of flat topography. This is an index of how expansive a more distant view is.

The model generally indicates that scenic beauty is strongly positively correlated with foliage density and vegetation (both of which can be affected by ozone) and strongly negatively correlated with the amount of dead or dying tree crown foliage (characteristics that can be induced by oxidant concentrations). These results provide our efforts with a foundation suggesting that the scenic impacts caused by these characteristics can be measured and estimated.

In 1978, Buhyoff et al. addressed the issue of how the perception and judgment of scenic beauty can vary with visible forest injury. The results of that effort indicated, (as would be expected) that marginal utility (using an SBE scale) decreases with the increasing proportion of visible forest damage.
This decrease is rapid up to about the 10% level of visible damage; thereafter, the decrease in utility continues steadily but at a much slower rate. This result suggests that it is visually more important to prevent initial outbreaks of forest damage than to mitigate damage in forests where injury is already substantial (see Figure 4-l), however, differences between an SBE scale and alternative product utility measures (such as an economic measure) may alter this interpretation of the results.

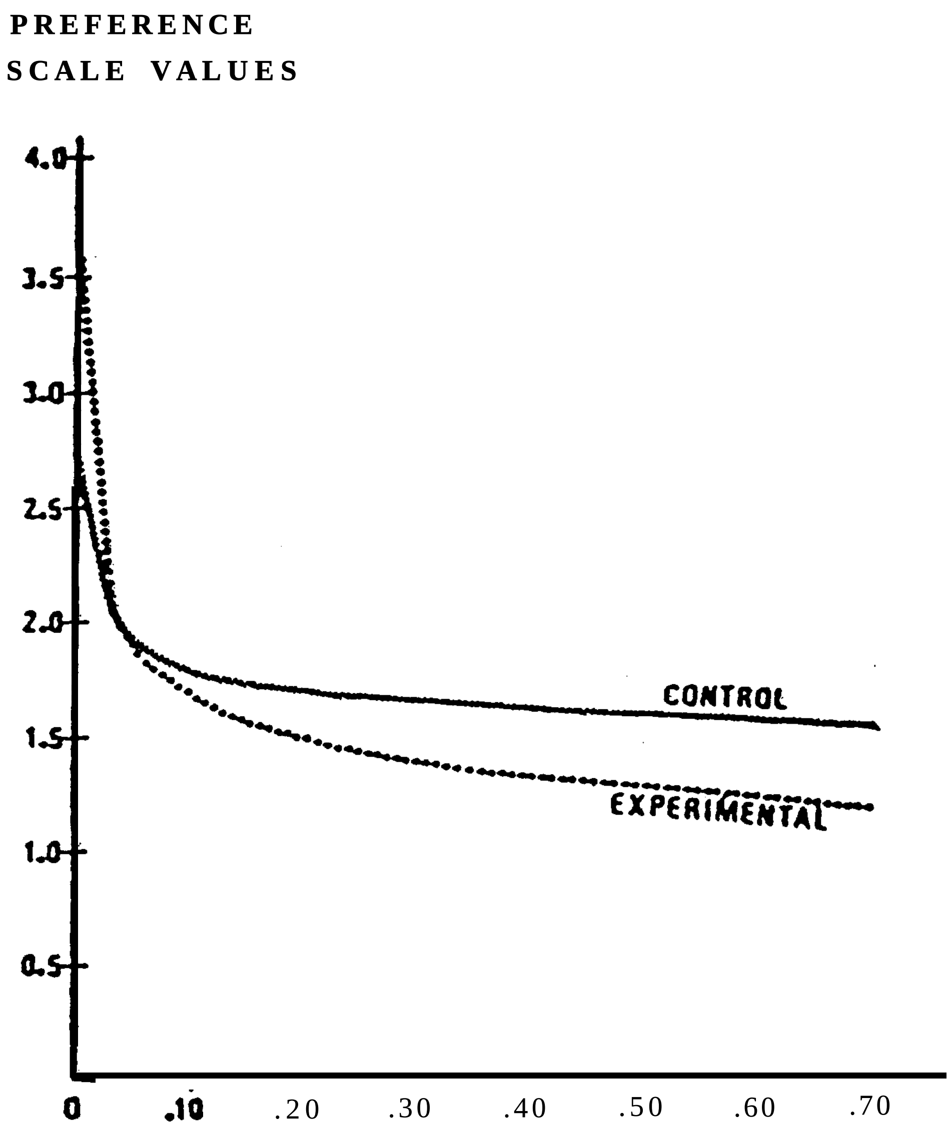
The specific physical characterisitcs of forests that impact the perception of scenic beauty have also been investigated for the case of urban forests. Buhyoff et al. (1984) in a study on how vegetation measurements could be used to predict urban forest scenic quality found that visual landscape preference for urban forest scenes increased with increasing average tree diameter (dbh), basal area per stem, and crown enclosure. The relationship between preference and the amount of vegetation appeared to be non-monotonic, suggesting limits to the effects of certain physical attributes. Another result indicated that people prefer scenes with fewer larger stems than those with many smaller stems.

4.4.3 Issues

Several issues and findings of SBE work, beyond which forest scene characteristics have what effect, are relevant to the current study. Among the issues is whether the source of the forest damage should be identified for the respondent. Does knowledge of the source or cause of the damage have any effect on the perception of scenic beauty? The results of a number of studies suggests that this knowledge is a significant factor in the way a scene is perceived. Buhyoff et al. (1978) estimated the "psychological disutility" of damaged forests caused by the southern pine beetle in forests along the Blue Ridge National Parkway. This study demonstrated that a difference exists in utility functions between observers who were told the scenes contained pine beetle damage (experimental group) and observers who were not told about the damage and were simply asked to judge the visual quality of different landscapes (control group). Both groups indicated scenic preference decline with increasing proportion of visual forest damage. However, observers in the experimental group exhibited both a greater range of scenic preference and a more rapidly decreasing scenic preference as a function of increasing proportion of forest damage (see Figure 4-l). This may be an important factor for the development of a survey in the current study and is taken up in Chapter 5.

Do SBE's sometimes attempt to infer that changes in the level of scenic beauty across slides or photographs reflect changes in the actual enjoyment of the area? This assumption has been defended on the grounds that enjoyment of forest lands is functionally dependent on visual aesthetic conditions that can be represented in the form of slides or photographs. Therefore, impacts that increase visible forest injury are likely to have an adverse effect on the welfare of people who visit the areas. The assumption that increases or decreases in an SBE reflect increases or decreases in enjoyment, or utility, are possibly merited. However, assumptions that the curvature of the relationship between visual characteristics and SBE indices reflect the curvature of the relationship between the visual characteristics and

Figure 4-1
Proportion of Forested Area in SPB Damage



Source: Buhyoff, et al. (1978)

utility (or enjoyment) are untested. This is because the SBE indices have not been tied to other measures of adversity or enjoyment of a scene, of which economics is one possible measure.

An issue that is related to whether differences in scenic beauty ratings of photographs indicate differences in enjoyment, is whether ratings of photographs are consistent with on-site ratings. A study currently in progress by Daniel and King (1985), in which they interviewed a number of campers in the national forests in Arizona, found that individuals generally rated the forest area around the campground that they were visiting higher than the photograph depicting the forest area around the same campground. The pattern of scenic beauty ratings performed with photographs and with on-site viewing were quite similar except that mean scores from on-site viewing was higher than the mean scores using photographs. This suggests that there may be a difference between photographic representations and actual experiential characteristics.

The final issue taken up in this chapter concerns the use of actual photographs depicting varying degrees of visible forest damage versus the use of manipulated images of a single scene. Image manipulation allows for highly controlled scene variation, which is desirable in contexts where only a limited number of scenes can be used (i.e., in a mail survey). Without the use of a large sample of photographs it is difficult to account for variations in other scene characteristics when pictures of different scenes are used. However, the use of manipulated images poses a number of problems, including:

> Highly specific variation within the same scene may void the issue of scenic beauty, and, moreover, entice respondents to respond to the variation across scenes in a rather prescribed fashion, by not putting the valuations in context of other possible resource variations.

This technique requires justification showing the representativeness of the manipulated image to actual conditions.

The use of photographs depicting actual scenes and conditions has been the most widely used approach in this area. Real scene photographs are both quickly justified and readily believed to represent actual conditions. However, in small samples it becomes impossible to draw conclusions about the effects of vegetation damage when the variations in other scene attributes cannot be determined. However, it is possible that the amount of variation of incidental characteristics between different scenes can be minimized, approaching the conditions in a series of one manipulated scene. Although variation can be minimized to a large degree, it is still necessary to use a sufficient sample of photographs to draw statistical conclusions.

Both approaches for representing forest scenes (manipulated and actual) pose difficulties for the interpretation of results obtained when a small sample of photographs is selected. However, one approach for resolving this dilemma is to pretest the photographs to be used in the mail survey with a group screening of a sample of scenes that incorporate the pictures to be used in the mail survey; thus the final mail survey scenes can be selected as representing typical SBE for a level of forest damage, and the group and mail survey results can be compared. Either actual or manipulated photographs could be used in this approach as long as significant variation among incidental factors is minimized.

4.5 Considerations For the Application of Valuing Ozone Induced Aesthetic Damages

The ability of a survey to elicit responses to a variety of questions creates opportunities that are generally absent in most scenic beauty studies and presentations. Questions relating visual cues to actual measures of use and measures of enjoyment will provide information that has been missing in interpreting the social welfare implications of previous SBE work. The use of a mail survey in valuing ozone induced aesthetic damages presents both limitations and opportunities. It is impractical and beyond the primary focus of this research to implement a complete scenic beauty study by mail with the number of photographs required for detailed statistical analysis for changes in many scenic characteristics. However, a combined approach using both a mail survey and group ratings could provide a defensible estimate of scenic preference and enhance the state of the current methodology. The insights developed through the many applications of scenic beauty studies and the experiences of researchers can be quite useful in the development of objective photographic presentation of alternative levels of visual aesthetic forest quality potentially related to ambient oxidant exposure.

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5.0 SURVEY DESIGN AND IMPLEMENTATION

5.1. Introduction

This chapter presents the procedures and methodologies used in conducting the primary data gathering effort for the Angeles and San Bernardino National Forests. Examples of the actual survey correspondence, and a description of the sampling area are also included in this chapter.

The acquisition of primary data for economic research into the valuation of environmental amenities using the low cost mail survey method proposed by Dillman (1978) allows new opportunities in seeking answers to questions for which little or no existing data has been compiled. For this study the Dillman Total Design Method (TDM) is especially useful. It makes possible the collection of data on the perceptions of recreators' and residents' forest quality for the Angeles and San Bernardino National Forests. With this data estimation of subjective benefits, and the impacts of perception biases on policy decisions can be studied.

Two different research methodologies are employed in the damage estimation. both of which rely on a careful quantification of the perception of physical in jury. Thus, data had to be collected to support both the Contingent Valuation Method (CVM) and the Hedonic Price Method (HPM) models.

The large volume of data required to generate damage estimates using both research methodologies made it necessary to implement two separate survey instruments. The use of two smaller, specifically targeted surveys rather than one large general survey has several benefits. First, reduced mailing costs per survey enable an increased sample size. Second, each survey was shorter in length, and easier to follow. Finally, the sample could be better targeted at; 1) residents of the Angeles and San Bernardino National Forests and 2) non-resident recreators to the Angeles and San Bernardino National Forests. The survey to residents was designed to collect data for the HPM (property value) and CVM approaches, while the recreators survey was used to collect data for the CVM approach.

5.2. Survey Design

The TDM was used in the development of the mail instrument. The intention of the TDM procedure is to achieve a planned target response rate through careful design and implementation. One of the key components to achieving the target response rate is presentation of the survey. Personalizing the mailing from the cover letter and cover page to the follow-up postcard and hand stamped envelopes, is a key factor for encouraging responses. According to the TDM the survey must be printed and folded into a booklet measuring 8 inches by 6 inches. The survey for residents and recreators was 16 and 12 pages long, respectively. Included in each mailout package was a two sided color supplement which contained a map of the area of study and photos of forest scenes within the Angeles and San Bernardino National Forests. The color supplement was printed on both sides and measured 10 inches by 17 inches. The survey and color supplement, a cover letter and a self-addressed stamped envelope were mailed to each individual in the sample.

An important component of the Dillman method, to maximize response, is the follow-up procedure. One week after the initial mailing a postcard was sent reminding the respondent of the importance of completing and returning the survey. If, after three weeks, a response was not received, a second survey, supplement, cover letter and self-addressed stamped envelope was sent. Five weeks after the initial mailing a fourth and final mailing, identical to the third mailout package, except for a new cover letter, was sent to those who still had not responded. According to the TDM, this-mail-out procedure should produce a response rate of about fifty percent.

5.3. Sample and Mailing List

R.L. Polk and Co, of Detroit, Michigan, a national mailing list firm, provided the sample of addresses used in the study. Names and addresses of residents were randomly selected from within Los Angeles, Orange, and San Bernardino Counties. The recreators sample consisted of approximately 1200 addresses, and the property owners sample consisted of approximately 800 addresses from within the boundries of the Angles and San Bernardino forests.

5.4. Slide Selection

The selection process for the photos used in the supplemental map and photo sheet mailed with the survey instrument was consistent with that outlined in Chapter 4. A group of 50 slides were obtained to be pretested for possible use in the study. Using the criteria described in Chapter 4 the research team photographed scenes in the Angeles and San Bernardino National Forests during the summer and Pall of 1986. A large number of photographs meeting these criteria came Prom the collection of Bob Miller, a forest service researcher. The Miller -photographs were especially valuable in that they showed documented ozone injury. The 50 slides used in the pretest pictured trees and forest scenes Prom within the San Bernardino National Forests depicting a wide range of tree quality and forest characteristics.

The pretest group consisted of seven University of Colorado students who live in the Los Angeles region. It was the original intent to follow this pretest group with another pretest group in Southern California. However, the ratings among the seven subjects were so consistent as to make a follow up local pretest unnecessary. The University of Colorado students were gathered together to individually rate the quality of the trees shown in the slides from 1 (lowest quality) to 10 (highest quality). Before viewing the slides the students were read the following text:

> "You are about to begin rating the next set of slides. You should assign one rating number Prom 1 to 10 to each slide. Your rating should indicate your judgment of the QUALITY of trees/forests shown in each slide. Please use the full range of numbers if you possibly can and please respond to each slide. Are these any questions before we start."

Each slide was shown for 20 seconds during which each student assigned the slide a rating of 1 to 10 on a rating sheet. Summary statistics from the process are shown in Table 5.1.

The 50 slides were then divided into 5 quality groups (poor, fair, good, very good, and excellent) on the basis of their mean in the pretest. All slides were then reviewed by the research team to check for the presence of characteristics that may have biased the pretest results. For example, many slides showed discolored needles which were a seasonal result of aging rather than ozone related tree damage. These slides were rated low in quality in the pretest, yet exhibited no ozone damages. As noted above, factors such as the amount of foreground in a scene, the presence of downed wood, tree and forest density, and the presence of distant views are all significant in slide rating studies. The eleven slides with the minimum variences within the five forest quality groups were then selected. Two were to be used as example photos with the forest quality ladder and nine were to be rated by the survey respondents. Following the selection of the 11 candidate slides a second pretest was conducted. This time 16 undergraduate students rated the 11 photos as they would appear in the survey supplement. The students, with the aid of a forest quality ladder, rated the photos on scale of one (lowest quality) to five (highest quality) as respondents would in the study. Through analysis of the data, it was discovered that the use of nine photos required each individual photo to be too small in size for the respondents to accurately assess quality ratings. Therefore it was determined that a six photo format with larger pictures was necessary. The final color supplement is shown in Figure 5-l in the packet at the back of the report. The five step forest quality ladder with the example pictures is presented at the top of the page. Below are the six photos labelled A through F to be rated by the respondent in the survey.

TABLE 5.1

Slide #	Mean	Standard Deviation	Min	Max
POOR				
44	1.17	.95	1	3
8	3.0	1.73	1	5
10	3.0	.81	2	4
13	3.14	1.46	1	6
46	3.14	1.46	2	6
34	3.29	1.11	2	5
14	3.43	1.81	2	7
30	3.43	1.13	2	5
33	3.43	.98	2	5
41	3.43	1.62	2	6
45	3.43	2.5	1	8
3	3.57	1.51	2	6
48	3.71	2.36	1	7
15	3.71	1.38	1	5
27	3.85	2.73	1	8
21	4.0	.82	3	5
1	4.14	1.21	3	6

Slide #	Mean	Standard Deviation	Min	Max
FAIR				
47	4.29	1.25	3	6
49	4.29	2.21	2	7
19	4.57	2.07	1	7
25	4.57	.98	3	6
31	4.57	.98	3	6
32	4.57	.79	3	5
17	4.7	1.7	1	6
29	4.7	1.5	2	6
2	4.86	.69	4	6
18	4.86	1.77	2	7
23	4.86	1.35	2	6
43	4.86	2.04	2	8
20	5.0	1.63	2	7
26	5.0	1.73	2	6
12	4.57	1.72	2	7
35	5.14	2.19	1	8
11	5.29	1.98	3	0

Slide #	Mean	Standard Deviation	Min	Max
GOOD				
42	5.42	2.07	2	8
24	5.57	1.51	4	8
5	5.71	1.89	4	9
9	5.71	1.98	2	7
28	5.86	1.95	3	8
22	6.0	1.53	3	7
4	6.43	2.07	4	9
40	5.42	2.07	2	8

Slide #	Mean	Standard Deviation	Min	Max
VERY GOOD				
16	7.43	2.07	3	9

Slide #	Mean	Standard Deviation	Min	Max
EXCELLENT				
36	7.86	1.95	5	10
6	8.14	1.57	5	10
39	8.57	1.39	6	10
38	8.71	1.38	6	10
37	8.86	1.06	7	10
7	8.86	1.21	7	10
50	9.57	.53	9	10

5.5. Map

The reverse side of the color supplement presents a detailed map of the area of study. The map shows the Angeles and San Bernardino National Forests as well as the surrounding metropolitan area. The map was reproduced by a graphic artist from National Forest Service maps so as to include only relevant information. All of the major towns, cities, highways and access roads are shown. Also included are campgrounds, picnic areas and lakes within the Forests that had the highest number of visitor days during 1985 and 1986 (source: National Forest RIMS reports, Confirmation from Forest Service Rangers).

Because of the physical size of the Angeles and San Bernardino National Forests and the great diversity of terrain, tree quality and recreation opportunities found within, it was neccesary to divide the map into 10 regions. The main criteria used for these divisions can be summarized as follows:

1) Presence of ozone related tree damages. As has been documented in Chapter 3 tree damage due to ozone is well is defined. This makes it possible to regionalize the forests by tree quality.

2) Presence of trees susceptible to ozone injury. Detailed vegetation maps of the Angeles and San Bernardino National Forests were used to locate areas of the forests that contained tree species prone to ozone injury.

3) Similiar recreation routes and destinations. Regions were specifically divided to help in the compilation of accurate data on travel. Individuals visiting the Angeles and San Bernardino National Forests often take the same trip or form of trip. Because of the limited number of destinations and routes available to the recreator, regional division was helpful in designing questions that would isolate some of the more commonly made trips.

4) Ozone concentration levels in the Forests. As it is possible to map levels of ozone within the forest, regions could be identified with similar ozone concentrations.

5.6 The Survey

Both the (resident and non-resident) survey booklets are contained in the packet at the end of the report. They are also reproduced (with results) as an Appendix at the end of Chapter 6. Although similiar in appearance and containing many of the same questions, the two surveys contain enough differences that each booklet content will be discussed separately.

5.6.1 Non-resident (recreator) survey

The survey is 10 pages long, and divided into four sections. Visual aids are used on the cover to get the attention of the potential respondent. The cover page introduces the respondent to the topic of the questionnaire, describes who should complete it and states who is conducting the research. In the first section "THE ISSUES," there are two questions which can be answered by all respondents. Question 1 introduces the respondent to the purpose of the supplement and asks them to rate the six photos. It is important to have the respondent rate the tree quality in the pictures before any biases can develop. Question 2 is used to find out how aware the respondents are of factors, including pollution which causes tree damage in the Forests. The section concludes with a question asking if the respondent has ever visited the forests in question. Those who have visited the Forests proceed to Section II where they are asked detailed information about their visits. Respondents who have never visited the forests are instructed to skip to Section IV of the survey.

The second section "About Your Visits to the Angeles and San Bernardino National Forests," has respondents relate their enjoyment of the forests during their last visit to different aspects of the trip. Questions 5 through 9 are designed to extract information about frequency of visitation such as when and how often the respondent visits the Forests. Questions 9 and 10 center upon where the respondent traveled on their last trip. With the aid of the map on the reverse side of the supplement, the respondent is asked to indicate which regions of the Forests they visited on their trip. Question 11 measures the respondents perception of tree quality in the regions visited.

Question 12 attempts to measure the respondent's time allocation on their last trip. Question 13 asked recreators, who stopped in the pine forests, to reveal details about the location duration, stop, and activities during their stop. They are further asked to rate tree, air and wildlife quality as well as the quality of facilities and amount of congestion. Questions 14 and 15 ask the respondent which recreational activities they participated in while in the National Forests. Question 16 is a three part question in which respondents who stayed overnight within the National Forests are asked how many nights they stayed, where they stayed and the dollar amount which they spent on lodging.

Questions 17 through 21 are designed to obtain data on the driving portion of the respondents last trip to the Forests. The respondent is asked to reveal information about their miles per gallon, miles traveled, traffic congestion and dollars spent on their last trip.

Question 21 is the final question in this section and asks how a one step decrease in tree quality would effect a respondents visitation to the Angeles and/or San Bernardino National Forests. The purpose of these questions is to get respondents to carefully evaluate the role of tree quality in their recreation decisions prior to answering the CVM questions in the next section.

Section Three, "The Value of Forest Quality to You," is filled out by all respondents, and contains three questions which gather CVM data. In Questions 22 through 24, the respondent is presented with a situation in which the tree quality in the 1) Angeles and San Bernardino National Forests (Question 22), 2) All California parks and forests (Question 23), and 3) All forests of the United States (Question 24) decrease by one step on the forest quality ladder. The respondent indicates if he or she would be willing to pay for management efforts to offset this decrease. Those who would support such a program are asked to indicate how much they would be willing to pay for such management efforts on a payment card. Those who refuse to bid a positive amount are asked why. Those who do bid are asked how they would allocate their bid over user, bequest and existence value.

Section Four, "ABOUT YOU," has nine questions in which the respondent is asked for basic sociodemographic information about themselves and their family. This information will be used to form a profile of all survey respondents. On the back cover of the survey booklet a space is provided for respondents to write any additional comments that they may have concerning the quality of trees in the Angeles and San Bernardino National Forests.

5.6.2 Property Owner Survey

As noted above, the property owner survey is very similiar in design and layout to the recreator survey. The property owner survey contains an additional two pages of text and is divided into 5 sections. Most of the additional questions focus on the respondents living experience in the Angeles and San Bernardino National Forests.

Section One, "The Issues," is exactly the same as the non-residents survey, so no further explanation is needed. In Section Two, "About Your Home in The Mountains," questions 4 through 7 are designed to locate, as precisely as possible, the respondents residence. Question 8 obtains the respondents perception of the quality of trees on their property. Questions 9 through 17 and question 19 ask the respondent for a variety of information about the size and type of residence they own. These questions will help form a profile of the mountain communities for the property value approach presented in Chapter 7.

Question 18 asks about recreational trips property owners make to other regions of the Angeles and San Bernardino National Forests. In Question 20, respondents rate the quality of various factors which may contribute to their enjoyment of their mountain residence such as the presence of wildlife, the quality of schools and the availability of recreation facilities. These will give subjective measures of how respondents value their mountain living experience.

Question 21 is used to split the respondents into two groups: primary residents (those who live in the Angeles or San Bernardino National Forest year round) and second homeowners (those whose primary residence lies outside the Angeles and San Bernardino National Forest boundary). Primary residents skip directly to Section Four while second homeowners continue with Section Three, “About Your Second Home in the Angeles and San Bernardino National Forests”.

Most of the questions in Section Three are taken directly from Section Two of the recreators survey. These questions focus mainly upon travel activities. Questions 23 thru 31 attempt to characterize the respondent’s last trip to their second home and ask for information on distance traveled, frequency and duration of visit, amount of dollars spent and time allocation on the trip. The respondents perception of traffic congestion and tree quality are also collected. Question 31 employs a CVM format similiar to Question 21 in the recreators survey. Respondents are presented with a situation in which the quality of the trees in the’ area of their second home decrease one step on the forest quality ladder. The respondents are asked how this loss in tree quality would effect the number of trips they make to their second home. Section III concludes with three questions in which the second homeowner is asked some basic information about the location and size of their primary residence.

Section Four of the property survey is analagous to Section Three of the recreator survey. Titled, “The Value of Forest Quality to You," this section consists of four lengthy CVM questions. Like the recreator survey, the questions ask the respondents if they would be willing to pay for programs to offset a one step decrease in tree quality in the area of their residence (Question 35), the whole Angeles and San Bernardino National Forests (Question 36), all California park and Forest lands (Question 37), and all of the forests of the United States (Question 38).

The survey concludes with Section Five, “About You”. This section is identical to Section Four of the recreator survey and is designed to obtain sociodemographic information about the respondent. The final page of the survey is reserved for the respondent to make any additional comments they may have on the quality of trees in the Angeles and San Bernardino National Forests.

5.7 Survey Response

The schedule for the mailings was staggered between the recreator, and property owner surveys. The initial recreators survey was mailed on the 23 June 1987 with subsequent mailings on 30 June, 14 July, and 28 July. The property owners survey was sent out on 30 June with the follow-up material going out on 7 July, 21 July, and 4 August. Responses began to appear from the recreators survey in seven days, and from the property owners survey in five days. Figures 5.2 and 5.3 plot the effective daily response as a percent of total adjusted response possible over the collection period for the recreator, and property surveys respectively.

These graphs both show noticable response peaks after each mailing. The cumulative effective response rate for the recreator, and property survey is shown in Figures 5.4 and 5.5 respectively. As can be seen from the figures a response rate of 49.5% was reached for the recreators survey while the property owners survey had a 52.1% response. These effective values fall within the predicted range using the TDM. It is important to note that these are adjusted response rates, and not raw rates.

The raw response data, 34.9% for the recreator survey, and 46.2% for the property owners survey, were adjusted for non-English speaking families in the three county study area. The 1980 Census shows that at that time approximately 27.6% of the families within the study area did not speak English at home. Since 1980 a new wave of immigrants from Asia and Mexico/Central America have entered the area. This 'language' problem was also pointed out by letters such as Figure's 5.6 and 5.7 which explained that the non-respondent (a Latin American and an Asian respectively) did not speak English and could therefore not respond to the questionnaire. It was then determined that a telephone survey of non-respondents was necessary.

Phone numbers were obtained through recent directories and directory assistance. Telephone contacts were attempted from 8 am to 8 pm on September 10 through 14 (Thursday through Tuesday) until 100 completed surveys were obtained. The survey targeted contact with only the person identified on the mailing label. If that person was not at home, a call back time was established. However, if the person answering the phone refused to identify a call back time, or otherwise indicated a strong refusal to assist, the contact was coded as a refusal.

PERCENTAGE OF RESPONSES BY DAY
RECREATOR SURVEY

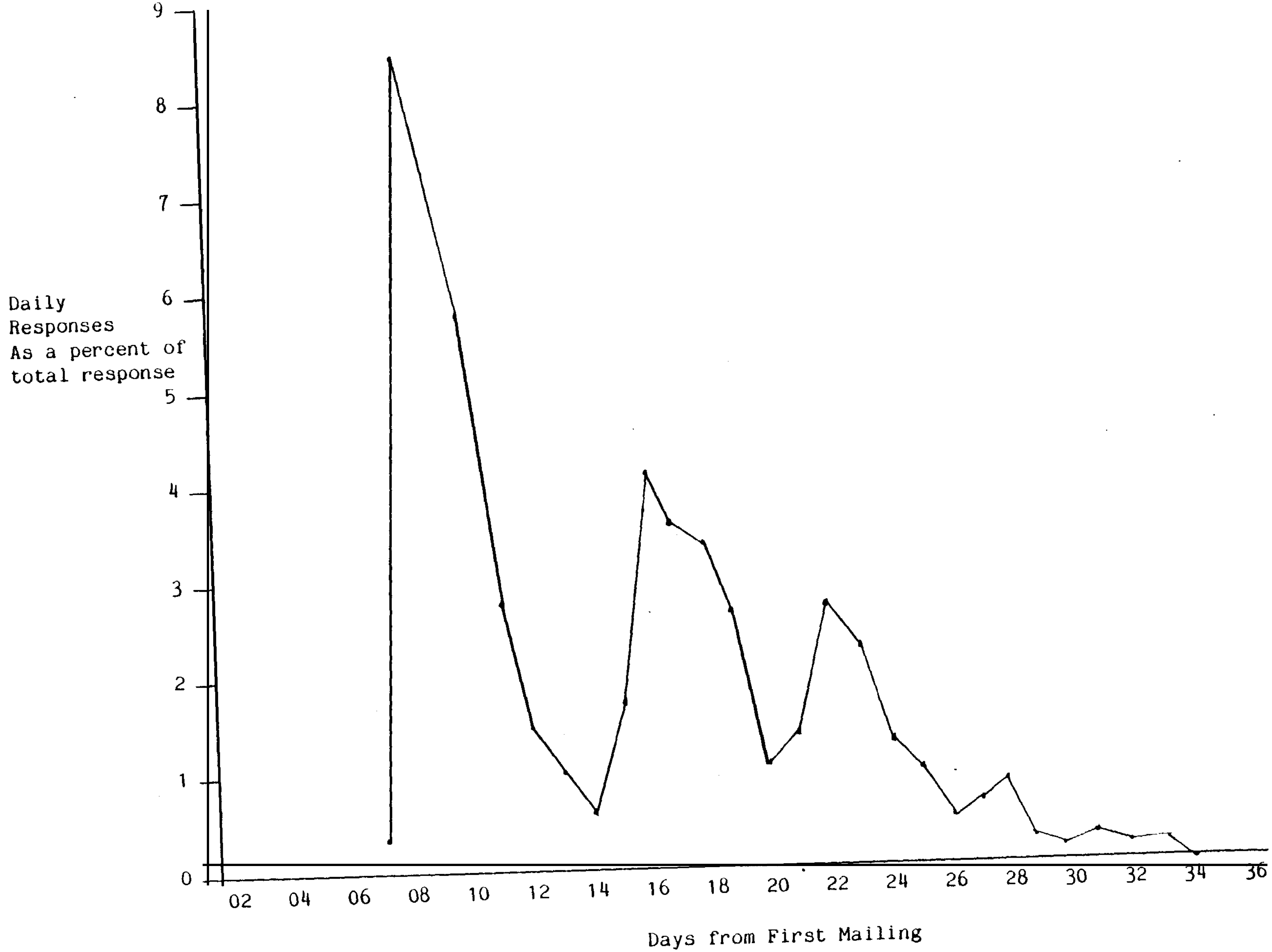

FIGURE 5.2

PERCENTAGE OF RESPONSES BY DAY
PROPERTY SURVEY

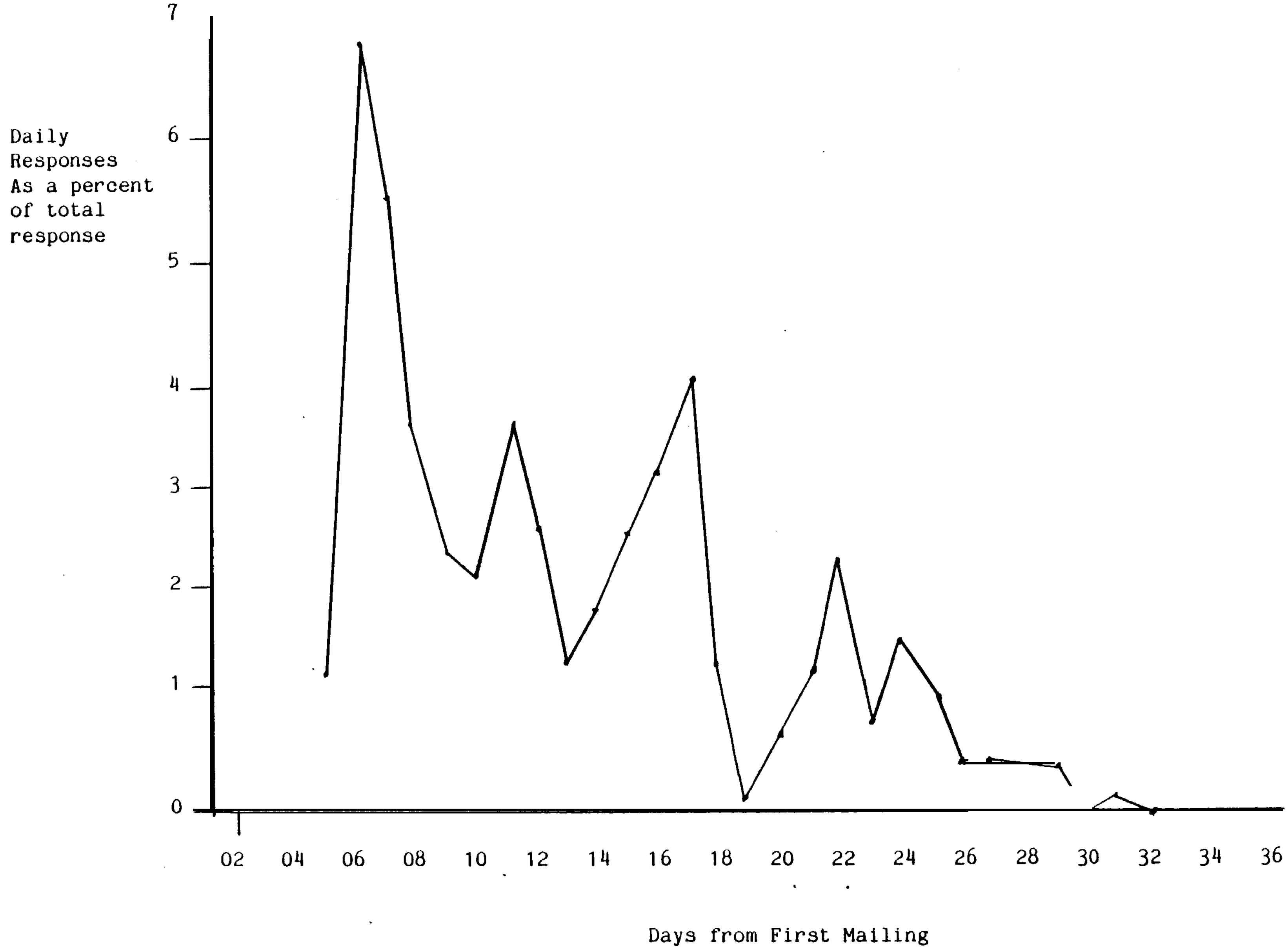

FIGURE 5.3

FIGURE 5.4

CUMULATIVE RESPONSE BY DAY-RECREATOR SURVEY

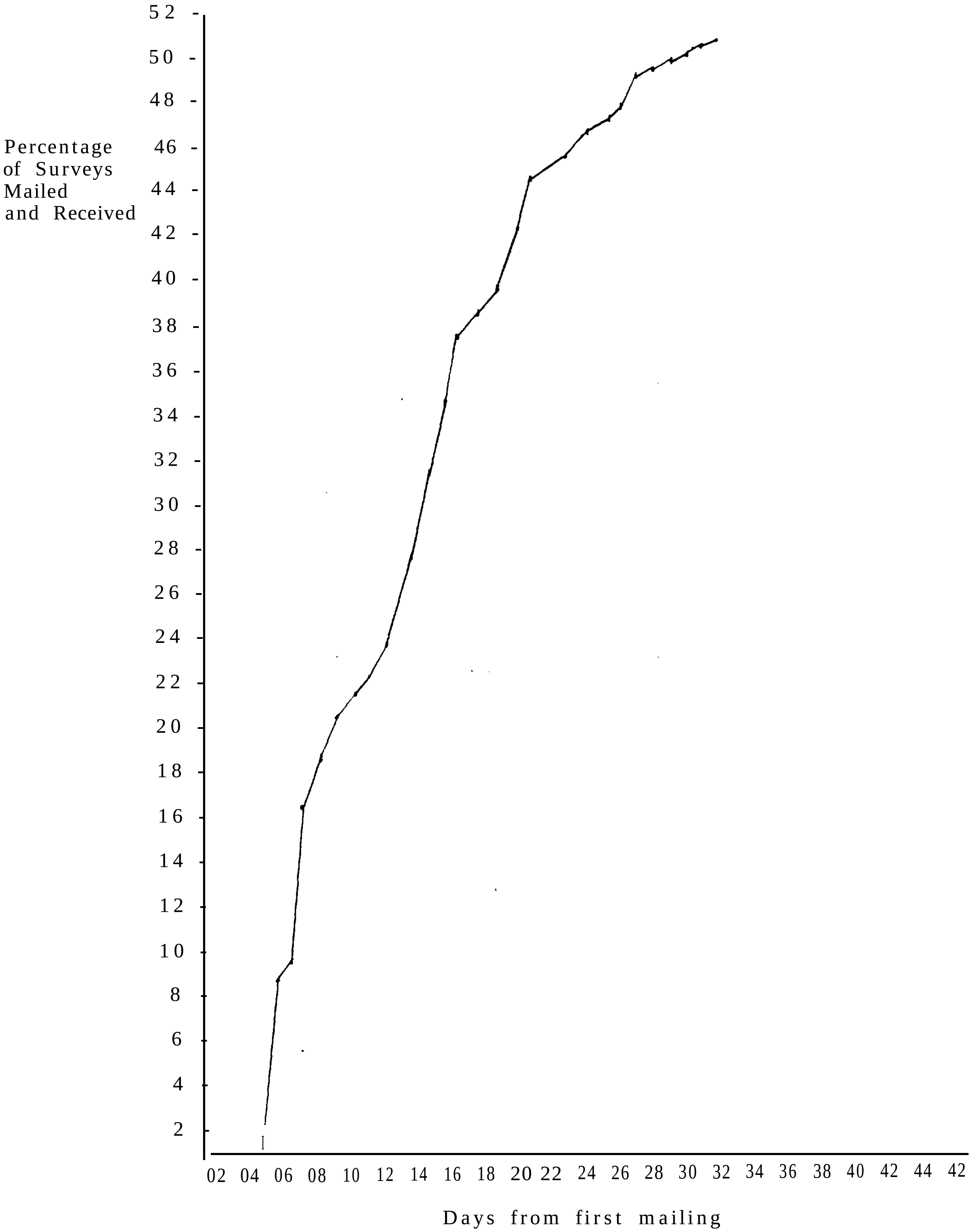

Figure 5.5
CUMULATIVE RESPONSE BY DAY-PROPERTY SURVEY

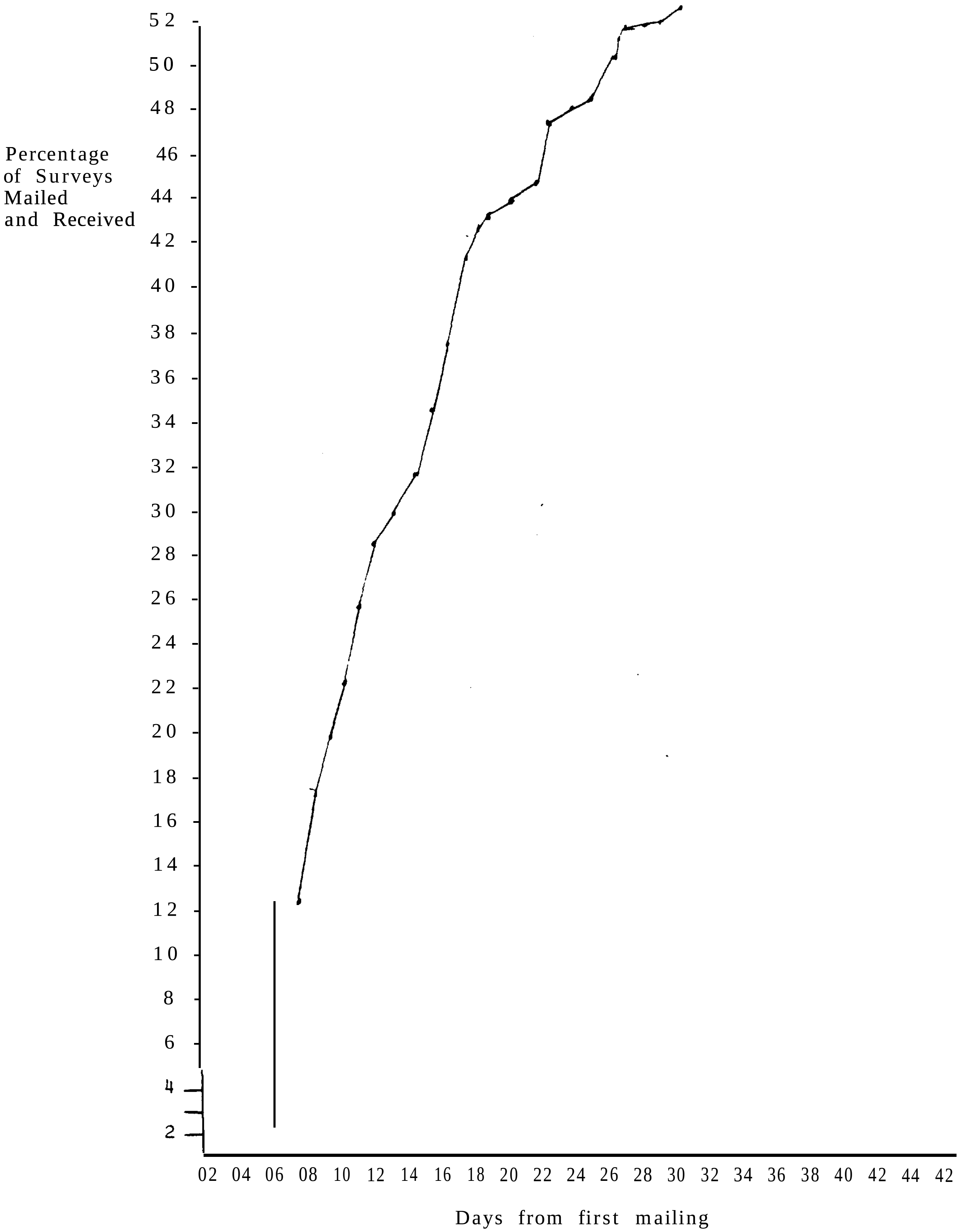

FIGURE 5.6

8 - 8 - 87 .

CENTER FOR ECONOMIC ANALISIS:

Señores me dirijo a Ustedes -
con las mas grande pena de no
saber leer el Ingles, lo po -
quito que yo se hablar es
Lirico; pero si tienen cueste -
narios en Español con mu
cho gusto lo contestare de -
ante mano, Pido Disculpas -
Su servidor.

NAME DELETED

161

TRANSLATION

Sir I am directing this to you - I feel badly I cannot read English.

I speak only a little English. If you have a questionnaire in Spanish, I will be glad to answer right away.

Your Servant.

8/1 blank

FIGURE 5.7

8-7-87

University of Colorado, Boulder
Mr. Bill Schulze, Project Director
Center for Economic Analysis
Campus Box 257
Boulder, Colorado 80309-0257

Dear Mr. Schulze:

Mr. NAME DELETED has received your questionnaire regarding our forest, etc. He speak very little English and does not read the language well enough to complete what is needed for your study.

I would suggest you send another packe to someone else on your list.

Thank you for your cooperation in this matter.

NAME DELETED

Potential respondent phone numbers were repeatedly called with the attempted contacts terminated only when the 100 target was completed or until a number had been attempted at least 7 times. When the process was terminated, 42 numbers had been attempted with no contact with the designated respondent. The average attempts (including no answers, busy and call back another time results) on these 42 numbers was 3.95.

According to statistics kept by local California survey firms, about 40 percent of the LA basin is unlisted. It appears that at least 11 percent of the addresses are invalid in terms of being not listed because they no longer exist. Of the remaining numbers, the telephone survey identified another 12 percent where the number was no longer in service or the person had moved or, died. Further, of the remaining number, 7 percent had a definite language barrier where they could not discuss the interview over the phone in English. Potential language barriers may have been present in some of the refusals, but the respondent at least clearly refused in English. Of the completed surveys, 3 were with households where English is not the primary language but where the telephone survey could be completed in English.

Based on the telephone survey effort we conclude that a minimum of 68-72 percent of the non-respondents still remaining after the mail waves are due to invalid or inaccurate addresses or definite language barriers, as discussed above. An important lesson from the telephone survey of non-respondent was the discovery that even with four mailings,. the postal service failed to return a sizeable number of surveys sent to non-existant addresses. The effective response rates are adjusted for these factors resulting in an effective response rates of 49.5 precent for the recreators survey, and 52.1 for the property ownwers survey It should be noted that this estimate is probably low.

Census data, along with estimates of ethnic growth trends point to as much as 30 percent of the population of the LA basin as having a language barrier which would push the effective response rate even higher. Results of specific questions asked in the telephone survey of non-respondents are presented in the next chapter. The telephone survey is also used to adjust the damage calculations of Chapter 8 for non-response bias.