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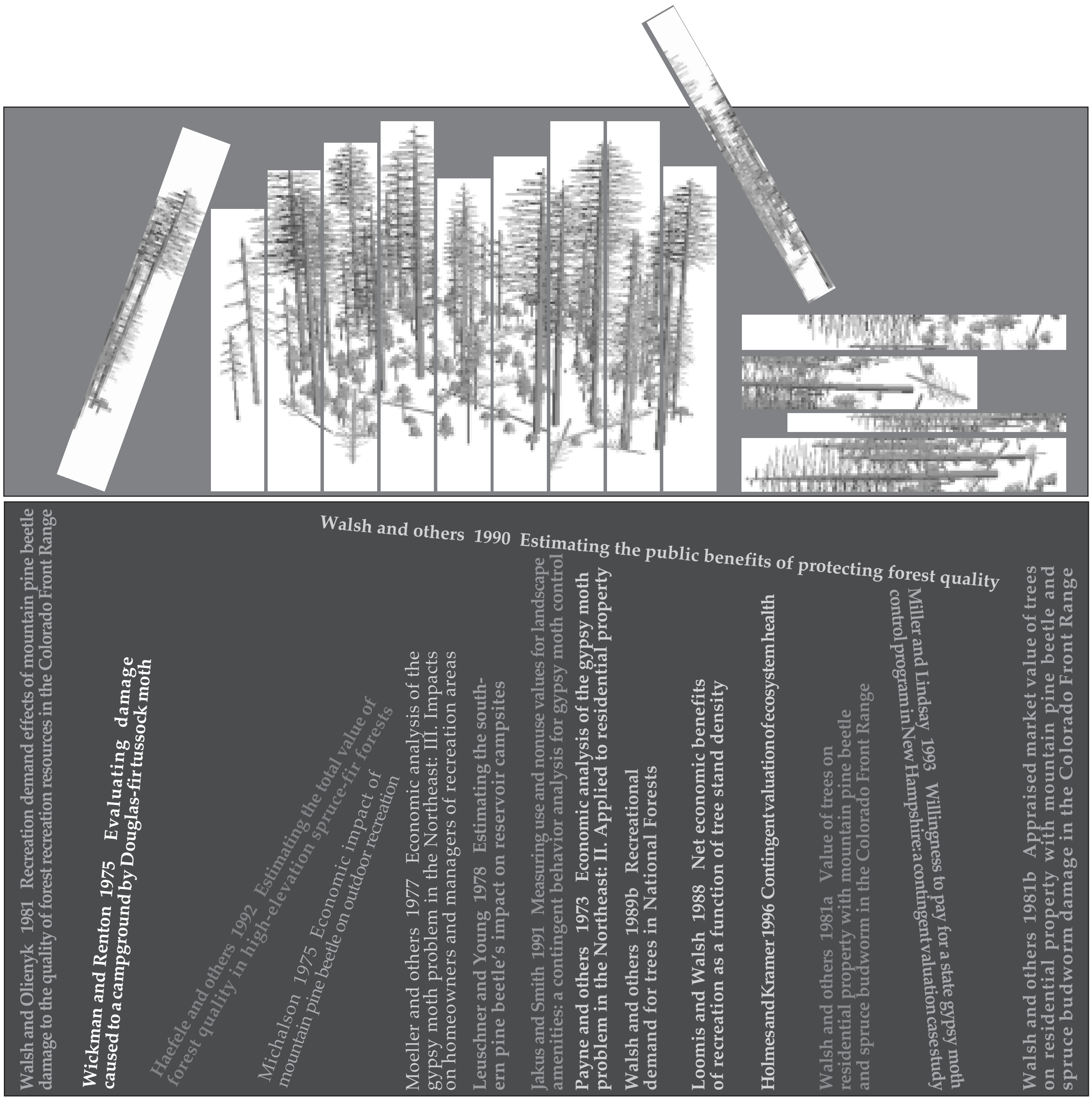
Nonmarket Economic Impacts of Forest Insect Pests: A Literature Review

Randall S. Rosenberger   Eric L. Smith



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Abstract

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This report summarizes the results of research on the nonmarket economic impacts of forest insect pests. The majority of the research reports are journal articles or fulfillment of three USDA Forest Service research contracts. This report also reviews the foundations for methodologies used and classifies the forest insect pests studied, the regions in which research has been conducted, the designated land-use areas, the stakeholders, the values, the measurement methods used, and the measures of value indicators. Information on each research project is described with relevant information condensed in tabular form.

Retrieval Terms: forest insects, nonmarket valuation, economic methods, forest health.

The Authors

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In Brief...

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Natural and human-caused disturbances affect the quality of forests by altering their ability to provide benefits to people. The direction and magnitude of these disturbances on forest quality, and their resulting implications for the level and flow of benefits from forests to people can be discovered in numerous ways. The magnitude and direction of disturbances on forest benefits can be depicted by economic methods. The measurement of values of nonmarket goods and services supplied by a healthy forest, such as recreation and esthetics, and their inclusion in total economic value, is relatively more difficult than market goods and services. However, there do exist several methods used by economists in the measurement of nonmarket benefits. Economic analysis, such as benefit-cost analysis, must include nonmarket values if it is to be a relevant and complete component in the decision making process. Exclusion of these substantial values from economic analysis can lead to misinformed and inefficient management and policy decisions. This report is a secondary analysis of past nonmarket economic research efforts to estimate the impacts of forest insect pests on nonmarket benefits derived from forest quality. This report also acts as a compilation and review of these studies.

This review covers forest insects from mountain pine beetles in the western United States to gypsy moths in the northeastern United States. Although there are many disturbance agents, this report is concerned only with studies on forest pests (no studies on the nonmarket economic impacts of diseases were found; thus by default only insects are included). Stakeholders, land-use designations, values measured, economic nonmarket methods used, and value estimates are identified for each study. These results are presented in summary tables throughout the report, with individual study summaries being presented in several summary tables included as an appendix.

A total of 15 studies were found that estimated the nonmarket economic impacts of forest insects. Nonmarket forest values that were estimated include recreation, esthetics, property, and total values, either in terms of willingness to pay, consumer surplus, or recreation days. Nonmarket economic methods used include cost estimation, contingent valuation, travel cost, and hedonic pricing. Other information identified for each study includes the region, land-use designation, stakeholders, and impact indicators.

It was found that forest insects can greatly affect the level and flow of benefits to people from forests, especially in the short-run. However, forest insects also have a natural role in the development and structure of forests. Not always is it safe to assume that insect impacts on forest health are negative, although nearly all aspects of the studies support this assumption. Education of the public and land managers concerning the ecological importance of forest insects may be enough to mitigate the perceived damages caused by forest insects, within "natural" boundaries. Although the results of these studies may not be transferable to other regions, land managers can greatly benefit from these results by identifying the relevant issues and obtaining additional information helpful to making more informed decisions.

Introduction

Forests are a source of benefits, providing many products and services, such as timber, water runoff, livestock forage, habitat for plants and animals, recreation opportunities, esthetic landscapes, and biodiversity. The capability of a forest to provide these and many other products and services and the quality of those products and services depend on its health. A healthy forest is an essential component of a healthy ecosystem, a natural system that is capable of self-renewal, resilient in its response to disturbances (such as pest, fire, and other nonhuman- and human-caused disturbances), and able to sustain the integrity of the natural and cultural benefits derived from it. In other words, a healthy forest is a dynamic bundle of natural processes that are interconnected through space and time.

Many factors affect the health of a forest, such as air quality, fire, forest management practices and other human activities, wind, drought, disease, and insects. Managers need to be aware of the potential impacts that these disturbances may have on the quantity and quality of benefits derived from forests. Also, since ecosystems and forests are constantly changing, information on the impacts of these disturbances and their relationship to the health and sustainability of natural systems is needed (Averill and others 1995).

Tradeoffs made by the forest manager to achieve objectives and goals can be evaluated or assessed in a number of ways. One method, economic benefit-cost analysis, evaluates a proposed management plan by comparing the benefits of the plan with its costs. A good benefit-cost analysis requires that all measurable benefits and costs be included. However, some benefits are more difficult to calculate than others. Factors not included in a benefit-cost framework are other social and cultural concerns (equity and welfare distribution issues, as well as noneconomic benefits and costs), physical and biological needs (functions and processes), and political realities (feasibility). Although benefit-cost analysis may be a necessary component of decision making, it is not sufficient in itself as a basis for decisions.

Price is an indicator of the worth of a good representing its economic marginal value. Some forest products, such as timber and livestock forage, have adequate measures of their economic worth (or the monetary value as the excess benefit over the cost of provision of the good or service) to society—established market goods with prices. Other forest products, such as some recreation opportunities and esthetic views, are nonmarket or extramarket goods without prices.

The purpose of this report is to review the literature concerning economic measurement of the impacts of forest insect pests on those products and services which do not have market-based prices (i.e., most recreation, esthetics, and homeowner benefits of property). Although there are many concerns about using these nonmarket valuation methods, the state of the art is continually improving. The results reported here should be accepted only tentatively. One significant problem with the results of the reviewed studies is that many of them are concerned with the flow of products from a forest, rather than the sustainability of the process or function of the forest. Because of this focus, most analyses are static, with the exception of some of the studies that address the issue of forest regrowth mitigating insect disturbances over time. No studies concerned with similar impacts due to diseases were found in the review.

Forest insect pests may directly damage forest commodities like timber, or they may indirectly affect noncommodity benefits such as recreation experiences. They also can have negative impacts on the flow of benefits from services provided. As with any damage, there is an associated cost or loss. The amount of this loss depends on a variety of factors, including the condition, type, and location of the forest, the magnitude of the outbreak, the kind of insect, the quality and intensity of the desired experience (esthetic, recreational), and the scope of the affected stakeholders. Insects attack trees, causing discoloration of foliage, defoliation, or both, resulting in dead and down trees and visible damage to forests which, in turn, may reduce the benefits derived from the forest and its products. One important question facing most forest managers is how much they can afford to pay for the protection of forest health. The answer to this question depends partly on the level of physical damages which result from forest insect attacks. Another part of the answer depends on the economic worth of these damages. One area that needs to be investigated further is the economic valuation of insect-related damages to forest products. These valuations can then be used in an economic evaluative framework that enables forest managers to make more informed decisions.

Another concern that received little attention in the past is the role of forest insects in the natural processes of a forest. A healthy forest can sustain tree damages due to insects, and can even benefit from these disturbances, which can change the composition of the forest to provide more diversity and energy flow (e.g., increased sunlight penetration may increase understory growth, providing more forage for animals). The view that forest insects primarily cause negative impacts is based on a static view of a forest or one which considers timber values only. When the dynamics of natural processes are considered, forest insects have an important and natural role in the complexity and overall health of a native forest. Therefore economic considerations may be better cast as the sustainability of the flow of benefits from a forest in both products and services provided.

This report summarizes the published economic valuation studies of the impacts of forest insect pests on nonmarket forest benefits. It identifies the key elements of each study, provides a narrative of each study, and includes an appendix of tables that summarize the studies. The scope of what constitutes a forest in the following studies ranges from large, publicly-owned tracts of forested land to small, privately owned clumps of trees (residential backyards). The benefits affected by insects include recreation, esthetic or scenic beauty of landscapes, and property values. The economic and financial worth reported in the summaries of the studies are all indexed[1] for inflation to 1995 dollars. Although this method of adjusting for inflation may not reflect actual relative changes in value of nonmarket benefits, this is the simplest method available. Some of the estimations in a particular study are based on the worth of the property at the time of the study; therefore, it may not be correct to assume that property values have increased at the same rate as the price index.

Arc elasticities of demand are included in the narratives of the studies either when they were reported in the publication or where there is enough information available to calculate them for this report (they have been calculated at the midpoint of the arc). These average arc elasticities show the responsiveness of demand if an important variable is changed, other things being equal. Technically, these elasticities represent the percent change in the demand for forest conditions divided by the percent change in forest condition. The number reported as the average arc elasticity is equal to the percent change in demand due to a 1-percent change in the forest condition variable, such as number of trees per acre, age of stand, or amount of insect damage. As an example, if the elasticity reported is 2, this means a 1-percent change in the average size of the trees on a site results in a 2-percent change in the demand for the site. An advantage of using elasticities as comparisons is that elasticities may be more directly transferable between time periods than unit-specific economic measures. The average arc elasticities are calculated over a 1-percent to 15-percent change in the forest condition variable from the initial level of forest quality (represented as the status quo state). This is probably the most relevant range for normal insect infestations. Impacts substantially greater than 15 percent may drastically alter the perceived damages to forests, resulting in the deterioration of the estimated demand function under conditions of catastrophic loss.

[1] The index used in the adjustment process was the Consumer Price Index for Commodities less Food (Economic Report of the President. 1995. Washington, DC: U.S. Government Printing Office.

Economic Nonmarket Valuation Methods

The adequacy of the methods used to estimate the economic worth of nonmarket goods has increased dramatically in the past few decades. Two of the more widely used methods to value nonmarket goods are the travel cost method (TCM) and the contingent valuation method (CVM). The U.S. Water Resources Council (1983), a federal interagency committee, produced one of the first reviews of these methods and established standard procedures for their implementation. A panel of experts convened by the National Oceanic and Atmospheric Administration (NOAA) also set guidelines for the use of the contingent valuation method to assess the economic worth of environmental changes (Arrow and others 1993). This group conducted a fairly critical review of the method and recommended approaches in an attempt to standardize its implementation. A third approach used in the reviewed literature is the hedonic pricing method.

The economic worth of an environmental resource such as forest health can be defined as the individual's net willingness to pay for the resource (U.S. Water Resources Council 1983; Rosenthal and Brown 1985). Willingness to pay is a monetary measure of the worth of a change in the quantity or quality of a good or service; it is the maximum amount of money (typically willingness to pay is expressed in monetary terms, although this is not required) one is willing to pay for the specific change. If the cost of the good or service is higher than one's willingness to pay, then one will not purchase the good or service. Total willingness to pay is the monetary amount actually paid for a good or service plus the amount one would be willing to pay for it. Net willingness to pay is the total willingness to pay less what was actually paid. Marginal willingness to pay is the amount one would be willing to pay for the last unit purchased. A simple way to calculate social worth is to aggregate individual values.

Some of the studies presented below estimate the impacts on recreation in terms of days of recreation. These recreation-day estimates can be easily transformed into commensurable monetary units if the monetary worth of a recreation day is known. Almost any cardinal unit can be used to measure the implicit tradeoffs associated with different levels of forest quality; however, the money metric (such as U.S. dollars) is widely recognizable and well-known as a medium of exchange. Typically, the costs associated with a management action are expressed in terms of dollars. Therefore, the economic valuation of nonmarket goods is typically expressed in commensurable monetary units. As Rosenthal and Brown (1985) show, price and willingness to pay on the margin are all equivalent units of the money metric. They are all indicators of the economic worth of a good or service. Choice of the indicator to be used relies on the level or magnitude of the change in quantity and/or quality of the resource under investigation. For small, incremental changes, demand remains fixed, so that price is equal to marginal willingness to pay. However, for large changes that shift demand, net willingness to pay is the relevant measure (*fig. 1*).

The travel cost, hedonic pricing, and contingent valuation methods of estimating the economic worth of nonmarket goods are derived from the household production approach to consumer theory. This approach assumes consumers combine purchased inputs (recreation equipment, gasoline, property) with publicly supplied inputs (forests, trails, unobstructed views) to produce experiences that give them the most satisfaction or enjoyment (Bockstael and McConnell 1981). The household production model allows the estimation of the derived demand for these experiences either by means of the travel cost method (Bockstael and McConnell 1981), the hedonic pricing method (Mendelsohn and Markstrom 1988), or if properly specified, the contingent valuation method (Loomis 1983).

Travel Cost Methods

The travel cost method is a valuation approach which uses variations in the costs of travel and other expenditures as implicit prices of destination sites to estimate the demand for the site. This method is typically used to estimate the onsite benefits of particular sites. It indirectly estimates the economic worth of a nonmarket resource by first defining the demand for the resource as a function of travel costs. Distance is an important factor in defining the demand curve. Travel costs are, in part, the variable costs of the trip. Therefore, the farther individuals are from the site, the more they pay in travel costs to the site, and in general, the fewer trips to the site they take. Different resource conditions (i.e., forest health levels) will result in shifts in the demand function for the resource. Economic worth of the resource change is measured as consumer surplus, which is equivalent to net willingness to pay. Consumer surplus is the amount of benefit gained from the purchase of a good or service beyond what was actually paid (entrance fees, travel costs) and is usually measured in monetary units.

Changes in forest health caused by pests are likely to shift the demand for recreation at the site, thus affecting the overall benefits derived from the experience (*fig. 2*). Two basic versions of the travel cost model are the individual and the zonal

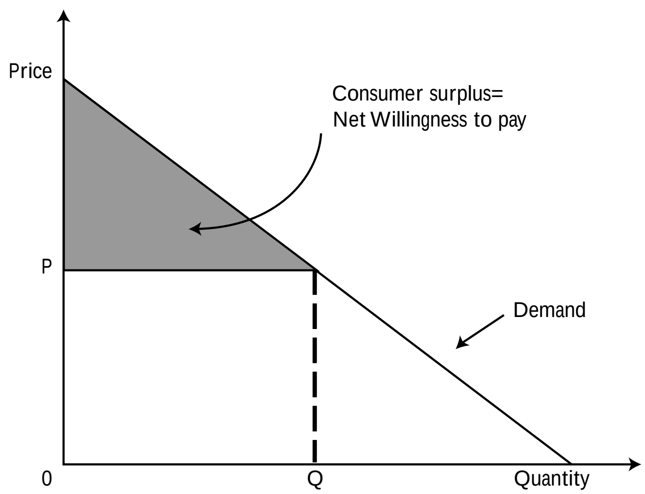

Figure 1—Equivalence of consumer surplus and net willingness to pay

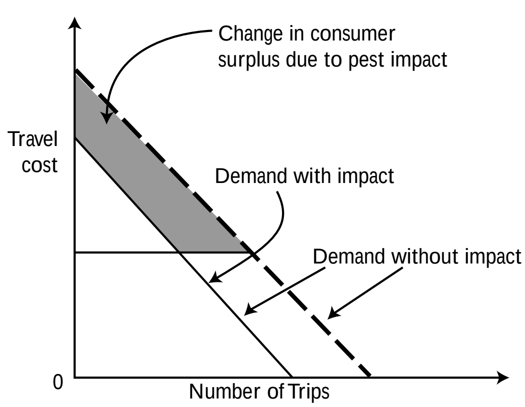

Figure 2—Travel cost estimation of loss due to pest impacts

method. The individual travel cost method defines the number of visits to a site for a given time period for an individual. The zonal travel cost method creates a set of zones from which visitors originate, and then defines the visitation rate from the different zones (where visitation rate is the number of visits from a zone divided by the population of that zone). For more detailed discussions concerning the travel cost method, see Rosenthal and others 1984; Walsh 1986.

Hedonic Pricing Method

The hedonic pricing method is another indirect estimation technique used in the economic valuation of nonmarket resources. This method estimates economic worth as a hedonic price, or the worth of an attribute as it is associated with the overall market price of a multi-attribute good such as a house or parcel of land. It is based on the variation in selling prices in an actual market and assumes that these variations are correlated with the presence of differing levels of specific attributes. For example, the price of a house may be based on the number of rooms, location, nearness to open space or public facilities, proximity of forests, and the like.

Hedonic pricing assumes that consumers choose market goods based on certain identifiable characteristics or attributes. It views any good as a bundle of attributes, each attribute contributing to the overall market worth of the good. Hedonic pricing statistically determines the marginal contribution of an attribute to the overall benefit of owning a good having the attribute by means of a two-stage process. Usually it relies on a sufficient number of sales transactions in order to allocate worth to specific attributes. For instance, assume there are two residences identical in all attributes except one: forest quality. If the residence with a preferred forest characteristic costs $X more than the other residence, then the forest attribute can be allocated a worth of $X. This is the implicit price paid for the attribute in the first stage of the analysis. In the second stage, the implicit price, along with other relevant information (such as the quality of the surrounding forest and socioeconomic variables) is used to estimate the demand for the attribute. Economic worth of the attribute is calculated as the area under the demand curve and above the implicit price line. The impact of pest-caused changes in forest health would be the reduced benefit derived from owning a good with forest health-dependent attributes. For more detailed discussions concerning the hedonic pricing method, see Freeman 1979; Brookshire and others 1982; Mendelsohn and Markstrom 1988.

Contingent Valuation Method

The contingent valuation method is a direct estimation method based on intended or stated behavior. This method asks individuals for their values (usually in monetary units) for defined changes in the quantity or quality of a good or service. Contingent valuation directly estimates economic worth as willingness to pay or compensation due[2] by surveying or interviewing individuals. Contingent valuation constructs a hypothetical market in which the quantity and/or quality of a nonmarket resource is varied or changed, for example, forest conditions. Thus, the individual bids for the resource in a hypothetical market contingent on the changes in the resource. The contingent valuation method assumes the individual can rationally express the economic worth of a nonmarket resource in this manner and that the individual's expressions are accurately elicited by the hypothetical situation.

Some concerns about the empirical application of this method have been raised, and procedural methods have been published to make its application more consistent (U.S. Water Resources Council 1983; Arrow and others 1993). Some of the concerns raised include many potential sources of bias in the results,

[2] Compensation due is also known as willingness to accept. Willig (1976) argues that, barring any wealth or income effects, willingness to pay and willingness to accept are equal. However, numerous empirical studies do not support this hypothesis for nonmarket goods exhibiting public goods characteristics. A brief review of the empirical disparity between willingness to pay and compensation-due measurements can be found in Gregory and Bishop (1988) and Fisher and others (1988).

such as interest, interviewer, and strategic biases. Another concern is the proper amount of information to be included in the survey and the best way to convey this information. The choice of the proper payment vehicle (taxes, donations, and the like) has also led to numerous arguments. Yet another concern is what the proper elicitation method should be. Some of the elicitation methods used include payment card, open-ended, dichotomous or discrete choice, and iterative bidding methods.[3] Many concerns about these issues can be overcome with proper survey design. For more detailed discussions concerning the contingent valuation method, see Mitchell and Carson 1989; and Walsh 1986.

[3] The payment card method of maximum willingness to pay elicitation is where the re–spondent is presented with information concerning ex–penditures on other goods and taxes, and then is asked to select his/her maximum willingness to pay from a list of dollar amounts presented. The modified payment card is a version of the payment card method in which no information concerning expenditures and taxes is presented. Open-ended is where the respondent is asked to write down the maximum amount he/she is willing to pay. The dichotomous choice, or discrete choice, is where the respondent is presented with a dollar amount and needs to reply only "yes" or "no" to the designated amount. This approach is also known as close-ended and take-it-or-leave-it method of value elicitation. Iterative bidding is an extension of the dichotomous choice approach in which the interviewer continues to present the respondent with increments or decrements in dollar amount, depending on initial response, until the maximum amount he/she would be willing to pay is elicited.

Key Elements Identified in Economic Valuation Studies

Some of the key elements identified in the reviewed studies are important in the transfer or application of the information and content of the different analyses. Some of the concerns in transferring models and results of studies include the site-specific nature of the data (e.g., region, forest type, kind of insect, magnitude of damages or infestation, visibility, and stakeholder groups represented), the valuation methodology used, choice of indicator variables, and the values at stake. Identification of these different elements in the studies is the first step in discovering the applicability of the study to current decisions. The studies reviewed are listed in *table 1*. The codes shown in the first column of *table 1* will be used in *tables 2-8* to identify the relevant studies.

Identification of Forest Insect Pests Studied

Table 2 identifies the different insects studied. Of course, many other insects that have not been studied in this way affect forest health. Moreover, insects are just one of many forest or ecosystem health disturbance agents with important management implications. Other disturbance agents include both natural ones (fire, wind, drought, and disease), and human-caused ones (silvicultural practices, pollution, and other human activities). The impacts of insects on forest health interact with other disturbances, creating problems for forest health management. The dynamics of ecosystems make management difficult because the susceptibility and magnitude of insect impacts are difficult to predict and control. Also, these disturbances can have positive effects on overall ecosystem (including forest) health and sustainability (Averill and others 1995).

Identification of Regions Studied

The regions studied are listed in *table 3*. Although the mountainous West has been the focus of the most studies, these primarily arose out of a USDA Forest Service project series, published in the early 1980's, that assessed the impacts of mountain pine beetle and western spruce budworm damage in the Colorado Front Range (Walsh and Olienyk 1981; Walsh and others 1981a and 1981b). Four studies measure the impacts of the gypsy moth in the Northeast. The other studies focus on the Douglas-fir tussock moth in the Southwest, the mountain pine beetle in the Northwest, the southern pine beetle in the South, and the balsam woolly adelgid in the Southeast.

Identification of Land-Use Areas Studied

The overall magnitude of the damages incurred as the result of insects can vary according to the different land-use designations. The three land-use designations in *table 4* include urban, urban/wildland interface, and wildland.

Table 1—*Economic studies of forest insect pests*

Code	Author(s)	Year	Title
1	Payne and others	1973	Economic analysis of the gypsy moth problem in the Northeast: II. Applied to residential property
2	Wickman and Renton	1975	Evaluating damage caused to a campground by Douglas-fir tussock moth
3	Michalson	1975	Economic impact of mountain pine beetle on outdoor recreation
4	Moeller and others	1977	Economic analysis of the gypsy moth problem in the Northeast: III. Impacts on homeowners and managers of recreation areas
5	Leuschner and Young	1978	Estimating the southern pine beetle's impact on reservoir campsites
6	Walsh and Olienyk	1981	Recreation demand effects of mountain pine beetle damage to the quality of forest recreation resources in the Colorado Front Range
7	Walsh and others	1981a	Value of trees on residential property with mountain pine beetle and spruce budworm in the Colorado Front Range
8	Walsh and others	1981b	Appraised market value of trees on residential property with mountain pine beetle and spruce budworm damage in the Colorado Front Range
9	Loomis and Walsh	1988	Net economic benefits of recreation as a function of tree stand density
10	Walsh and others	1989b	Recreational demand for trees in National Forests
11	Walsh and others	1990	Estimating the public benefits of protecting forest quality
12	Jakus and Smith	1991	Measuring use and nonuse values for landscape amenities: a contingent behavior analysis for gypsy moth control
13	Haefele and others	1992	Estimating the total value of forest quality in high-elevation spruce-fir forests
14	Miller and Lindsay	1993	Willingness to pay for a state gypsy moth control program in New Hampshire: a contingent valuation case study
15	Holmes and Kramer	1996	Contingent valuation of ecosystem health

Table 2—*Forest insect pests studied*

Insect pest	Study code[1]
Gypsy moth (*Lymantria dispar*)	1, 4, 12, 14
Douglas-fir tussock moth (*Orgyia pseudotsugata*)	2
Mountain pine beetle (*Dendroctonus ponderosae*)	3, 6, 7, 8, 9, 10, 11
Southern pine beetle (*Dendroctonus frontalis*)	5
Spruce budworm (*Choristoneura occidentalis*)	7, 8, 11
Balsam woolly adelgid (*Adelges piceae*)	13, 15

[1]See *table 1* for description of study codes.

Table 3—*Regions of the United States where economic studies of forest insect pests were conducted*

Region	Study code[1]
Mountainous west	6, 7, 8, 9, 10, 11
Northeast	1, 4, 12, 14
Northwest	3
South	5
Southeast	13, 15
Southwest	2

[1]See *table 1* for description of study codes.

Table 4—*Forest insect pest studies by designated land-use areas*

Land-use area	Study code[1]
Urban	1, 4, 12
Wildland	2, 3, 5, 6, 9, 10, 11, 13, 15
Wildland/urban	7, 8, 14

[1]See *table 1* for description of study codes.

Table 5—*Stakeholders identified in forest insect pest studies*

Stakeholder	Study code[1]
General public	13, 14, 15
Homeowners	1, 4, 7, 12
Land managers	4
Real estate appraisers	8
Recreationists	2, 3, 5, 6, 9, 10, 11, 13, 15

[1]See *table 1* for description of study codes.

Table 6—*Values identified and measured in economic studies of forest insect pests*

Value	Study code[1]
Esthetics	2, 12
Passive-use	11, 13, 15
Property	1, 7, 8
Recreation	2, 3, 4, 5, 6, 9, 10, 11, 13, 15
Total value	11, 13, 14, 15

[1]See *table 1* for description of study codes.

Table 7—*Nonmarket valuation methods used in economic studies of forest insect pests*

Nonmarket valuation method	Study code[1]
Contingent	6, 7, 8, 9, 10, 11, 12, 13, 14, 15
Hedonic property	1
Other	2, 4
Travel cost	3, 5, 6, 10

[1]See *table 1* for description of study codes.

Table 8—*Forest insect impact indicator variables used in economic studies*

Impact indicator	Study code[1]
Number of trees	1, 2, 6, 7, 8, 9, 10, 11
Other	5, 6, 7, 8
Presence of insect	4
Tree size	6, 7, 8, 9
Visible damage	2, 3, 4, 6, 7, 12, 13, 14, 15

[1]See *table 1* for description of study codes.

The magnitude of damage caused by insects is expected to be greater in the urban and urban/wildland interface areas. Property value is little affected by distant damage, where damages are less visible. However, in urban and urban/wildland interface areas, property values can be quite sensitive to insect damage in the near view. Although insect damages are typically short-term (the forest will recuperate through regrowth), the decrease in recreation, esthetic, and property values as a result of these damages is real and substantial. Some of the studies are concerned with the value added by trees to recreation activities, property values, and esthetic viewsheds. Others are primarily concerned with wildland areas, where forests dominate the landscape and the supply of recreation and forest commodities is most affected.

Identification of Stakeholders

Equally important in the management of forests is the identification of the relevant stakeholders involved. Stakeholders are those affected directly and/or indirectly by the changes in the quality of a forest which result from an insect infestation. Properly identifying the stakeholders is a necessary beginning in any management plan. *Table 5* shows the stakeholders identified in the studies. Implicit in this list are forest managers, planners, and decision makers.

The stakeholders identified in any specific study are not assumed to be an exhaustive list, but just one element in the overall collection of insect damage information. For instance, the studies by Walsh and Olienyk (1981) and Walsh and others (1981a and 1981b) each identify different stakeholders: recreationists, real estate appraisers, and property owners.

Identification of Values Estimated

Many values are at stake in insect infestations. *Table 6* lists the economic values of a forest identified in the studies.

The value of recreation use is the most often identified. Others include property, esthetics, passive use values (including option, existence, and bequest values for forest health), and total value (which is the sum of use and passive-use values). With increased development of wildland fringe areas, creating more urban/wildland zones, protection of property and esthetic values will likely increase in management importance. The economic estimates included in the studies are primarily short-term responses to a static comparison of forest conditions. Therefore, these estimates do not necessarily include the social, cultural, and ecological importance of forest functioning, such as maintaining biodiversity, sustaining natural processes, and providing historic cultural identity.

Identification of the Nonmarket Valuation Methods Used in Each Study

As *table 7* shows, the contingent valuation method is the most often used method of benefit estimation in these studies. It is the most viable method of measuring total economic worth (Randall and Stoll 1983) and can measure recreation, property, and esthetic benefits, making it broader in its applicability. The travel cost method is used in the four studies that measured recreation use benefits, and the hedonic pricing method is used in one study that measured property value. Other methods used include replacement and expenditure cost estimations.

Identification of Forest Insect Impact Indicators Used

Insects can affect a forest in many ways, including the amount of dead and down trees, density of the forest, and amount of visible tree damage. *Table 8* lists the different indicators used in each study.

The number of trees and amount of visible damage are the most often used indicators of insect damages. When insects attack trees, they damage and sometimes kill them, resulting in fewer trees per acre and, in the short term, increased evidence of damage. The specific indicators used and impacts estimated by each study are summarized in the appendix tables. However, these indicators are static, measuring forest conditions only at a point in time. Both the visual and biological impacts of insects consist of a series of forest changes which are not well identified in many studies.

General Relationships Between Indicator Variables and Values Identified in the Studies

Table 9 lists some of the relationships discovered in the different investigations, along with two examples of the estimates derived from the studies.

Table 9 shows that forest density (the number of trees per acre) is positively related to property, recreation, and esthetic benefits. This is a generalization; some of the studies showed a decrease in benefits when forest density increased beyond some quantity of trees (Walsh and Olienyk 1981; Walsh and others 1981a and 1981b). The presence of a few large trees [>24 in. diameter at breast height (dbh)], together with the presence of a greater variety of tree species, is positively correlated with benefit levels. The presence of visible damage, dead and dying trees, and smaller average tree size has a negative impact.

Table 9—***Indicator variable and value sources relationship, with two examples of value estimates from a forest insect pest infestation***

	Value source		
Indicator variable	Property	Recreation	Esthetic
Decrease in no. of trees/acre	Decreases	Decreases[1]	Decreases
Increase in visible damage	Decreases	Decreases	Decreases
Increase in dead and dying trees	Decreases	Decreases	Decreases
Decrease in average tree size	Decreases	Decreases	Decreases
Presence of large trees >24 in. dbh.	Increases	Increases	Increases
Increase in tree species mixture	Increases	Increases	Increases

Examples of economic estimates[2, 3]

Visible damage	$2,700 to $7,000 per acre decrease in urban/wildland private property value with a 15-pct increase in visible damage to surrounding forest
	$19 to $70 annual household willingness to pay for reducing visible damage in corridors (roads, trails) to statewide programs
	$254 to $670 annual household willingness to pay for reducing damage in urban areas
Number of trees/acre	$201 to $984 per acre reduction in urban to urban/wildland private property value due to a 15-pct decrease in no. of trees/acre
	$97 to $321 reduction in annual recreation benefit per visitor with a 15-pct decrease in no. of trees/acre

[1]Depends on recreation activity. Most recreation activities were found to be positively related to number of trees per acre (within bounds), but off-road-vehicle use was found to be negatively related to the indicator variable.

[2]Economic estimates are in 1995 dollars.

[3]Insect, region, forest type, and stakeholder differences across the studies are ignored in the examples.

Table 9 also reports ranges of estimates for changes in two of the indicator variables across the relevant studies. The examples tentatively lead to the conclusion that property values are much more sensitive to insect damages than are esthetics and recreation. Therefore, as more sites are developed near the wildland fringe, it can be expected that damages will continue to grow and management of these areas will become more difficult. A disturbance that had little impact or need for management involvement may change completely with the increase in urban development of wildland fringes because of the increased demand for stable esthetic views.

Summary of Nonmarket Economic Valuation Studies

1. Payne and others, 1973. Residential property in the Northeast and the Gypsy Moth (appendix table 1)

Payne and others (1973) estimate the gypsy moth's impact on residential property value in the northeastern United States. Gypsy moths are most destructive in residential areas where the worth of trees for conversion to wood products is greatly exceeded by the amenity benefits produced by the trees. Federal, state, and local agencies need estimates for the impacts of gypsy moths on the residential property in order to improve decisions on controlling gypsy moths. The authors present a method for estimating the losses in residential property values due to gypsy moths.

This study uses the hedonic pricing method to determine the contributed worth of trees to residential property where the trees are not normally separable from the land parcel itself. The amenity benefits of trees for property owners include shade, microclimatic effects, and esthetics, and are reflected in the market price of the property. A gypsy moth attack, through repeated defoliation, can kill the tree and completely eliminate the production of its amenity benefits until a different tree has matured to the point of total replacement for the lost tree. The authors test the Amherst model by applying it in a similar environment: Stroudsburg, Pennsylvania. The data include the fair market value of the parcel, the size of the parcel, the number of trees [≥6 inches diameter at breast height (dbh)], and an estimate of the level of tree mortality associated with a given level of insect infestation.

In the pre-attack scenario (with a gypsy moth control program of 100 percent effectiveness), it is estimated that the contributed worth of trees to residential property is $7,767/acre with 29 trees/acre; or about $270/tree. Incremental per-tree benefits represent diminishing returns per tree. Beyond this level of 29 trees/acre, each incremental tree adds less to the property value (up to the observed maximum of 50 trees per acre in the sample). The average arc elasticity of demand for trees on residential property is 0.24, meaning that a 0.24-percent reduction in the contributed worth of trees to residential property results from a 1-percent decrease in the number of trees ≥6 inches dbh.

In the post-attack period (without a gypsy moth control program), the loss in property value is equal to the predicted number of trees killed times the estimated per-tree worth, according to this study's estimates. The net worth of the change in property value after attack by gypsy moths is the difference between the pre-attack and post-attack estimates. Therefore, a gypsy moth attack with a 15-percent mortality rate (29 trees per acre to 24.65 trees per acre) results in a loss of approximately $1,175/acre. The estimated worth is only for the benefits accruing to the onsite property owners. Benefits not measured are the offsite values accruing to the general population (neighbors, passers-by). Impacts not accounted for include non-mortality effects like discoloration and defoliation of trees, and the unpleasant effects of the presence of moths (caterpillars, feces, cocoons, allergic reactions to moths). Other losses associated with pest infestations include the removal and replacement costs of dead trees, and the costs of control. The model used is applicable only to areas similar to the two study areas.

2. Wickman and Renton, 1975. Esthetics at the Stowe Reservoir Campground in California and the Douglas-fir Tussock Moth (appendix table 2)

Wickman and Renton (1975) estimate the total loss of recreation benefits of camping at a Forest Service campground at Stowe Reservoir in the Warner Mountains, Modoc National Forest, California, caused by the Douglas-fir tussock moth infestation. The moth can cause heavy defoliation of white fir, resulting in tree mortality and top-kill. This damage can have a significant impact on the recreation benefits at specific sites by reducing the amount of shade, esthetic quality, and privacy screening. The authors estimate the insect damages by adding the actual costs of clean-up to a calculated unit worth of trees as esthetic value.

The esthetic worth component of trees in the campground is equivalent to the total replacement costs of the campground. With 46 trees on each of eight camp units, the esthetic value of the campground based on estimated replacement costs is $20,610 (about $2,576 per camp unit or $56 per tree). The actual costs of clean-up (felling, removal, and topping of affected trees) is estimated to be $324 for the campground with 25 trees killed due to insect infestation. The total loss in campground worth if 25 trees are killed is estimated to be about $1,725 (total esthetic damage plus clean-up costs), or about $216 per camp unit.

The method employed in this study may be sufficient to estimate nonmarket benefits if the economic evaluation is concerned with cost-minimization or cost-savings approaches on the public good supply side. However, on the demand side, the manager may be more interested in the benefits generated by the resource (in this study, the camp unit with pre-infestation characteristics). The actual and replacement cost valuation approach may not adequately estimate nonmarket benefits (Loomis 1993). Total replacement costs of a camp unit may not be a good proxy for the total worth of the unit if it does not account for potentially high benefits generated by the unit (esthetic value). The replacement costs also may not be feasible for a 60- to 70-year-old stand of white fir. If anything, the loss of nonmarket benefits will continue to accrue until replacement trees grow to sufficient size, mitigating the damage caused by the insects.

3. Michalson, 1975. Recreationists in the Targhee National Forest and the Mountain Pine Beetle (appendix table 3)

Michalson (1975) estimates the impact of the mountain pine beetle on the benefits of recreation in the Targhee National Forest in eastern Idaho. Mountain pine beetle infestation in the predominantly lodgepole pine forested area affects recreation by killing trees, thus reducing esthetics in the short run. This study estimates the impact on recreation of the increased presence of dead trees caused by a mountain pine beetle infestation. The purpose of this study is to estimate recreation losses, allowing the decision maker to determine the amount of investment needed, if a control program is to be implemented.

The author estimates the losses to recreation in the study area by means of the travel cost method, using expenditure and visitor-day loss calculations. He calculates the impact of the beetles by estimating the consumer surplus and expenditure per visitor day, and the number of visitor days for campgrounds with >30-percent infestation and for campgrounds with <30-percent infestation. The study's hypothesis is that the difference between these estimates equals the amount of recreation loss, or economic impact, associated with the mountain pine beetle damage. Although, as discussed earlier, expenditure is not a good measure of economic loss, it is a helpful measure if a cost-minimization approach is chosen.

Michalson (1975) estimates that a scenario without mountain pine beetle infestation generated $30.49 in average consumer surplus per visitor day, per person; with each visitor spending on average $5.28 per visitor day and staying approximately 3.3 visitor days per person per visit. The estimate for a scenario with mountain pine beetle infestation is $26.40 in average consumer surplus per visitor day, per person, with each visitor spending on average $4.85 per visitor day and staying approximately 2.1 visitor days per visit. The difference between the estimates for the scenario without infestation and those for the scenario with infestation is the economic impact of a mountain pine beetle infestation. These impact estimates, on average, are a loss of $4.09 in consumer surplus per visitor day per person, a reduction in the amount spent per visitor day per person of $0.43, and a reduction in length of stay per visit of 1.2 visitor days per person. Based on an estimated 124,783 visitor days per year (in the early 1970's), there is an estimated loss of $510,362 in consumer surplus per year in the Targhee National Forest, and a loss in local expenditures of $53,657 per year with the level of damage at the time of the study.

4. Moeller and others, 1977. Homeowners and Recreation Area Managers in the Northeast and the Gypsy Moth (appendix table 4)

Moeller and others (1977) estimate the gypsy moth's impact on homeowners and managers of recreation areas as control costs, financial losses, and lost recreational use. The authors identify five ownership classes: (1) homeowners using public control methods, (2) homeowners using commercial control methods, (3) commercial campgrounds, (4) quasi-public recreation areas, and (5) public recreation areas. Federal, state, and local agencies need estimates of the gypsy moth's impact on the economic and ownership objectives of the different ownership classes. Decision makers can use the information in the design, implementation, and coordination of gypsy moth control programs.

Gypsy moth infestations can affect specific objectives of the owner/manager of a property. The authors interviewed 540 homeowners and 170 managers of recreation areas in Pennsylvania and New York in 1973. The authors identify four objectives for each ownership category that can be affected by gypsy moths. Homeowner objectives, excluding the need for a place of residence, include (1) the enjoyment of natural beauty, (2) backyard recreation, (3) property value, and (4) the maximization of recreation use. The study identifies the following management objectives for managers of recreation areas: (1) the maximization of recreation revenue, (2) the maximization of property value, (3) the maximization of the enjoyment of natural beauty, and (4) the maximization of recreation use. The authors identify four possible effects gypsy moth infestations can have on the ownership objectives: (1) nuisance (presence of insects, feces, and egg masses), (2) defoliation of trees and shrubs (reducing the shade and esthetic quality of the property), (3) mortality (the killing of trees by the moths), and (4) other (allergic reactions to the moths and the like).

Calculations of important indices provide a measure of the relative importance of the impact of moths on a specific ownership objective. The study found that the nuisance effect affected the enjoyment of natural beauty and backyard recreation the most for homeowners, regardless of whether public or commercial control methods were employed. The nuisance effect of a gypsy moth infestation also affects the enjoyment of natural beauty in recreation areas the most, in the opinion of managers of commercial campgrounds and managers of quasi-public recreation areas (such as land owned and operated by the Boy Scouts organization). Managers of public recreation areas believed that the maximization of recreation revenue and enjoyment of natural beauty are affected most by the nuisance effect associated with a gypsy moth infestation. The only other effect that shows significant impacts on specific management objectives is defoliation.

The authors also report financial information on the control costs of a gypsy moth infestation, as well as financial losses and economic information on recreation losses for the different ownership classes attributable to the infestation. Control costs represent an economic measure of the importance owners place on goods and services and include what the owners actually spend on gypsy moth control programs, including the cost of equipment, materials, services, and the owners' own labor input. This study assigns labor a worth of $2 (in 1977 dollars) per hour in moth control. Homeowners who participate in a public control program spend on average $102 per year, whereas those who participate in commercial control methods spend on average $240 per year. Managers of recreation areas spend $441 on average for commercial campgrounds and $722 per year for quasi-public recreation areas in control costs. No data were collected for managers of public recreation areas for either control costs or financial losses.

Financial losses are another measure of the impacts of gypsy moths on property through the capital cost reduction in property value and the increase in maintenance costs and revenue losses. Homeowners who participate in public control programs report $125 in financial losses per year on average, whereas those who participate in commercial control programs report losses of $479 per year on average. Managers of recreation areas report financial losses of $249 per year for the average commercial campground operation, and $996 per year for the average quasi-public recreation area.

Effects of gypsy moth infestations can alter the recreation benefits derived from private and public property. The economic effects of a moth infestation on recreation are not included in the above estimates. Recreation use losses in the different ownership classes are estimated as the number of person-days of recreation use lost per year. Homeowners with public controls report a loss of 108 person-days in recreation use per year on average, whereas homeowners with commercial controls report an average recreation use loss of 133 person-days per year. Managers of recreation areas report larger impacts on recreation use than homeowners. Managers of commercial campgrounds report an average of 161 lost person-days of recreation use per year. Managers of quasi-public campgrounds report an average recreation use loss of 240 person-days per year. Managers of public recreation areas report an average loss of 36,660 person-days per year.

This study ranks the relative effects of a gypsy moth infestation on the different ownership/management objectives. It estimates financial as well as economic measures of gypsy moth impacts. It measures the economic losses of recreation use of property in person-days which can be converted to a commensurable dollar metric if the dollar worth of a person-day in recreation use is known. This is the first study to address the direct impacts of the presence of gypsy moths through the nuisance effect. Most studies estimate the secondary effects of a pest infestation, such as tree mortality, defoliation, and discoloration which result in reduced recreation quality, esthetic or scenic quality, property value, and other amenity benefits produced by trees or forests, ignoring the direct effects the presence of insects may have on benefits.

5. Leuschner and Young, 1978. Recreation at East Texas Reservoir Campsites and the Southern Pine Beetle (appendix table 5)

Leuschner and Young (1978) estimate the southern pine beetle's impact on recreation use of reservoir campsites in east Texas, where beetles kill patches of trees near the reservoirs. This affects many different forest products, including the recreation benefits of the surrounding campgrounds. To deal with these effects, forest managers need to be able to quantitatively evaluate pest control programs. One method of quantitative analysis is through the use of benefit-cost analysis. In order to use benefit cost analysis, all relevant values must be measured and included. Recreation benefit is negatively affected because the beetle-killed trees reduce the shade available and the number of living trees in campsites. Normally, two reactions will be forthcoming following a beetle-infestation: (1) the recreationists will continue to use the site but at a reduced enjoyment level, or (2) the recreationists will substitute unattacked sites for their recreation outings. The authors report that they do not attempt to estimate the first reaction because they lack a state-of-the-art means for estimating this form of a recreation impact.

The authors estimate the demand functions for two types of campgrounds on the basis of secondary data collected by the managing agencies. The two managing agencies are the USDA Forest Service (FS) and the U.S. Army Corps of Engineers (COE). Seven FS and 12 COE campgrounds are included in the study. The impact indicator variable is the percentage of pine crown cover, estimated from aerial photos taken in 1969 (black and white photos) and in 1970 (color photos). Secondary data on recreation use collected by the managing agencies on site are used to estimate the recreation demand for campgrounds (based, in part, on the percentage of pine crown cover) through the use of the zonal travel cost method. The unaffected recreation benefit is estimated as the area under the derived demand curve. By changing the percentage of pine crown cover in the derived demand functions for recreation at different campgrounds to simulate beetle infestations, the authors were able to predict the impact of a beetle infestation on the recreation benefit at the site. They estimate total recreation benefit for the campgrounds included in the study as $12,350,800 to $19,889,600, depending on assumptions about the worth of travel time to the recreation site. The smaller amount is when travel time costs are not included, and the larger amount is when a positive travel time cost is allocated on the basis of a methodology current at the time of the study (Cesario 1976).

The recreation damages incurred from a beetle infestation are calculated for each of the campgrounds in the study. Aggregate impacts cannot be calculated because (1) unattacked campgrounds are substituted, by campers, in place of infested campgrounds, (2) some of the sites are not included in the simulated pest infestation, (3) the probability is low that all sites would be affected identically, and (4) there is no estimate for the decreased recreation benefit for those who continue to use the affected site. However, a rough aggregate estimate can be calculated assuming all sites are equally affected and no substitution occurs. Recreation benefit at FS campgrounds, with a 10-percent reduction in pine crown cover, are negatively impacted by $1.12 per visit. With a 30-percent reduction in pine crown cover, recreation benefits decrease by $3.37 per visit. This results in an estimated recreation loss at FS campgrounds of approximately $287,400 with a 10-percent reduction in pine crown cover and $862,300 with a 30-percent reduction. Recreation benefit at COE campgrounds with a 10-percent reduction in pine crown cover is negatively affected by $0.82 per visit. With a 30-percent reduction the decrease in benefit is $2.44 per visit. This results in an estimated loss at COE campgrounds of approximately $1,045,000 with a 10-

percent reduction in pine crown cover and $3,113,000 for a 30-percent reduction. A total loss of $1,332,400 in recreation benefit at east Texas reservoirs is estimated with a 10-percent reduction in pine crown cover. Estimated total loss with a 30-percent reduction is $3,975,300.

The authors also investigate the effect of substitution on the recreation loss of a simulated pest infestation at two campgrounds. Site-specific damage estimates are reduced by 85 to 90 percent when unattacked sites are substituted for the attacked site. However, the larger the affected area, the smaller this reduction is, because few or no unaffected substitute sites are available. The damages incurred from a beetle infestation are short-term, but multi-period. These damages may eventually be mitigated through the natural regeneration of forest quality through regrowth, but during the replacement and regrowth periods, some positive level of recreation losses are realized.

6. Walsh and Olienyk, 1981. Recreation in the Colorado Front Range and the Mountain Pine Beetle (appendix table 6)

Walsh and Olienyk (1981) estimate the impacts of the mountain pine beetle on recreation demand in the Front Range of the Colorado Rocky Mountains. Recreation activities include developed camping, semi-developed camping, backpacking, hiking, fishing, picnicking, and using off-road vehicles (ORVs). Mountain pine beetles attack and kill ponderosa pines, resulting in the short-run discoloration of needles and dead and down trees that detract from the perceived quality of the forests. The long-run effect of a beetle infestation is a reduction in the density of the forest. Both the very short-run and the short-run effects on forest quality affect the demand for recreation use of these forests. The results of the study contributed to the assessment of a USDA Forest Service forest insect and disease management program including the assessment of forest insect control programs, and of citizen participation in management decisions and cost-sharing programs.

A stratified random sample of 435 recreation users was interviewed onsite at six different forest recreation sites in 1980. Using contingent valuation (with an iterative bidding technique) and individual travel cost methods, the authors estimate the worth of these beetle impacts on recreation demand as willingness to pay (in dollars) and willingness to participate (in user days). The beetle-contingent changes in forest quality (depicted through the use of color photos) investigated by the authors include the following indicators: (1) the number of trees 6 inches in dbh or more on the site, on adjacent land affecting the near view, and on distant land affecting the far view, (2) the size of trees, (3) the presence of visible beetle damage, (4) the presence of dead and down trees, (5) the distribution of trees over the area (the presence of treeless patches caused by a beetle infestation), and (6) the presence of large specimen trees.

The authors estimate the average arc elasticities for aggregate recreation demand (excluding ORV use) in a 1- to 15-percent decrease from the predicted level of the indicator variable with a mean number of 178 trees per acre. The elasticities show that a 1-percent decrease in the number of live trees per acre onsite results in a 0.28-percent decrease in recreation demand. A 1-percent decrease in the number of live trees on adjacent property affecting the near view results in a 0.25-percent decrease in the demand for recreation onsite. A 1-percent decrease in the number of live trees on distant land affecting the far view results in a 0.16-percent decrease in the demand for recreation onsite. Recreation demand decreases by 0.32 percent with a 1-percent decrease in the average size of the trees surviving a beetle infestation (calculated in the 3-inch to 12-inch dbh range). Recreation demand decreases by 2.30 percent with either a 1-percent increase in visible damage such as needle discoloration or a 1-percent increase in the presence of dead and down trees with slash on the ground. A 1-percent increase in treeless areas caused by a beetle infestation results in a 0.24-percent decrease in the demand for recreation onsite. Recreation demand decreases by 2.20 percent with a 1-percent decrease in the presence of large specimen trees bigger than 24 inches dbh (this is approximately two specimen trees) at the recreation site. Evidently, recreation demand is more sensitive to visible damage and the presence of large trees than it is to the other factors.

Walsh and Olienyk (1981) estimate the loss in user days of recreation use for the Colorado Rocky Mountains Front Range as the result of a 15-percent effect on the following forest attributes by a beetle infestation. Aggregate recreation demand (excluding ORV use) decreases by 370,000 user days per year with a 15-percent reduction in the number of trees onsite; by 330,000 user days per year with a 15-percent reduction in the number of trees on adjacent land; and by 207,000 user days per year with a 15-percent reduction in the number of trees on distant land. A 15-percent reduction in the average size of the trees on the recreation site reduces demand by 422,000 user days per year. Either a 15-percent increase in the percentage of visible beetle damage or a 15-percent increase in the amount of dead and down trees decreases recreation demand by 3,045,000 user days per year. If 15 percent of the recreation site is a contiguous treeless area as the result of beetle infestations, recreation demand for the site decreases by 317,000 user days per year. A 1-percent decrease in the number of large specimen trees on the recreation site decreases recreation demand by 192,700 user days per year. The authors also report the impacts of a beetle infestation on the demand for the individual recreation activities.

The authors also estimate the impact on consumer surplus per user day with a 15-percent reduction in the number of live trees 6 inches in dbh or more, per acre, by means of the contingent valuation method. They estimate a range of $1.50 to $1.70 per user day in lost consumer surplus, depending upon the initial number of trees per acre. The $1.50 is calculated for 178 trees per acre, and the $1.70 is calculated for 270 trees per acre. Using the travel cost method of recreation demand analysis, the authors also estimate the effect of a 15-percent decrease in the number of trees per acre on the number of trips to a recreation site in the Colorado Front Range per person per year, and on the consumer surplus per person per trip. The study found that a 15-percent decrease in the number of trees per acre results in 0.16 fewer trips per person per year and in a reduction in consumer surplus of $11.60 per person per year, or an average reduction of $1.75 in consumer surplus per person per trip.

To account for the natural recovery of a forest from an insect infestation, Walsh and Olienyk (1981) developed a regrowth model which adjusts the losses over time to reflect the natural regenerative abilities of the forest. The losses estimated are per year and will continue to be realized for Colorado Front Range forests until replacement trees are of sufficient size and quality so that the original losses are completely offset. Benefits not included in the present study are the benefits of forest quality to the general public who may be willing to pay for the preservation of forest quality, for the option of future use of the forest, for the knowledge that forest quality exists and is protected, and for the satisfaction from the bequesting of forests and forest quality to future generations. Other sources of value held by the general public include psychological and ecological values. The psychological and ecological benefits associated with forest health may be large enough to exceed the economic estimates listed in this study.

7. Walsh and others, 1981a. Residential Property Owners in the Colorado Front Range and the Mountain Pine Beetle and Western Spruce Budworm (appendix table 7)

Walsh and others (1981a) estimate the impacts of the mountain pine beetle and the western spruce budworm on the contributed worth of trees to residential property in the Front Range of the Colorado Rocky Mountains. Trees provide shade, esthetic quality, wildlife habitat, privacy, and other amenity benefits to the owners of property. Mountain pine beetles attack and either kill or cause visible damage to ponderosa pine trees. Western spruce budworms attack Douglas-fir trees, causing extensive visible damage, but rarely kill the trees. Insect infestations that kill or cause visible damage to trees near residential mountain properties have an effect on the satisfaction derived from owning and living on mountain property, which is reflected in the property value. The study was conducted to develop and apply a procedure for measuring the effect of mountain pine beetle and western spruce budworm infestations on the worth of trees to owners of residential property in the Front Range of the Colorado Rocky Mountains. The results of the study contributed to the assessment of a USDA Forest Service forest insect and disease management program including the assessment of forest insect control programs, and of citizen participation in management decisions and cost-sharing programs.

A representative sample of 64 mountain homeowners was interviewed at five different study sites along the Front Range of the Colorado Rocky Mountains in 1980. Using the contingent valuation method (with an iterative bidding technique), Walsh and others (1981a) estimated the insect impacts on the contributed worth of trees to mountain residential property as the owners' willingness to pay for different levels of forest quality. The contingent changes in forest quality caused by insect infestations investigated by the authors and depicted in color photos include (1) the number of trees 6 inches in dbh or more on the residential property and on adjacent property in the near view, (2) the size of the trees on the property, (3) an expert expectation of a severe insect infestation, (4) the presence of visible tree damage, (5) the distribution of ponderosa pine and Douglas-fir on the property, (6) the distribution of trees over the property (the presence of treeless patches caused by an insect infestation), and (7) the presence of large specimen trees. The study divides mountain properties into improved lots (lots where a mountain home has been constructed) and unimproved lots (plotted lots where a subdivision has been filed but where no mountain homes have been constructed).

The authors estimate the average arc elasticities for the contributed worth of trees to mountain properties in a 1- to 15-percent range decrease from the predicted optimal level of the indicator variable with a mean number of 212 trees per acre. The elasticities show that a 1-percent decrease in the number of trees 6 inches in dbh or more on the property results in a 0.34-percent decrease in the contributed worth of the trees to improved lots and a 0.28-percent decrease for unimproved lots. A 1-percent decrease in the number of trees on property adjacent to improved lots affecting the near view decreases the worth of the improved lots by 0.20 percent. The worth of improved and unimproved lots decreases by 0.35 percent and 0.33 percent, respectively, with a 1-percent decrease in the average size of the trees surviving a beetle infestation on the lot (calculated in the 3-inch to 12-inch dbh range). The worth of improved lots decreases by 0.76 percent and the worth of unimproved lots decreases by 0.61 percent with a 1-percent increase in an expert expectation of insect damage to trees on the lot. A 1-percent increase in visible damage caused by an insect infestation results in a 2.27-percent decrease in improved lot worth and a 1.80-percent decrease for unimproved lots. A 1-percent increase in treeless areas caused by insects results in a 0.29-percent decrease in improved lot worth and a 0.40-percent decrease in unimproved lot worth. The worth of improved lots and unimproved lots increase by 0.02 percent and 0.04 percent, respectively, with a 1-percent change in the distribution of tree species from ponderosa pine to Douglas-fir. A 1-percent decrease in the presence of large specimen trees bigger than 24 inches dbh (approximately two trees per acre) decreases improved lot worth by 3.64 percent and unimproved lot worth by 2.61 percent. Property value is evidently more sensitive to visible damage and the presence of large trees.

Walsh and others (1981a) estimated the dollar equivalents in reduced mountain property value due to a 15-percent change in the forest quality indicator variables (calculated with an average of 212 trees per acre and mountain lots averaging 1 acre per lot). A 15-percent reduction in the number of trees on the lot decreases improved lot worth by $984 and unimproved lot worth by $578. Improved lot worth decreases by an additional $602 if the number of trees on adjacent property affecting the near view decreases by 15 percent. A 15-percent reduction in the average tree size results in a $1,228 reduction in the worth of improved lots and a $783 reduction in that of unimproved lots. With an increase of 15 percent in expected damage due to an insect infestation, based on expert opinion, improved lot worth decreases by $2,351 and unimproved lot worth decreases by $1,364. A $7,034 reduction in the worth of improved lots and a $4,045 reduction in that of unimproved lots results from a 15-percent increase in visible insect-caused damage to trees. With 15 percent of the lot treeless because of an insect infestation, the worth of improved lots and unimproved lots decrease by $907 and $896, respectively. A 15-percent change in the distribution of tree species from ponderosa pine to Douglas-fir results in an increase in the worth of improved lots by $61 and that of unimproved lots by $84. The increasing percentage of Douglas-fir on the property leads to increased property value probably because Douglas-fir is scarce in the elevation range in which the study was conducted. A 1-percent decrease in the number of large specimen trees per lot decreases the worth of improved lots by $918 and that of unimproved lots by $449.

To account for the natural recovery of a forest from an insect infestation, Walsh and others (1981a) developed a regrowth model. The regrowth model adjusts the losses over time as a result of the natural regeneration abilities of the affected forest. The losses estimated are per year and continue to be realized for Colorado Front Range forests until replacement trees are of sufficient size and quality so that the original losses are completely offset. Benefits not included in this study are the benefits of forest quality to the general public who may be willing to pay for the preservation of forest quality, and for option, existence, and bequest values. Other sources of value held by the general public include the psychological and ecological values. The psychological and ecological benefits associated with forest health may be large enough to exceed the economic estimates listed in this study.

8. Walsh and others, 1981b. Appraised Market Value of Trees on Residential Mountain Properties in the Colorado Front Range and the Mountain Pine Beetle and Western Spruce Budworm (appendix table 8)

Walsh and others (1981b) estimate the impact of the mountain pine beetle and western spruce budworm on the market value of improved and unimproved mountain properties in the Front Range of the Colorado Rocky Mountains. Trees provide shade, esthetic quality, wildlife habitat, privacy, and other amenity benefits to the owners of property. Mountain pine beetles attack and either kill or cause visible damage to ponderosa pine trees. Western spruce budworms attack

Douglas-fir trees, causing extensive visible damage, but rarely kill the trees. Insect infestations that kill or cause visible damage to trees near residential mountain properties have an impact on the satisfaction derived from owning and living on mountain property, which is reflected in the property value. Real estate appraisers allocate worth to all marketable attributes of a property in appraising the property's market value for potential or current owners. This study was conducted to develop and apply a procedure for measuring the effect of mountain pine beetle and western spruce budworm infestations on the contributed worth of trees to residential property in the Front Range of the Colorado Rocky Mountains. The results of the study contributed to the assessment of a USDA Forest Service forest insect and disease management program including the assessment of forest insect control programs, and of citizen participation in management decisions and cost-sharing programs.

A representative sample of 21 real estate appraisers of Front Range mountain property were interviewed in 1980. Using the contingent valuation method (with the iterative bidding technique), Walsh and others (1981b) estimate insect impacts on the contributed worth of trees to mountain residential property through the professional opinions of mountain property real estate appraisers for changes in different forest quality indicator variables. The contingent changes in forest quality caused by insect infestations investigated by the authors and depicted in color photos include (1) the number of trees 6 inches in dbh or more on the residential property and on adjacent property in the near view, (2) the size of the trees on the property, (3) an expert expectation of a severe insect infestation, (4) the presence of visible tree damage on the property, on adjacent property affecting the near view, and on distant property affecting the far view, (5) the distribution of ponderosa pine and Douglas-fir on the property, (6) the distribution of trees over the property (the presence of treeless patches caused by an insect infestation), and (7) the presence of large specimen trees. The study divides mountain properties into improved lots (lots where a mountain home has been constructed) and unimproved lots (plotted lots where a subdivision has been filed but where no mountain homes have been constructed).

The authors estimate the average arc elasticities for the contributed worth of trees to mountain properties in a 1- to 15-percent decrease from the optimal level of the indicator variable with a mean number of 106 trees per acre. The elasticities show that a 1-percent decrease in the number of trees 6 inches in dbh or more on the property results in a 0.14-percent decrease in the appraised contributed worth of the trees to improved lots and a 0.15-percent decrease in that of unimproved lots. A 1-percent decrease in the number of trees on property adjacent to improved lots affecting the near view decreases the worth of these lots by an additional 0.12 percent. The worth of improved and unimproved lots decreases by 0.53 percent and 0.54 percent, respectively, with a 1-percent decrease in the average size of the trees on the lots (calculated in the 3-inch to 12-inch dbh range). The worth of improved lots decreases by 0.94 percent and that of unimproved lots decreases by 0.92 percent with a 1-percent increase in the expert expectation of insect damage to trees on the lot. A 1-percent increase in visible damage caused by an insect infestation results in a 2.48-percent decrease in the worth of improved lots and a 2.06-percent decrease in that of unimproved lots. Improved property decreases in worth by 1.07 percent and unimproved property decreases by 1.85 percent with a 1-percent increase in the visible damage caused by insects on adjacent property affecting the near view from the residential property. A 1-percent increase in visible damage affecting the far view decreases in worth by 0.16 percent for improved property and by 0.64 percent for unimproved property. A 1-percent increase in treeless areas caused by insects results in a 0.29-percent decrease in the worth of improved and unimproved lots. The worth of improved and unimproved lots increases by 0.05 percent and 0.06

percent, respectively, with a 1-percent change in the distribution of tree species from ponderosa pine to Douglas-fir. A 1-percent decrease in the presence of large specimen trees bigger than 24 inches dbh (approximately two trees per acre) decreases the worth of improved lots by 1.94 percent and that of unimproved lots by 2.70 percent. Appraiser estimation of property value is most sensitive to visible damage and the presence of large trees.

Walsh and others (1981b) estimate the dollar equivalents in reduced mountain property value due to a 15-percent change in the forest quality indicator variables (calculated with an average of 106 trees per acre and mountain lots averaging 1 acre per lot). A 15-percent reduction in the number of trees on the lot decreases the worth of improved lots by $209 and that of unimproved lots by $201. The worth of improved lots decreases by an additional $241 if the number of trees on adjacent property affecting the near view decreases by 15 percent. A 15-percent reduction in the average tree size results in an $1,155 reduction in the worth of improved lots and a $1,014 reduction in that of unimproved lots. With an increase of 15 percent in the expectation of damage due to an insect infestation based on expert opinion, the worth of improved lots decreases by $1,810 and that of unimproved lots decreases by $1,492. A $3,902 reduction in the worth of improved lots and a $2,715 reduction in that of unimproved lots results from a 15-percent increase in visible damage to trees. The worth of improved lots decreases by an additional $1,688 for visible damage affecting the near view and by $259 because of visible damage affecting the far view with a 15-percent increase in visible damage on surrounding property. The worth of unimproved lots decreases by an additional $2,445 for visible damage affecting the near view and by $848 because of visible damage affecting the far view with a 15-percent increase in visible damage on surrounding property. With 15 percent of the lot treeless due to an insect infestation, improved lot and unimproved lot worth decreases by $493 and $476, respectively. A 15-percent change in the distribution of tree species from ponderosa pine to Douglas-fir results in an increase in the worth of improved and unimproved lots by $102. The increasing percentage of Douglas-fir on the property leads to increased property value probably because Douglas-fir is scarce in the elevation range in which the study was conducted. A 1-percent decrease in the number of large specimen trees per lot decreases the worth of improved lots by $251 and unimproved lots by $294.

To account for the natural recovery of a forest from an insect infestation, the authors developed a regrowth model. The regrowth model adjusts the losses over time as a result of the natural regeneration abilities of the affected forest. The losses estimated are per year and continue to be realized for Colorado Front Range forests until replacement trees are of sufficient size and quality that the original losses are completely offset. Benefits not included in this study are the benefits of forest quality to the general public who may be willing to pay for the preservation of forest quality, and for option, existence, and bequest values. Other values potentially held by the general public include those derived from psychological and ecological values. The psychological and ecological benefits associated with forest health may be large enough to exceed the economic estimates listed.

The two samples used by Walsh and others (1981a and 1981b) (residential property owners and real estate appraisers, respectively) can be compared directly. Residential property owners reported the contributed worth of forest quality to their perceived property value. Real estate appraisers gave their professional opinions concerning what they believed trees contribute to the worth of residential mountain property. The average arc elasticities reported show that real estate appraisers preferred the number of trees per acre less than property owners did. Owners of property with large specimen trees appreciate them more highly than real estate appraisers do, supporting the belief that specific trees may carry larger psychological benefits for the owner of the property. Real estate appraisers place greater emphasis on insect impacts to unimproved property than do property owners. This may be because unimproved property relies more heavily on the contribution of natural assets to its overall market value than does improved property. Improved property includes structures such as homes that comprise a large portion of its overall market value. Also, owners of improved property probably spend more of their time on their property than do owners of unimproved property.

9. Loomis and Walsh, 1988. Recreation and Tree Stand Characteristics in the Colorado Front Range (appendix table 9)

Loomis and Walsh (1988) estimate the net economic benefits of recreation in the Colorado Rocky Mountains Front Range as a function of tree stand density and tree size. This study is included because the data set used for analysis is the Walsh and Olienyk (1981) data set. Effects of tree stand density and tree size on recreation are the result of perceived impacts from mountain pine beetles. Information on the effects of tree stand density and tree size on recreation use and benefit is important to the management of forests for stocking rates and tree growth. Different tree densities and average tree size in a forest stand can give rise to different recreation activities. This study investigates the recreation use and benefits of six recreation activities: camping, picnicking, backpacking, hiking, fishing, and use of off-road vehicles (ORVs). The results of the study can be used to derive the management implications of intensive forest management (e.g., planting affected areas instead of relying solely on natural regeneration, silvicultural practices like thinning).

A stratified random sample of 435 recreation users of six forest recreation sites composed of mixed-age ponderosa pine in the Front Range of Colorado was interviewed onsite in summer 1980. The contingent valuation method was used to estimate the recreationist's maximum net willingness to pay for different quantities of trees per acre and for changes in average tree size per acre, the changes being presented to the respondents through the use of color photos. The implied factor that caused the changes in tree stand density and average tree size is the mountain pine beetle. Therefore, the survey shows that changes in net willingness to pay are contingent on changes in tree stand density and average tree size, in this case being the result of insect infestations.

All of the recreation activities considered in the survey were found to be positively related to tree stand density and tree size except for the use of ORVs, which is negatively related to these factors. This means that 5 out of 6 of the activities have increased benefits with increased tree stand density and average tree size. The estimated annual recreation benefits as maximum willingness to pay per visitor, estimated at an average of 200 trees per acre, are $145 for camping, $169 for picnicking, $161 for backpacking, $302 for hiking, $321 for fishing, and $97 for the use of ORVs. The annual recreation benefits per visitor as a function of tree size are estimated to be $28 when the average tree size per stand is 2.5 inches dbh, and $210 with an average tree size per stand of 10.5 inches dbh. Other estimates reported include recreation benefits per visitor day of $5 when average tree size is 4 inches dbh, and of $13 when average tree size is 13 inches dbh.

10. Walsh and others, 1989b. Recreation and the Demand for Trees in National Forests in the Colorado Front Range and the Mountain Pine Beetle (appendix table 10)

Walsh and others (1989b) estimate and compare the average benefits per recreation trip in the Colorado Front Range as a function of the number of trees per acre 6 inches in dbh or more. This study is based on the original Walsh and Olienyk (1981) data set. The main purpose of this paper is to compare the benefits measured by means of the contingent valuation method as dollars willingness to pay for forest quality (the number of trees 6 inches in dbh or more) and benefits estimated by means of the travel cost method as consumer surplus. The study is included in this report because it includes three estimates of average benefits per recreation trip that are not considered in the Walsh and Olienyk (1981) study.

Recreation demand functions are derived using contingent valuation and travel cost methods. One measure of the average benefit per recreation trip is estimated by means of the contingent valuation method, and two measures are estimated by means of the travel cost method using two different econometric regression procedures (ordinary least squares and two-stage least squares). The results of the study support the hypothesis that the contingent valuation and travel cost methods produce comparable estimates. The estimates reported can be included in an economic assessment of a forest management alternative that incorporates market and nonmarket recreation use benefits.

A stratified random sample of 435 recreation users of six forest recreation sites composed of mixed-age ponderosa pine in the Front Range of Colorado was interviewed onsite in summer 1980. The contingent valuation method is used to derive the recreationist's demand for trees as an essential part of the recreation experience. A subsample of 220 recreationists (excluding off-road vehicle users and nonresidents) was selected for participation in the travel cost method of demand analysis. The travel cost method indirectly derives the recreation demand for trees. Both demand functions are derived on the basis of the changes in the number of trees per acre as represented in color photos. After the recreation demand functions are derived, total benefits can be calculated as willingness to pay for the contingent valuation method and as consumer surplus for the travel cost method.

Walsh and others (1989b) estimate the net average recreation benefits per user day from the contingent valuation method as $24. This and the following estimates are based on approximately 178 trees per acre and 2.7 days per trip. From the travel cost method of demand analysis, net average recreation benefits per user day, using the ordinary least squares regression technique, are estimated as $26. From the travel cost method, using the two-stage least squares regression technique, net average recreation benefits per user day are estimated as $20. Statistical tests show that the estimates based on all three methods are not statistically different.

11. Walsh and others, 1990. Total Economic Nonmarket Worth of Forest Quality in Colorado National Forests and the Mountain Pine Beetle and Western Spruce Budworm (appendix table 11)

Walsh and others (1990) estimate the total economic nonmarket worth or public benefits of protecting forest quality in National Forests in Colorado. Total economic nonmarket worth accrues from recreation use, option, existence, and bequest values (Randall and Stoll 1983). Recreation use value is the benefit derived from the recreation experience and is restricted to onsite direct use of the resource. Option, existence, and bequest values are nonuse or passive-use benefits and can be derived either onsite or offsite. Option value is the satisfaction of knowing that a resource is protected for its potential use in the future. Existence value is the satisfaction of knowing that a resource is protected for its own sake. Bequest value is the satisfaction of knowing that a resource is protected for the potential use of others, including family and future generations. Measuring passive-use value of protecting forest quality is important because an economic assessment of a management alternative that includes only direct-use benefits would understate the true worth of the forest, possibly resulting in a socially inefficient outcome. The general population, including users and nonusers of forest resources, are affected by changes in forest quality and may be willing to pay to protect forest health. Therefore, in deciding between management alternatives, the total economic nonmarket worth of forest resources must be incorporated in the decision process.

A random sample of 198 households in the Fort Collins and surrounding rural areas was interviewed in 1983. The sample was found to be socially and demographically representative of Colorado residents. The study uses the contingent valuation method (with an iterative bidding technique) to estimate the maximum net total benefits and recreation use benefits of protecting forest quality. The indicator variable for forest quality used is tree density measured as the number of trees 6 inches in dbh or more as depicted in color photos. The households surveyed state their maximum net willingness to pay for different forest stand densities as the result of mountain pine beetle and western spruce budworm infestations.

Walsh and others (1990) find that total average annual willingness to pay per Colorado household for the protection of forest quality is $52 (estimated with an average tree stand density of 150 trees per acre). Recreation-use benefit is 27.4 percent of total benefits, or $14 per household per year. Nonuse or passive-use benefit (option, existence, and bequest) make up 72.6 percent of the total, or $38 per household per year. Option and existence benefit is $11 per household per year each, and bequest benefit is $16 per household per year. The results show that nonuse or passive-use benefits are more than three and a half times greater than recreation-use benefits. Therefore, assessments of management alternatives that rely on direct onsite use value alone greatly understate the total benefits of a resource quality protection program and may result in inefficient resource allocations. These results are consistent with those collected by Brown (1993) who showed that existence and bequest value estimates derived through the contingent valuation method can be two to 10 times larger than direct onsite recreation-use value.

12. Jakus and Smith, 1991. Private and Public Landscape Amenities in the Pennsylvania/Maryland Area and the Gypsy Moth (appendix table 12)

Jakus and Smith (1991) collected data on households' willingness to pay for esthetic benefits that accrue solely to their own household versus benefits that accrue to the neighborhood in general from different gypsy moth control programs in the southcentral Pennsylvania/northcentral Maryland area. One program sprayed the residential (privately owned) areas only, while the public program sprayed both residential and common areas in the neighborhood. The author's study used the data collected to compare use and nonuse benefits associated with protection of landscape amenities. The hypothesis of the research is whether contingent behavior questions can be used for measuring use and nonuse values derived from an environmental resource (such as landscape esthetics) that provides both private and public benefits. The contingent valuation method, with dichotomous choice elicitation, was used in a telephone-mail (informative brochure)-telephone survey of a 10-county area; 436 surveys were completed.

Respondents were asked to bid their maximum willingness to pay for each of two public gypsy moth control programs. The programs bid on include (1) spraying of a bacterial insecticide on residential properties only, and (2) spraying of a bacterial insecticide on residential and surrounding public areas (local parks and greenways). From the data, two linear and two nonlinear models are estimated, both with and without sample selection correction. A sample selection adjustment is introduced to account for nonparticipants in the second telephone interview stage. The estimated average household willingness to pay per year for the uncorrected linear model with a 25-percent reduction in defoliation ranges from $348 to $352 for the private program, and from $395 to $474 for the public program. The uncorrected nonlinear model for a 25-percent reduction in defoliation estimates average annual household willingness to pay as ranging from $464 to $534 for the private program, and $608 to $670 for the public program. When sample selection is corrected for, the linear specification for the private program results in an average annual household willingness to pay of $254 to $271, and for the public program of $314 to $344. The corrected nonlinear model estimates the average annual household willingness to pay as $376 to $420 for the private program, and $511 to $527 for the public program.

The authors conclude that individuals distinguish between private and public services provided by a gypsy moth control program through protecting landscape amenities. The results show an increase of 12 to 36 percent in average annual household willingness to pay for a public-scope program over a private-scope program with the uncorrected models, and an increase of 16 to 36 percent for the sample selection corrected models. Therefore, individuals derive both use and nonuse benefits from environmental resources that exhibit private and public goods characteristics. This can be an important motivation for the private support of public programs.

13. Haefele and others, 1992. Total Economic Nonmarket Worth of Forest Quality in the Southern Appalachian Mountains and the Balsam Woolly Adelgid (appendix table 13)

Haefele and others (1992) estimate the total economic nonmarket worth of protecting forest quality in the Southern Appalachian Mountains in North Carolina, Tennessee, and Virginia. The study decomposes total economic nonmarket worth into use and nonuse or passive-use value components. Nonuse value is further decomposed into bequest and existence values. Over the past few decades, two major impacts have affected the sustainability of the spruce-fir ecosystem in the Appalachians. The first is the decline in the number of Fraser fir trees in the area. The balsam woolly adelgid attacks the Fraser fir, resulting in high tree mortality rates. The other impact is the result of atmospheric deposition, such as acid rain, which is reducing the red spruce population and its regrowth potential. The results show that the general public is willing to pay for forest quality protection in the eastern United States, that individuals value forests for more than their own personal direct use, and that nonuse or passive-use value is greater than recreation-use value in the total economic nonmarket worth of protecting forest quality.

A random sample of 1,200 households was surveyed through the mail within a 500-mile radius of Asheville, North Carolina, in 1991. The contingent valuation method was used to estimate the maximum net benefits as willingness to pay for forest quality protection in the Southern Appalachian Mountains. The elicitation methods employed in the study are modified payment card and discrete choice, allowing for a comparison of the two methods for consistency of benefit estimates. The households were also asked to partition total willingness to pay into its component values: use, existence, and bequest values. The indicator variable is visual quality as depicted in color photos with changes in visual quality as the result of insect infestation or atmospheric deposition. The households surveyed state their maximum willingness to pay contingent on changes in forest quality for two areas: along roads and trails, comprising approximately one third of the total forest area, and for the whole forest area.

The pretest and focus group results for this study are presented by Holmes and others (1990). Haefele and others (1992) find that total average annual willingness to pay per household for forest quality along roads and trails ranges from $19 for the modified payment card version to $63 for the discrete choice version. The estimated total average annual willingness to pay per household for the whole forest ranges from $22 for the modified payment card version to $107 for the discrete choice version. The disparity between the two method estimates may be due to anchoring in the modified payment card approach, in which respondents are conditioned by the bid levels, providing them with valuation clues. Discrete choice may also exhibit anchoring along with upward rounding and the desire to provide "correct" answers by the respondents, thus inflating willingness to pay bids. Walsh and others (1989a) show that discrete choice models typically return larger willingness to pay estimates than modified payment card and open-ended question formats.

The allocation of total economic nonmarket worth to its components is very similar for the two elicitation methods. Total benefits estimated by means of the modified payment card method ($22) are allocated as 8 percent for use, 59 percent for existence, and 30 percent for bequest value.[4] This results in the average annual willingness to pay, for the use of a spruce-fir forest at a given quality level, of $2; the existence benefit of the forest being $13; and the bequest benefit of the forest being $7. These benefits, based on the modified payment card method, are very similar to those estimated in the pretest (Holmes and others 1990). The allocation of total economic nonmarket worth via the discrete choice method ($107) is 13 percent for use, 56 percent for existence, and 31 percent for bequest value. This results in average annual willingness to pay, for the use of a spruce-fir forest at a given quality level, of $14—existence benefits being $60 and bequest benefit being $33. The results show that when nonuse or passive use values are included in the benefit estimate of forest quality protection, the total benefits are 7 to 12 times greater than recreation use value alone. These results support the evidence in Walsh and others (1990) and Brown (1993). The efficient allocation of forest resources depends on the estimation of total economic worth.

[4] The percentages reported by the authors add up to 97 percent. It is not known why this is less than 100 percent.

14. Miller and Lindsay, 1993. Support for a Gypsy Moth Control Program in New Hampshire (*appendix table 14*)

Miller and Lindsay (1993) estimate the public support for a gypsy moth control program in New Hampshire through residents' willingness to pay for the program. In 1981, the gypsy moth population peaked, causing severe defoliation of 195,000 acres out of 2,000,000 infested acres in New Hampshire forests. At the time of the study, New Hampshire did not have a state gypsy moth program, leaving towns, cities, landowners, and homeowners to bear the costs of controlling gypsy moths. The costs include control methods, clean-up, and tree loss. Other costs include the psychological and social costs such as esthetic degradation, recreation loss, and nuisance factors. Other impacts include wildlife habitat changes in tree browse and protective foliage.

This study uses the contingent valuation method, with dichotomous choice elicitation of willingness to pay. Miller and Lindsay surveyed 669 households from three towns: Bow, Conway, and Exeter. Bow represents the towns that experienced severe defoliation and had implemented a municipality-wide moth control program. Conway represents areas that experienced moderate to severe defoliation but did not adopt any central control program. Exeter represents towns that experienced no appreciable gypsy moth-caused damage. The results show that Bow residents' mean and median annual willingness to pay per household is $84 and $62, respectively. Conway residents' mean and median annual willingness to pay per household is $55 and $31, respectively. And Exeter residents' mean and median annual willingness to pay per household is $56 and $27, respectively. Aggregating the annual willingness to pay of the three towns results in mean and median annual willingness to pay per household of $70 and $43, respectively. On a per-acre basis, the aggregate mean and median annual willingness to pay per household is $16 and $10, respectively. This results in aggregate public support for a statewide gypsy moth control program of $13 million to $28 million mean annual willingness to pay, and $8 million to $17 million median annual willingness to pay. These results show strong support for a gypsy moth control program in New Hampshire.

15. Holmes and Kramer, 1996. Total Economic Nonmarket and Existence Worth of Forest Quality in the Southern Appalachian Mountains and the Balsam Woolly Adelgid (appendix table 15)

Holmes and Kramer (1996) estimate the total economic nonmarket and existence worth of protecting forest quality in the Southern Appalachian Mountains in North Carolina, Tennessee, and Virginia. Total nonmarket economic worth is defined as the summation of use and existence values, where use value is the utility (or satisfaction) derived from active use of the resource and existence value is the utility derived from the resource for all other reasons other than active use. The researchers investigate the economic measures of forest health protection for the boreal montane forest ecosystem, 75 percent of which is contained in the Great Smoky Mountains National Park. Over the past few decades, mortality of the spruce and fir trees in this ecosystem has increased dramatically. This is generally attributable to the balsam woolly adelgid and air pollution.

The households sampled are within a 500-mile radius of Asheville, North Carolina, and were surveyed through a mail-out, mail-back questionnaire. This study elicited willingness to pay for the protection of the remaining healthy spruce-fir forests through the use of the contingent valuation method with a dichotomous choice elicitation procedure. Of the 210 surveys returned with usable dichotomous choice responses, 175 were for users of the ecosystem who stated total economic nonmarket worth, and 35 were for nonusers of the ecosystem who stated existence worth only. This allows for testing whether the existence component can be distinguished from total economic value. The indicator of forest health was visual quality as depicted in color photos with changes in quality resulting from insect infestation or atmospheric deposition. This and other data collected were used in a test on the convergent validity of two contingent valuation elicitation methods: dichotomous choice and modified payment card (Holmes and Kramer 1995).

Holmes and Kramer (1996) estimate the median annual willingness to pay as $36.22 for users (representing total economic nonmarket worth) and as $10.81 for nonusers (representing the existence component). They found the two estimates to be statistically different. The study draws three conclusions. First, the responses are consistent with the compositional approach to total economic worth, i.e., a component is less than the whole. Second, existence worth is a distinct and substantial component of total economic worth of forest health (existence comprised approximately 30 percent of the total). And third, the existence component is distinct from the use component, based on economic characteristics of direct-use and passive-use values.

Summary

This review of the literature supports the conclusion that forest insect pests affect forest quality, causing significant impacts on the nonmarket goods and amenity benefits provided by a healthy forest. The affected values identified include property values for residential and commercial uses; recreation and esthetic values; and nonuse values such as existence, bequest, and option. Other damages caused by insects are increased costs of mitigation and financial losses.

The insects identified include the mountain and southern pine beetle, western spruce budworm, balsam woolly adelgid, gypsy moth, and Douglas-fir tussock moth. These pests have caused significant damage to the potential of areas spanning the United States from the East Coast to the West Coast to generate nonmarket benefits. Areas specifically studied in the past include the northeast, northwest, mountainous west, and the south. The studies identify different stakeholders, including individuals, communities, and the general public. Property and homeowners are significantly affected by insect infestations, as are users (recreationists) and nonusers. Land managers, both public and private, are affected by insect damages, especially in areas where there are large numbers of users and passers-by, such as campgrounds, urban parks, and scenic greenways. Decision makers are interested stakeholders in determining the relevant extent of insect damage mitigation to undertake. Land-use zones include urban, urban/wildland, and wildland areas.

The techniques employed in the economic estimation of these nonmarket damages (benefits) of pest infestations (control programs) are the contingent valuation, travel cost, and hedonic pricing methods. Also employed are direct cost estimations through the estimation of replacement costs and financial losses. The relevant metrics used in these measurements include dollars (either market prices, expenditures, willingness to pay, or consumer surplus) and recreation days. The estimated models for the relevant studies identify several indicators of pest impacts. These include number of trees per acre, percentage of visible damage (e.g., dead and down trees, defoliation rates, and discoloration of foliage), physical presence of insects, size of trees, and percentage of tree species composition. All indicators were found to be positively related to the benefits generated, with the exception of tree species composition, which may be either positively or negatively related. In other words, the negative impacts of pest infestations on the level of the indicator variables predominantly result in a decrease in benefit derived from the resource (or conversely, result in an increase in the level of damages).

With the preponderance of evidence suggesting that insects do cause significant economic damage to environmental resources beyond market commodities in the short term, site-specific information is beneficial to the management decision process. The transferability of the economic measures and models developed is not addressed here. Some of the research results can provide thumbnail sketches of the possible benefits from a control program or policy; however, these are only tentatively acceptable. Further research in the area of the economic impacts of insects and other disturbance agents on the productive capability and sustainability of different environmental resources or areas will aid in resolving the more borderline decision scenarios. Parallel arguments can be made for other factors which affect environmental quality, such as fire and pollution.

An issue requiring further inquiry is the role static measures of economic damages have in a larger, dynamic ecosystem management context. Static economic analysis does not estimate the economic worth of natural processes or ecosystem functions that define healthy forests and ecosystems. However, when management objectives converge (ecological, economic, and social), static measures may themselves be indicators of the human component of forest health management.

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Appendix: Summary Tables of Nonmarket Economic Studies of Forest Insect Pest Damages

Appendix Table 1—*Payne and others, 1973. Economic analysis of the gypsy moth problem in the Northeast: II. Applied to residential property*

Category	Description
Region, forest type	Pennsylvania/Maryland, mixed hardwood on residential properties
Stakeholder	Homeowners
Insect	Gypsy moth (*Lymantria dispar*)
Indicator variable effect	Decrease in no. of trees ≥6 in. dbh
Value type	Contributed residential property value of trees
Valuation method, estimate type	Hedonic pricing, hedonic price/acre or per tree
Estimated value	$1,175/acre or $270/tree loss with 15-pct decrease in no. of trees

Appendix Table 2—*Wickman and Renton, 1975. Evaluating damage caused to a campground by Douglas-fir tussock moth*

Category	Description
Region, forest type	Stowe Reservoir campground in California, white fir
Stakeholder	Recreationists
Insect	Douglas-fir tussock moth (*Orgyia pseudotsugata*)
Indicator variable effect	Decrease in no. of trees in campground
Value type	Recreation, esthetic
Valuation method, estimate type	Replacement and clean-up costs allocation, cost/tree
Estimated value	$56 esthetic value/tree, $13 clean-up cost/dead tree, with 25 trees killed total damage to campground is $1,725

Appendix Table 3—*Michalson, 1975. Economic impact of mountain pine beetle on outdoor recreation*

Category	Description
Region, forest type	Island Park area in Targhee National Forest (Idaho), lodgepole pine
Stakeholder	Recreationists
Insect	Mountain pine beetle (*Dendroctonus ponderosae*)
Indicator variable effect	Increase in no. of visible dead trees
Value type	Recreation
Valuation method, estimate type	Travel cost, consumer surplus/person-expenditure/person-visitor days/person
Estimated value	$4.09 consumer surplus, $0.43 expenditure, and 1.2 days with a >30-pct infestation

Appendix Table 4—*Moeller and others, 1977. Economic analysis of the gypsy moth problem in the Northeast: III. Impacts on homeowners and managers of recreation areas*

Category	Description
Region, forest type	New York/Pennsylvania, northeastern deciduous
Stakeholder	(a)[1] homeowners (b)[1] managers of recreation areas
Insect	Gypsy moth (*Lymantria dispar*)
Indicator variable effect	Presence of moth, defoliation, tree mortality
Value type	(i)[2] control cost (ii)[2] financial loss (iii)[2] recreation loss
Valuation method, estimate type	(i, ii, iii) sample average, (a-i, ii) annual public and commercial control costs and financial loss/household, (b-i, ii) annual control costs or financial loss for commercial and quasi-public campgrounds, (a-iii) annual person-days per household, (b-iii) annual person-days per campground
Estimated value	(a-i) $102 for public control, $240 for commercial control cost; (a-ii) $125 with public control, $479 for commercial control financial loss; (a-iii) 108 person-days with public control, 133 person-days with commercial control recreation loss; (b-i) $441 for commercial campgrounds, $722 for quasi-public campgrounds control costs; (b-ii) $249 for commercial campgrounds, $996 for quasi-public campgrounds in financial loss; (b-iii) 161 person-days for commercial, 240 person-days for quasi-public, 36,660 person-days for public campgrounds per unit in recreation loss

[1](a) and (b) refer to corresponding stakeholder.
[2](i), (ii), and (iii) refers to corresponding value type.

Appendix Table 5—*Leuschner and Young, 1978. Estimating the southern pine beetle's impact on reservoir campsites*

Category	Description
Region, forest type	East Texas Forest Service and Corps of Engineers campgrounds, mixed pine and hardwood
Stakeholder	Recreationists
Insect	Southern pine beetle (*Dendroctonus frontalis*)
Indicator variable effect	Decrease in percent pine crown cover
Value type	Contributed recreation value of pine crown cover
Valuation method, estimate type	Travel cost, consumer surplus/person/visit
Estimated value	$3.37 for Forest Service campgrounds, $2.44 for Corps of Engineers campgrounds per person with a 30-pct reduction in pine crown cover

Appendix Table 6—*Walsh and Olienyk, 1981. Recreation demand effects of mountain pine beetle damage to the quality of forest recreation resources in the Colorado Front Range*

Category	Description
Region, forest type	Colorado Front Range, 6,000-8,000 ft elevation in Rocky Mountains, mixed-age ponderosa pine
Stakeholder	Recreationists
Insect	Mountain pine beetle (*Dendroctonus ponderosae*)
Indicator variable effect	(a)[1] decrease in no. of trees ≥6 in. dbh/acre
	(b)[1] decrease in average tree size
	(c)[1] increase in pct visible tree damage
	(d)[1] increase in pct dead and down trees on ground with slash
	(e)[1] increase in pct pest-caused treeless areas in acres
	(f)[1] decrease in no. of large tree ≥24 in. dbh
Value type	Contributed recreation value of indicator variable
Valuation method, estimate type	(i)[2] contingent valuation, annual willingness to participate in user-days
	(ii)[2] contingent valuation, consumer surplus/user-day
	(iii)[2] travel cost, no. of trips/person
	(iv)[2] travel cost, annual consumer surplus/person and per trip
Estimated value	(i) 370,000 user-days loss with 15-pct decrease in (a) on-site, 330,000 user-days loss with 15-pct decrease in (a) in near-view, 207,000 user-days loss with 15-pct decrease in (a) in far-view, 422,000 user-days loss with 15-pct decrease in (b), 3,045,000 user-days loss with 15-pct increase in (c) or (d), 317,000 user-days loss with 15-pct increase in (e), 192,700 user-days loss with 15-pct decrease in (f);
	(ii) $1.50/user-day loss at 178 trees/acre, or $1.70/user-day loss at 270 trees/acre with 15-pct decrease in (a);
	(iii) 0.16 fewer trips per person with 15-pct decrease in (a);
	(iv) $11.60/person, or $1.75/person/trip with 15-pct decrease in (a)

[1](a), (b), (c), (d), (e), and (f) correspond to indicator variable effect.
[2](i), (ii), (iii), and (iv) correspond to valuation method and estimate type.

Appendix Table 7—*Walsh and others, 1981a. Value of trees to residential property owners with mountain pine beetle and spruce budworm damage in the Colorado Front Range*

Category	Description
Region, forest type	Colorado Front Range, 6,000-8,000 ft elevation in Rocky Mountains, mixed-age ponderosa pine
Stakeholder	Homeowners, property owners
Insect	Mountain pine beetle (*Dendroctonus ponderosae*), western spruce budworm (*Choristoneura occidentalis*)
Indicator variable effect	(a)[1] decrease in no. of trees ≥6 in. dbh/acre
	(b)[1] decrease in average tree size
	(c)[1] expectation of 50-pct tree loss
	(d)[1] increase in pct visible tree damage
	(e)[1] increase in pct dead and down trees on ground with slash
	(f)[1] increase in pct pest-caused treeless areas in acres
	(g)[1] decrease in no. of large tree ≥24 in. dbh
Value type	Contributed property value of indicator variable
Valuation method, estimate type	Contingent valuation, annual willingness to pay
Estimated value	$984/acre impr. lots, $578/acre unimpr.[2] lots loss with 15-pct decrease in (a) on-site;
	$602/acre impr. lots loss with 15-pct decrease in (a) on adjacent lots in near view;
	$1,228/acre impr. lots, $783/acre unimpr. lots loss with 15-pct decrease in (b);
	$2,351/acre impr. lots, $1,364/acre unimpr. lots loss with (c);
	$7,034/acre impr. lots, $4,045/acre unimpr. lots loss with 15-pct increase in (d);
	$907/acre impr. lots, $896/acre unimpr. lots loss with 15-pct increase in (e);
	$61/acre impr. lots, $84/acre unimpr. lots gain with 15-pct increase in (f);
	$918/acre impr. lots, $449/acre unimpr. lots loss with 15-pct decrease in (g)

[1](a), (b), (c), (d), (e), (f), and (g) correspond to indicator variable effect.
[2]Improved lots (lots with buildings, primarily residences) is abbreviated "impr.," while unimproved lots (lots with no buildings) is abbreviated "unimpr."

Appendix Table 8—*Walsh and others, 1981b. Appraised market value of trees on residential property with mountain pine beetle and spruce budworm damage in the Colorado Front Range*

Category	Description
Region, forest type	Colorado Front Range, 6,000-8,000 ft elevation in Rocky Mountains, mixed-age ponderosa pine
Stakeholder	Real estate appraisers, homeowners, property owners
Insect	Mountain pine beetle (*Dendroctonus ponderosae*), western spruce budworm (*Choristoneura occidentalis*)
Indicator variable effect	(a)[1] decrease in no. of trees ≥6 in. dbh/acre
	(b)[1] decrease in average tree size
	(c)[1] expectation of 50-pct tree loss
	(d)[1] increase in pct visible tree damage
	(e)[1] increase in pct dead and down trees on ground with slash
	(f)[1] increase in pct pest-caused treeless areas in acres
	(g) decrease in no. of large tree ≥24 in. dbh
Value type	Contributed property value of indicator variable
Valuation method, estimate type	Contingent valuation, appraised market value
Estimated value	$209/acre impr. lots, $201/acre unimpr.[2] lots loss with 15-pct decrease in (a) on-site;
	$241/acre impr. lots loss with 15-pct decrease in (a) on adjacent lots in near view;
	$1,155/acre impr. lots, $1,014/acre unimpr. lots loss with 15-pct decrease in (b);
	$1,810/acre impr. lots, $1,492/acre unimpr. lots loss with (c);
	$3,902/acre impr. lots, $2,715/acre unimpr. lots loss with 15-pct increase in (d) on-site;
	$1,688/acre impr. lots, $2,445/acre unimpr. lots loss with 15-pct increase in (d) on adjacent lots in near-view;
	$259/acre impr. lots, $848/acre unimpr. lots loss with 15-pct increase in (d) in far-view;
	$493/acre impr. lots, $476/acre unimpr. lots loss with 15-pct increase in (e);
	$102/acre impr. lots, $102/acre unimpr. lots gain with 15-pct increase in (f);
	$251/acre impr. lots, $294/acre unimpr. lots loss with 15-pct decrease in (g)

[1](a), (b), (c), (d), (e), (f), and (g) correspond to indicator variable effect.

[2]Improved lots (lots with buildings, primarily residences) is abbreviated “impr.,” while unimproved lots (lots with no buildings) is abbreviated “unimpr.”

Appendix Table 9—*Loomis and Walsh, 1988. Recreation and tree stand characteristics in the Colorado Front Range*

Category	Description
Region, forest type	Colorado Front Range, 6,000-8,000 ft elevation in Rocky Mountains, mixed-age ponderosa pine
Stakeholder	Recreationists
Insect	Mountain pine beetle (*Dendroctonus ponderosa*e), western spruce budworm (*Choristoneura occidentali*s)
Indicator variable effect	(a)[1] decrease in no. of trees ≥6 in. dbh
	(b)[1] decrease in average tree size
Value type	Contributed recreation value of indicator variable
Valuation method, estimate type	Contingent valuation, annual willingness to pay
Estimated value	(a) $145 benefit/visitor for camping with 200 trees/acre; $169 benefit/visitor for picnicking with 200 trees/acre; $161 benefit/visitor for backpacking with 200 trees/acre; $302 benefit/visitor for hiking with 200 trees/acre; $321 benefit/visitor for fishing with 200 trees/acre; $97 benefit/visitor for off-roading with 200 trees/acre;
	(b) $210 annual benefit/visitor with avg. tree size at 10.5 in. dbh, $28 annual benefit/visitor with avg. tree size at 2.5 in. dbh; $13 annual benefit/visitor/day with avg. tree size at 13 in. dbh; $5 annual benefit/visitor/day with avg. tree size at 4 in. dbh

[1](a) and (b) correspond to indicator variable.

Appendix Table 10—*Walsh and others, 1989b. Net economic benefits of recreation as a function of tree stand density*

Category	Description
Region, forest type	Colorado Front Range, 6,000-8,000 ft elevation in Rocky Mountains, mixed-age ponderosa pine
Stakeholder	Recreationists
Insect	Mountain pine beetle (*Dendroctonus ponderosa*e)
Indicator variable effect	Decrease in no. of trees ≥6 in. dbh/acre
Value type	Contributed recreation value of indicator variable
Valuation method, estimate type	(i)[1] contingent valuation, annual willingness to pay/person/day
	(ii)[1] travel cost, annual consumer surplus/person/day
Estimated value	(i) $24 net average benefit with 178 trees/acre and 2.7 days/trip;
	(ii) $20 to $26 net average benefit with 178 trees/acre and 2.7 days/trip

[1](i) and (ii) correspond to valuation method and estimate type.

Appendix Table 11—*Walsh and others, 1990. Estimating the public benefits of protecting forest quality*

Category	Description
Region, forest type	Colorado National Forests, mixed tree stands
Stakeholder	Recreationists
Insect	Mountain pine beetle (*Dendroctonus ponderosa*e), western spruce budworm (*Choristoneura occidentali*s)
Indicator variable effect	Decrease in no. of trees ≥6 in. dbh/acre
Value type	Recreation, bequest, existence, option
Valuation method, estimate type	Contingent valuation, annual willingness to pay/household
Estimated value	$52 average annual total value for 150 trees/acre where $14 is for recreation-use, $16 is for bequest, $11 is for existence, and $11 is for option

Appendix Table 12—*Jakus and Smith, 1991. Measuring use and nonuse values for landscape amenities: a contingent behavior analysis of gypsy moth control*

Category	Description
Region, forest type	Southcentral Pennsylvania and northcentral Maryland, urban residential, parks, and greenways
Stakeholder	Homeowners
Insect	Gypsy moth (*Lymantria dispa*r)
Indicator variable effect	Decrease in esthetic quality (pct defoliation)
Value type	Esthetics
Valuation method, estimate type	Contingent valuation, annual willingness to pay/household
Estimated value	$254 to $534 for a private control program, $314 to $670 for a public control program

Appendix Table 13—*Haefele and others, 1992. Estimating the total value of forest quality in high-elevation spruce-fir forests*

Category	Description
Region, forest type	4,400 to 6,684 ft elevation in Appalachian Mountains of North Carolina, Tennessee, and Virginia, spruce-fir forests
Stakeholder	Recreationists, general public
Insect	Balsam woolly adelgid (*Adelges picea*e)
Indicator variable effect	Increase in perceived visible damage (dead and dying trees)
Value type	Recreation, bequest, existence, and option
Valuation method, estimate type	Contingent valuation, annual willingness to pay/household
Estimated value	$19 to $63 for forests near roads and trails, $22 to $107 for total forest

Appendix Table 14—*Miller and Lindsay, 1993. Willingness to pay for a state gypsy moth control program in New Hampshire: a contingent valuation case study*

Category	Description
Region, forest type	New Hampshire, northeastern deciduous forest
Stakeholder	New Hampshire residents
Insect	Gypsy moth (*Lymantria dispar*)
Indicator variable effect	Increase in perceived visible damage
Value type	Total value
Valuation method, estimate type	Contingent valuation, annual willingness to pay/household
Estimated value	$70 average annual, $43 median, or mean $16/acre, median $10/acre

Appendix Table 15—*Holmes and Kramer, 1996. Contingent valuation of ecosystem health*

Category	Description
Region, forest type	4,400 to 6,684 ft elevation in Appalachian Mountains of North Carolina, Tennessee, and Virginia, spruce-fir forests
Stakeholder	Recreationists, general public
Insect	Balsam woolly adelgid (*Adelges piceae*)
Indicator variable effect	Increase in perceived visible damage (dead and dying trees)
Value type	Existence and total
Valuation method, estimate type	Contingent valuation, annual willingness to pay/household
Estimated value	$11 median existence value, $36 median total value