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**Forest Pest
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**Methods
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Dwarf Mistletoe Impact Modeling System

Users Guide and Reference Manual

USDA Forest Service
Forest Pest Management
Methods Application Group

Dwarf Mistletoe
Impact Modeling System

User's Guide and
Reference Manual

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1.1 Understanding the Threat of Dwarf Mistletoe on Coniferous Forests in the Western United States

Dwarf mistletoe species have substantial deleterious impacts on the growth and mortality of trees and stands in the Western United States.

The dwarf mistletoes (*Arceuthobium* spp.) are some of the most widespread and serious forest disease-causing agents of western conifers. They adversely affect the growth, survival, and reproductive potential of a number of important tree species in western North America. The estimated loss of more than 400 million cubic feet of timber per year due to dwarf mistletoe infection (Drummond 1982) is probably conservative, and since volume losses are reported for commercial forest lands only, this figure does not take into account the effects on forest stands used for recreation, wildlife, watershed, and visual quality. Another source estimates the timber product losses due to dwarf mistletoe at 3.3 billion board feet annually. Fifty percent of lodgepole pine and Douglas-fir forests and 35% of ponderosa pine forests in the central and southern Rockies are affected by dwarf mistletoe (Hawksworth and Scharpf 1984). On the following page, Exhibit 1.1 summarizes annual timber loss estimates due to growth reduction and tree mortality caused by dwarf mistletoe for various forest regions of the United States (Drummond 1982; unpublished data, Paul Hennon).

Region	Area of All Species of Commercial Host Type *(millions of acres)*	Infected Area *(millions of acres)*	Total Annual Loss of Merchantable Timber *(millions of cu.ft.)*
Montana and Northern Idaho	12.9	3.4	47
Colorado and Eastern Wyoming	2.5	1.2	18
Arizona and New Mexico	7.6	2.8	25
California	13.6	2.8	122
Oregon and Washington	36.1	8.5	148
Alaska	5.8	3.4	11
Michigan, Minnesota and Wisconsin	2.1	0.3	11
Southern Idaho, Utah, Nevada and Western Wyoming	6.5	2.6	36
Total	**87.1**	**25**	**418**

Exhibit 1.1 Estimates of Annual Timber Losses Attributed to Dwarf Mistletoe

1.2 Using the Dwarf Mistletoe Impact Modeling System (DMIM): Practical Needs, Benefits, and Applications

Because of the tremendous losses encountered in forests of the Western United States due to dwarf mistletoe infections, the need for a more comprehensive mistletoe model for pest management, silvicultural planning, and timber and forest management is extremely important.

Since these damaging agents can often be controlled by silvicultural means (Hawksworth *et al.* 1987), growth and yield models that predict dwarf mistletoe impact have been of considerable interest to forest managers as they can be used for planning cultural operations and for estimating yields in specific stands. However, the programs available up to now were limited to certain forest types and conditions in the Southwest and Central Rocky Mountains, so they were not generally applicable to most affected areas in the West.

The first growth and yield model that included the effects of dwarf mistletoe (which was also the first for any forest pest) was for lodgepole pine dwarf mistletoe in the Central Rocky Mountains (Myers *et al.* 1971; Edminster 1987a). This was a whole-stand model that was applicable only to managed, even-aged stands. A similar model was developed for even-aged southwestern ponderosa pine (Myers *et al.* 1972), which was later expanded to include two-storied stands (Myers *et al.* 1976). These programs were later combined into the more generalized model (RMYLD) to provide for more flexible management options and a wider range of stand conditions (Edminster 1987b). These programs, plus an additional submodel for southwestern mixed conifer stands which includes the effects of dwarf mistletoes on Douglas-fir, Engelmann spruce, and blue spruce, were then updated and incorporated into the broader growth and yield model, GENGYM (Edminster *et al.* 1991). GENGYM simulates stands from single-species, single-story to multi-species and age groups.

Other growth and yield stand models that have been developed for dwarf mistletoe-infected stands are for western hemlock in southern British Columbia (Bloomberg *et al.* 1980; Bloomberg and Smith 1982; Muir 1986), ponderosa pine in the Pacific Northwest (DeMars and Barrett 1987), black spruce in the Lake States (Baker *et al.* 1982), and ponderosa pine in the Southwest (Larsen 1975). In addition, a number of other studies on various aspects of dwarf mistletoe epidemiology, spread, and damage have been published, but these have not yet been incorporated into formal growth and yield models:

- spread of dwarf mistletoe in southwestern ponderosa pine (Dixon and Hawksworth 1979);
- epidemiology of dwarf mistletoe in even-aged ponderosa pine in the Pacific Northwest (Strand and Roth 1976); and
- epidemiology and effects of dwarf mistletoe in uneven-aged ponderosa pine stands in Colorado (Maffei 1989).

Meanwhile, the Forest Vegetation Simulator (FVS, formerly PROGNOSIS) growth and yield program, based on individual tree-diameter distributions, was being developed for stands in the northern Rocky Mountains (Wykoff *et al*. 1982). Later it was expanded to other areas in the Pacific Northwest, the Intermountain region, and California. The original FVS program did not include the effects of dwarf mistletoes. However, because of the widespread occurrence of these parasites in the coniferous forests of the West, forest managers soon saw the need for incorporating their effects in growth and yield projections. The first attempt to include dwarf mistletoe effects in an FVS model was in SORNEC, a variant developed for southern Oregon and northeastern California (Johnson *et al*. 1986). Since this preliminary model considered only the effects of dwarf mistletoe on diameter growth (other effects of dwarf mistletoe such as tree mortality were not modeled), it underestimated the effects of these disease agents. Thus, it was decided at a modeling workshop in 1990 (McNamee *et al*. 1990) that further investigation and analyses were needed to incorporate more dwarf mistletoe effects into the FVS variants that include coastal and southwestern ponderosa pine, lodgepole pine, Douglas-fir, western larch, true firs, and western hemlock. As an interim step until all the research and analyses could be performed to complete the task, it was also suggested that a preliminary model, based on analyses of all existing data and "best guesses," be prepared. With this information in mind, the Dwarf Mistletoe Impact Modeling (DMIM) System was written to run in conjunction with the FVS model for 14 of the FVS variants.

1.3 How to Use This Dwarf Mistletoe Model User's Guide and Reference Manual

This user's guide and reference manual is written in modular format and is comprised of three chapters: 1) *Introduction*; 2) *Scientific Background*; and 3) *Using the Model*

The Dwarf Mistletoe Impact Modeling (DMIM) System User's Guide and Reference Manual is written in a modular format. Each module is two to four pages long and addresses a specific DMIM system function or issue. Each contains a headline, a summary statement about the module, the module content, and usually one or more exhibits, such as a table or graph.

The first chapter, *Introduction*, provides pest information and discusses the need for the DMIM system. The second chapter, *Scientific Background*, deals with the development of the model and provides detailed explanations for each of the main modules of the DMIM system:

- spread and intensification using the nonspatial or spatial equations,
- diameter growth modification, and
- mortality.

The final chapter, *Using the Model*, gives instructions on how to access and manipulate the dwarf mistletoe model.

The appendices include a list of tree species abbreviations, a list of common abbreviations used in this document, and a list of species affected by mistletoe by variant. The tree species list includes tree species abbreviations, common names, and scientific names. The second list of abbreviations is comprised of those words and phrases in this document (other than tree species) that are commonly abbreviated. The reference list that follows the appendices includes sources specifically referred to in the text and sources used by the authors for more general information. Those sources referred to within the manual are noted by a reference (e.g. Hawksworth and Geils 1990).

Prior to using the DMIM system, the user should:

- have a general knowledge of dwarf mistletoe,
- know how to run Forest Vegetation Simulator (FVS), and
- have access to the *User's Guide to the Stand Prognosis Model* (Wykoff *et al*. 1982).

Chapter 2

Biological Background

2.1 How Dwarf Mistletoe Modeling Data Was Adapted from Various Sources

Dwarf mistletoe impact data were collected from numerous publications and personal communications involving a variety of geographical locations, for different tree species and stand types.

Data for the DMIM system were collected from studies conducted all over the Western United States, as well as from personal communications with Forest Service personnel from many regions. Data were taken from forests in Alaska, Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, Oregon, Washington, and Wyoming. The model focuses on the following species: lodgepole pine, ponderosa pine, Douglas-fir, true firs, western larch, and western hemlock.

These species were selected for various reasons: their susceptibility to dwarf mistletoe infection, their importance in stands in the Western United States, their availability in the FVS (PROGNOSIS) model, and the availability of dwarf mistletoe infection study data on these species. The model was, therefore, limited by the amount and type of data available. Other species that are similarly affected by dwarf mistletoe infections are included wherever possible and are represented by one of the species listed above.

While the spatial spread and intensification model accounts for patterns of infestation and spatial relationships between trees, the nonspatial model is based on more directly measurable attributes in order to make it available for use in a timely manner. The model dynamics are based on Hawksworth's six-class dwarf mistletoe rating (DMR) system (Hawksworth 1977). Besides species, DBH, site index, stand density in trees per acre, and height growth also contribute to the projected changes in infection status.

The map in Exhibit 2.1 shows the range of locations from which data (both published and unpublished) was obtained for the design and modeling of the Dwarf Mistletoe Impact Modeling (DMIM) system.

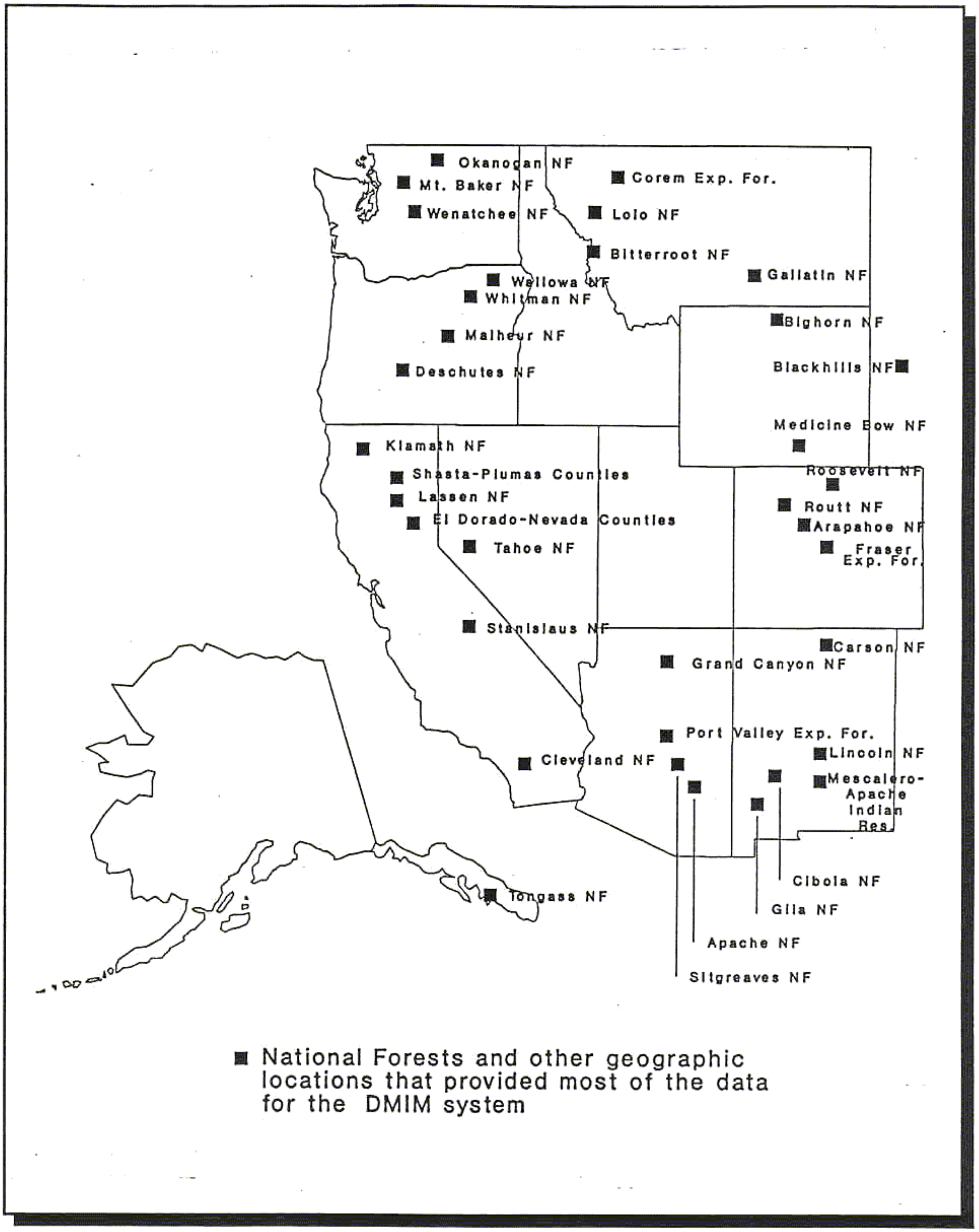

Exhibit 2.1 Data Sources for Dwarf Mistletoe Impact Model.

2.2 Understanding the Main Modules of the Dwarf Mistletoe Impact Model

The DMIM system is made up of four main modules: 1) and 2) predict the nonspatial and spatial spread and intensification; 3) predicts diameter growth modification; and 4) predicts mortality. Generally, each of these modules is also broken down by tree species and DMR class.

The model accounts for three indicators when projecting the impact of dwarf mistletoe on a tree or a stand. The first of these indicators is the change in an individual tree's DMR as mistletoe spreads through a stand. This measure also includes the intensification of dwarf mistletoe within trees that are already infected. Two methods are available for simulating the process of spread and intensification: regression-based nonspatial equations, and a spatially based process-model. The first method makes its projection by simulating the likelihood that an individual tree will increase or decrease its dwarf mistletoe rating during the current cycle, given certain factors. Besides tree species and current DMR, factors that affect the likelihood of increasing or decreasing DMR are the estimates of DBH, stand density, and height-growth. The second method predicts changes in the same indicators: DMR for an individual tree, but bases its projection upon more spatial information: stem density, species mixture, the level of infection within trees in the stand, crown geometry and composition, and various assumptions about the arrangement of trees in the stand and the arrangement of infected trees. Model users have the option of using either the first or the second method.

The model's second indicator is the change in periodic diameter growth caused by dwarf mistletoe infestation. This projection is based on the species and current DMR. For some species, low levels of dwarf mistletoe infection have no adverse effects on diameter growth. Trees of some other species may experience growth loss with even the low levels of mistletoe infection.

The model's third indicator is the mortality caused by dwarf mistletoe infestation. Predicted mortality depends on species, DMR, DBH, and site index. As with other pest extensions to the FVS models, a reconciliation must be made between the mortality predicted to occur because of dwarf mistletoe, and the mortality predicted by the base FVS model (including suppression and all other causes). This is done by comparing the two predictions and using the greater of the two values as the loss for that cycle.

Each cycle, these modules are called from FVS in a certain order, consistent with the sequence in which the base (non-mistletoe) FVS model projections are made. For example, mistletoe diameter growth modifications are computed and put into effect before dwarf mistletoe ratings have been updated for that cycle (in the spread and intensification module). The diagram in Exhibit 2.2 shows the sequence in which the mistletoe modules are called in relation to other FVS activities, including when mistletoe statistical output tables are produced for each cycle.

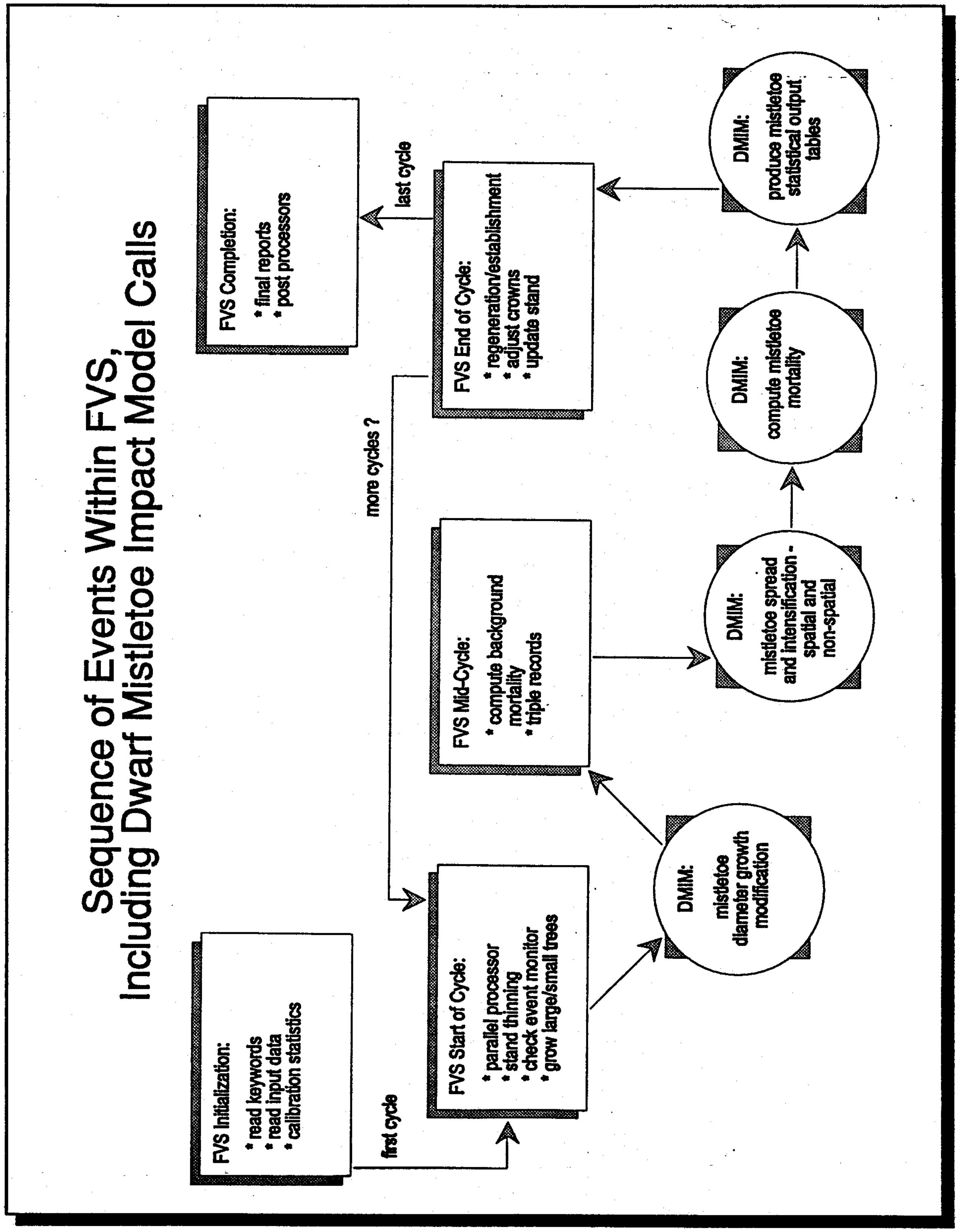

Exhibit 2.2 Sequence of Events Within FVS, Including DMIM Model Calls.

2.3 Spread and Intensification of Dwarf Mistletoe Through a Stand

2.3.1 Nonspatial

In the nonspatial model, two equations determine spread and intensification of dwarf mistletoe through each tree in a stand: one equation for the probability of an increase in DMR and one for the probability of a decrease in DMR.

If a tree record is listed as dwarf mistletoe-infected, there needs to be an equation-based mechanism for passing this infection on to other trees in the stand, as well as for increasing or decreasing the level of infection on already-infected tree records. This mechanism is what is known as the spread and intensification module of the DMIM system. It is based on a study of 1,200 lodgepole pine in Gallatin National Forest in Montana (Dooling et al. 1986). (Intensification data are available from other studies and may be used in a more comprehensive model, but the nonspatial model uses equations from Region 1.) Using the data collected from this study, a logistic regression was fitted to estimate the probability of a tree changing from one dwarf mistletoe rating to the next (Ralph Johnson, unpublished data). The probability of change is calculated separately for increases in DMR (a tree in which more of the crown becomes infected) and decreases in DMR (a tree growing out of its mistletoe infection). Once these probabilities are calculated for a tree in the current cycle, they are compared to a number that is drawn at random from a uniform distribution with a range of 0 to 1. If the probability of increase is larger than the random number, then the tree DMR is increased by one. If the probability of decrease is larger than another separately drawn random number, then the tree DMR is decreased by one. With this method it is not possible for a tree to increase or decrease by more than one rating in a given growth cycle. The probabilities of tree DMR changes are adjusted for cycle lengths other than 10 years.

See Appendix C for a list of tree species by FVS variant which are affected in the model by spread and intensification of dwarf mistletoe through a stand in the model.

Probability of an increase in DMR for any species that is affected by dwarf mistletoe in a given variant is calculated from a logistic regression as follows:

$$P_I = \frac{1}{1 + e^{-(-1.67226 + MD - 0.0747205 \times HG - 0.0012397 \times TPA)}} \times UIM$$

Similarly, the probability of a decrease in DMR for any species that is affected by dwarf mistletoe in a given variant is calculated as follows:

$$P_D = \frac{1}{1 + e^{-(-5.59798 + 0.013267 \times HG - 0.000115053 \times TPA + 0.0983757 \times DMR)}} \times UIM$$

where:

P_I = probability that the rating will increase by 1
P_D = probability that the rating will decrease by 1
DMR = current dwarf mistletoe rating
HG = height growth of the tree (feet per cycle)
TPA = density of the stand (trees per acre)
UIM = user input multiplier supplied using the MISTMULT keyword
MD = mistletoe "dummy" variables with the following values:

DMR	***Coefficient***
0	0.0
1	2.45047
2	2.30723
3	1.88090
4	2.11457
5	1.43293
6	0.0

The model structure makes it impossible to increase the rating of a tree with a DMR of 6, nor is it possible to decrease the rating of a tree with a DMR of 0.

2.3 Spread and Intensification of Dwarf Mistletoe Through a Stand

2.3.2 Spatial

In the spatial model, spread between trees is affected by the mixture of species in a stand, the amount of tree clumping, the patchiness and severity of infestation, the crown position of infested sources and uninfested targets, and the amount of interception between sources and targets. Intensification results when seed trajectories are intercepted within an already-infested tree.

The spatial spread and intensification model provides an alternative to the default nonspatial spread and intensification equations, and is integrated with all variants of FVS. It was developed in workshops involving pathologists, foresters, and modelers (Robinson *et al.* 1993). Compared to the nonspatial model equations, the spatial model is better able to simulate infections in patchy multi-species, multi-storied stands. Some parts of the simulation dynamics are explicitly spatial while other parts are statistical simulations based on known or assumed spatial relationships between individual trees. Users are provided many keywords that will alter the model's behavior. A more detailed description of the model's operation can be found in the Detailed Model Description (Robinson *et al.* 1994). The description found here is a concise and equation-free summary of that document.

In contrast to the regression-based spread and intensification procedure of the nonspatial model, the spatial model treats spread and intensification as the outcome of spatial relationships between infected and uninfected trees. The model actually uses FVS treelist records and is consistent with the existing FVS paradigm; however, in the discussion below we refer to "trees" for the sake of clarity. Consistency with FVS means that tree height and crown characteristics are included explicitly and that the location of individual trees is not known exactly. As a result, height and crown relationships in the model are explicit and location relationships are statistical.

The model simulates dwarf mistletoe infection levels in three parts of each tree: the upper, middle and lower thirds of the live crown. Thus, it follows Hawksworth's method of classifying infestation by assigning each crown third a 0-2 rating, and bases its initial crown third ratings on the inventoried whole-tree DMR and on a simple rule that assigns higher crown third ratings lower in the crown before "filling up" the middle and upper thirds. The model assumes that the same infection level exists throughout the crown third, so that the absolute amount of infection is directly proportional to the volume of the crown third. Crown volumes and geometry are computed from the relationships described in the COVER extension (Moeur 1985). As the model run proceeds, the initial relationship between infection load and DMR is modified in two ways: First, simulated infection loads that lie between two DMRs are assigned to one of the two categories by a random process. Second, infections that are more dense than the level required to give a crown third DMR of 2 are capped at that level. Thus, the spatial model will not allow arbitrarily large amounts of infection to reside in a small volume of canopy. The position of each crown third then changes as trees grow, potentially "outgrowing" mistletoe infections through lower crown senescence and rapid growth of the upper third's leader.

Infected crown thirds can introduce infection to their neighbors. But because of physical constraints on ballistic spread, infection is most likely to be transmitted outward anddownward from an infection source, travelling laterally about 14 meters at most. As a result, an infection in a higher tree will usually expose a lower neighbor to infection, but not the reverse. The model uses the results of a pre-computed trajectory simulation to predict the expected amount of infection arriving in neighboring regions. To make the computations faster, these predictions are made for regions of space that are 8 m^3 in size. Together, these regions make up a three dimensional mesh extending from the ground to the top of each infected ("source") tree. If a neighboring tree happens to be within a infected tree's mesh it may become a target and be subject to receiving some infection from the source.

Infected crown thirds can also reinfect themselves. Depending on the density of foliage within a source tree, some infection will be retained either in the crown third in which infection is located, or in one of the adjacent crown thirds. The notion of *opacity*[1] is used to describe the retention process that leads to self-infection. Defined as the likelihood of a seed being intercepted during one meter of dispersal flight, opacity is used to modify other processes such as screening, which reduces the spread between neighboring trees.

Stands are made up of trees that may be of different species, may have different heights, and may have different crown shapes and opacities. The average opacity at different heights above the forest floor is computed by a Monte Carlo simulation containing stems in proportion to their trees/acre density as treelist records. After assigning a random location to each stem, the average opacity is a function of the amount of space which is clear of foliage at a given height, combined with the opacity of foliage. This average opacity is used to reduce spread as flight trajectories are simulated.

Knowing the height of two trees is necessary, but not sufficient, for modelling the spread of mistletoe. Two trees (and infected source and a target) must have compatible heights and be in the same neighborhood. The actual neighborhood is simulated using a random process that allows stems to be either evenly distributed or clumped, depending on the choice of the model user. In statistical terms, the distribution of stems can range continuously from the Binomial to the Poisson to the Negative Binomial. In addition, the model has the ability to simulate autocorrelation among infection classes. This effectively groups trees by their level of infection and makes it more likely that trees of similar DMR are neighbors compared to trees of unlike DMR. These alternative spatial patterns have been found to alter the model behavior in significant ways.

Following the successful transfer of infection, the model simulates a number of mistletoe life history events. These life history events link the model, which has so far used an abstract measure of infection load, to actual dwarf mistletoe plants. The model uses simple independent probability relationships and scalars (e.g. probability of being female, probability of germination, and plants/unit DMR/m3 of canopy) to link the theoretical index of infection to a predicted number of germinating new infections. These new infections are initially immature and do not contribute to the DMR classification. They progress from immature to latent (mature but non-flowering) after a delay of four years. After that, the production of active flowering plants is modelled as a function of the available light at the height where the infection is located. Light availability is modelled by an extinction curve based on the simulated stem map and the average opacity at different heights in the stand (i.e. light is intercepted by the stand canopy in the same way that mistletoe seeds are intercepted). By default, the proportion of latent infections that become active is proportional to the proportion of incident light that reaches the infection. Furthermore, active plants can regress to a latent state if light conditions are reduced. Both active and "regressed" infections contribute to the calculation of the DMR of a host tree. Each year, all life history classes of dwarf mistletoe plants are subject to an individual mortality rate that is distinct from mortality due to the death of host trees or from crown senescence.

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[1]Concise definitions of the spatial model terms can be found in the glossary in Appdendix B. Detailed explanations can be found in the draft model description document, which contains a complete description of the model's features and actions (Robinson et al. 1994).

2.4 How Diameter Growth is Modified

There are five different equations for diameter growth modification, one for each of the following species: lodgepole pine, western larch, Douglas-fir, true firs, and ponderosa pine. All other species whose growth is significantly affected by dwarf mistletoe are currently emulated by one of these five equations.

Diameter growth for an individual tree may be modified when a dwarf mistletoe infection is present. A healthy tree has a potential of 100% growth for a given cycle. The model then calculates the proportion of that growth that would be lost due to mistletoe, based on that tree's DMR, species, and DBH. In addition, factors such as the FVS variant and the cycle length can modify diameter growth. This predicted mistletoe growth loss is then translated into a proportion of potential growth, which is used as a multiplier against the estimated healthy growth. Normal (healthy) diameter growth (in inches) is estimated using a variety of factors such as basal area, current diameter, site index, crown competition, elevation, aspect, slope, and species. In turn, the calculated diameter growth plays a role in making other calculations such as estimated height growth. Therefore, any diameter growth lost due to mistletoe will automatically alter estimated height growth for a tree.

Mistletoe diameter growth modification proportions for the model are stored in table format based on DMR, species, and the FVS variant. These are average values taken from a number of published and unpublished sources across the western US. These DMR, species, and variant-specific values are used in equations which also take into account cycle length, site factors, and user input mistletoe diameter growth modification proportions (see the MISTGMOD keyword section of this manual). There are essentially five of these equations, one to model each of the following species: lodgepole pine, western larch, Douglas-fir, true firs, and ponderosa pine. Any other species native to a given area which is affected by mistletoe will be emulated by one of the five models listed above based on which species it is more closely related to in terms of how it is affected by mistletoe.

Only sample trees with a DMR of 1 or greater at the start of the cycle are considered to be infected. No change in tree growth is calculated by this model for sample trees that are not infected (DMR=0) at the start of the cycle.

See Appendix C for a list of tree species by FVS variant which are susceptible to diameter growth loss in the model due to dwarf mistletoe infection.

2.4 How Diameter Growth is Modified

2.4.1 The Lodgepole Pine Growth Modification Equation

This section includes the data used to build the lodgepole pine mistletoe growth modification equation which is also used to emulate other species similarly affected by dwarf mistletoe.

The lodgepole pine diameter growth modification equation is based on the percentages listed in the table in Exhibit 2.4, which shows how diameter growth potential corresponds to DMR:

Dwarf Mistletoe rating	0	1	2	3	4	5	6
10-year diameter growth potential (percent)	100	100	100	100	94	80	59

Exhibit 2.4 Relationship of Lodgepole Pine Diameter Growth Potential to DMR.

Other species similarly affected by dwarf mistletoe which also use the lodgepole pine percentages are:

- sugar pine,
- white pine,
- white bark pine,
- limber pine, and
- western hemlock.

After diameter growth is calculated in FVS it is altered to account for dwarf mistletoe as in the following equation:

$$ADG = NDG * DGP * CL / 10.0$$

where:

ADG = altered diameter growth, in inches
NDG = normal diameter growth, in inches
DGP = dwarf mistletoe diameter growth potential based on DMR (taken from Exhibit 2.4, where percent is converted to a decimal or supplied using the `MISTGMOD` keyword)
CL = cycle length (converted from 10-year period to user input length)

The data used to formulate the relationship between DMR and diameter growth potential (Exhibit 2.4) are presented with sources in Exhibit 2.5 (all entries were translated from the original source into percent potential growth in 10 years and then averaged together for the model):

Dwarf Mistletoe Rating	Region 6 Values (1) (%)	25 Even-aged Stands in CO(2) (%)	Open Stands in CO and WY(2) (%)	Dense Stands in CO and WY(2) (%)
0	100	100	100	100
1	100	100	100	100
2	100	100	100	100
3	100	100	100	100
4	94	94	95	93
5	80	80	82	78
6	59	59	56	61

Sources:

A. H. Maffei and P. Hessburg, personal communication; Hawksworth and Hinds 1964.

B. Hawksworth and Johnson 1989.

Exhibit 2.5 Data and Sources for Exhibit 2.4

Exhibit 2.6 is a graph of the diameter growth modification equation for lodgepole pine with mistletoe infection (black points) and the data used to formulate the relationship between DMR and diameter growth (white points).

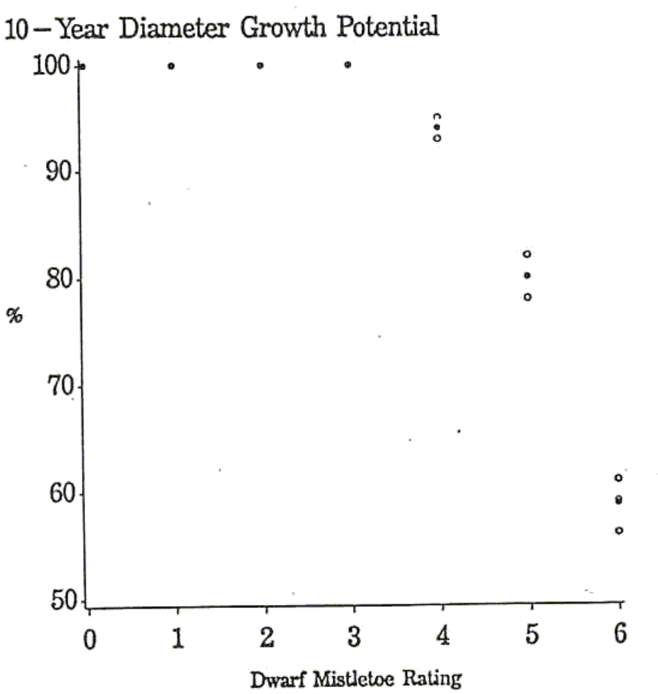

Exhibit 2.6 Lodgepole Pine Diameter Growth Potential vs. DMR.

2.4 How Diameter Growth is Modified

2.4.2 The Western Larch Growth Modification Equation

This section includes the data used to build the western larch mistletoe growth modification equation which is also used to emulate other species similarly affected by dwarf mistletoe.

The western larch growth modification equation is based on the percentages listed in the table in Exhibit 2.7, which shows how growth potential corresponds to DMR:

Dwarf Mistletoe rating	**0**	**1**	**2**	**3**	**4**	**5**	**6**
10-year diameter growth potential (percent)	100	100	100	100	94	80	59

Exhibit 2.7 Relationship of Western Larch Diameter Growth Potential to DMR.

After diameter growth is calculated in FVS it is altered to account for dwarf mistletoe as in the following equation:

$$ADG = NDG * DGP * CL / 10.0$$

where:

ADG = altered diameter growth, in inches
NDG = normal diameter growth, in inches
DGP = dwarf mistletoe diameter growth potential based on DMR (taken from Exhibit 2.7 where percent is converted to a decimal or supplied using the MISTGMOD keyword)
CL = cycle length (converted from 10-year period to user input length)

The data used to formulate the relationship between DMR and diameter growth potential (Exhibit 2.7) are presented with sources in Exhibit 2.8 (all entries were translated from the original source into percent potential growth in 10 years and then averaged together for the model):

Dwarf Mistletoe Rating	Region 6 Value (%)	70-year-old Stands in OR (%)	Thinned Stands (above) in OR (%)	Thinned Stands (below) in OR (%)
0	100	100	100	100
1	97	94	93	92
2	90	94	93	92
3	85	89	89	89
4	69	89	89	89
5	57	56	69	48
6	44	56	69	48

Source: Filip *et al.* 1989.

Exhibit 2.8 Data and Sources for Exhibit 2.7

Exhibit 2.9 is a graph of the diameter growth modification equation for western larch with mistletoe infection (black points) and the data used to formulate the relationship between DMR and diameter growth (white points).

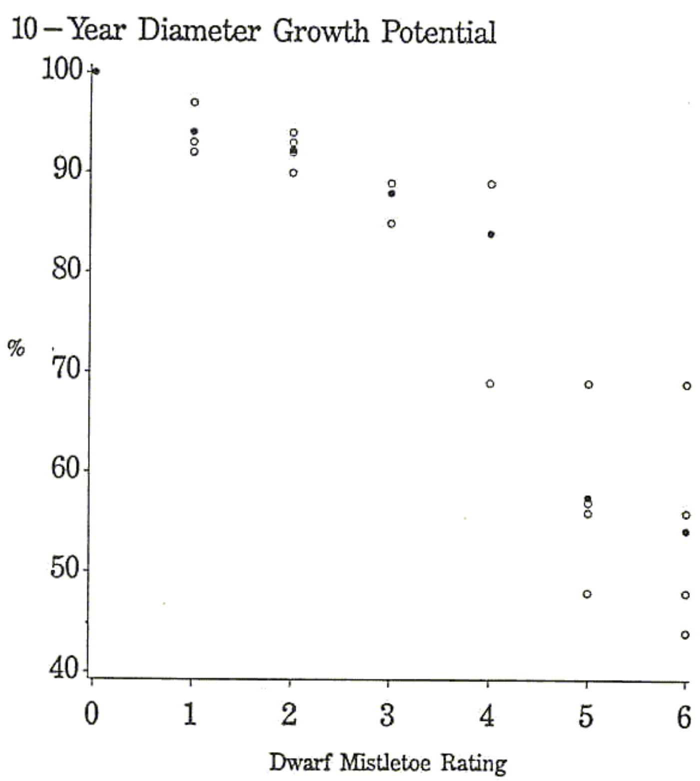

Exhibit 2.9 Western Larch Diameter Growth Potential vs. DMR

2.4 How Diameter Growth is Modified

2.4.3 The Douglas-fir Growth Modification Equation

This section includes the data used to build the Douglas-fir mistletoe growth modification equation which is also used to emulate other species similarly affected by dwarf mistletoe.

The Douglas-fir diameter growth modification equation is based on the percentages listed in table in Exhibit 2.10, which shows how growth potential corresponds to DMR:

Dwarf Mistletoe Rating	**0**	**1**	**2**	**3**	**4**	**5**	**6**
10-year diameter growth potential (percent)	100	98	97	85	80	52	44

Exhibit 2.10 Relationship of Douglas-fir Diameter Growth Potential to DMR.

Another species similarly affected by dwarf mistletoe which also uses the Douglas-fir percentages is:

- Engelmann spruce.

After diameter growth is calculated in FVS it is altered to account for dwarf mistletoe as in the following equation:

ADG = NDG * DGP * CL / 10.0

where:

ADG = altered diameter growth, in inches
NDG = normal diameter growth, in inches
DGP = dwarf mistletoe diameter growth potential based on DMR (taken from Exhibit 2.10 where percent is converted to a decimal, or supplied using the MISTGMOD keyword)
CL = cycle length (converted from 10-year period to user input length)

The data used to formulate the relationship between DMR and diameter growth potential (Exhibit 2.10) are presented with sources in Exhibit 2.11 (all entries were translated from the original source into percent potential growth in 10 years and then averaged together for the model):

DMR	A (%)	B (%)	C (%)	D (%)	E (%)	F (%)	G (%)	H (%)	I (%)	J (%)	K (%)	L (%)
0	100	100	100	100	100	100	100	100	100	100	100	100
1	90	100	91	93	100	100	100	100	100	100	100	100
2	90	100	82	97	100	100	100	100	100	100	100	100
3	60	100	86	80	98	78	87	99	71	96	71	91
4	60	79	77	93	81	78	87	99	71	96	71	73
5	30	79	57	77	62	45	41	51	43	49	37	57
6	30	79	23	63	33	45	41	51	43	49	37	39

Sources:

A. Region 6 values (Knutson an dTinnin 1986; Pierce 1960)
B. Thinned Douglas-fir plots, Lolo Natl. Forest (MT) (Dooling *et al.* 1986)
C. Age 58-70 Douglas-fir stands, Malheur Natl. Forest (OR) (Knutson and Tinnin 1986)
D. Age 58-70 Douglas-fir stands, Okanogan Natl. Forest (WA) (Knutson and Tinnin 1986)
E. Thinned Douglas-fir plots, Malheur Natl. Forest (OR) (Tinnin 1988)
F. 0.0-5.9" DBH trees, Malheur Natl. Forest (Tinnin 1988)
G. 6.0-11.9" DBH trees, Malheur Natl. Forest (Tinnin 1988)
H. >12.0" DBH trees, Malheur Natl. Forest (Tinnin 1988)
I. Age 0-49 trees, Malheur Natl. Forest (Tinnin 1988)
J. Age 50-79 trees, Malheur Natl. Forest (Tinnin 1988)
K. Age >79 trees, Malheur Natl. Forest (Tinnin 1988)
L. Mixed-conifer stnads, five national forests (AZ, NM) (Mathiasen *et al.* 1990)

Exhibit 2.11 Data and Sources for Exhibit

Exhibit 2.12 is a graph of the diameter growth modification equation for Douglas-fir with mistletoe infection (black points) and the data used to formulate the relationship between DMR and diameter growth (white points).

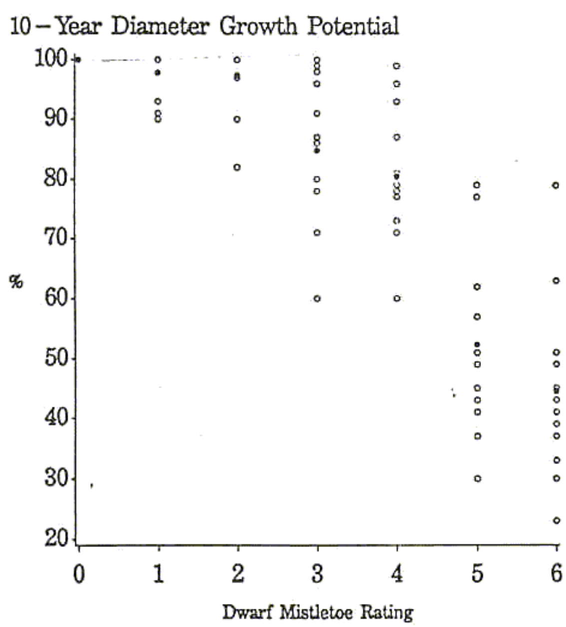

Exhibit 2.12 Douglas-fir Diameter Growth Potential vs. DMR

2.4 How Diameter Growth is Modified

2.4.4 The True Fir Growth Modification Equation

This section includes the data used to build the true fir mistletoe growth modification equation which is also used to emulate other species similarly affected by dwarf mistletoe.

The true fir diameter growth modification equation is based on the percentages listed in the table in Exhibit 2.13, which shows how growth potential corresponds to DMR:

Dwarf Mistletoe rating	0	1	2	3	4	5	6
10-year diameter growth potential (percent)	100	100	100	98	95	70	50

Exhibit 2.13 Relationship of True Fir Diameter Growth Potential to DMR.

Other species similarly affected by dwarf mistletoe which also use the true fir percentages are:

- red fir,
- white fir,
- alpine fir,
- grand fir,
- noble fir,
- pacific silver fir, and
- corkbark fir.

After diameter growth is calculated in FVS, it is altered to account for dwarf mistletoe, as in the following equation:

ADG = NDG * DGP * CL / 10.0

where:

ADG = altered diameter growth, in inches
NDG = normal diameter growth, in inches
DGP = dwarf mistletoe diameter growth potential based on DMR (taken from Exhibit 2.1 where percent is converted to a decimal, or supplied by the MISTGMOD keyword)
CL = cycle length (converted from 10-year period to user input length

The data used to formulate the relationship between DMR and diameter growth potential (Exhibit 2.13) are presented with sources in Exhibit 2.14 (all entries were translated from the original source into percent potential growth in 10 years and then averaged together for the model):

Dwarf Mistletoe Rating	Rgion 6 Values(1) (%)	Region 5 Values(2) (%)
0	100	100
1	100	100
2	100	100
3	95	100
4	90	100
5	55	85
6	50	50

Sources:

A. Unpublished data, R. Scharpf; Filip 1984.

B. Unpublished data, Dennis Hart

Exhibit 2.14 Data and Sources for Exhibit 2.13.

Exhibit 2.15 is a graph of the diameter growth modification equation for true fir with mistletoe infection (black points) and the data used to formulate the relationship between DMR and diameter growth (white points).

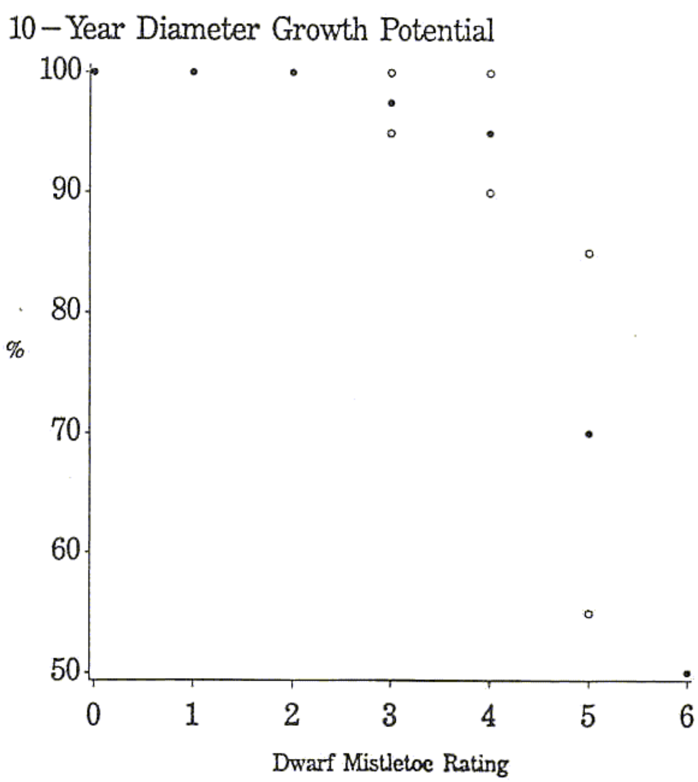

Exhibit 2.15 True Fir Diameter Growth Potential vs. DMR.

2.4 How Diameter Growth is Modified

2.4.5 The Ponderosa Pine Growth Modification Equation

This section includes the data used to build the ponderosa pine mistletoe growth modification equation which is also used to emulate other species similarly affected by dwarf mistletoe.

The ponderosa pine diameter growth modification equation is based on the percentages listed in the table in Exhibit 2.16, which shows how growth potential corresponds to DMR:

Dwarf Mistletoe rating	**0**	**1**	**2**	**3**	**4**	**5**	**6**
10-year diameter growth potential (percent)	100	100	100	98	86	73	50

Exhibit 2.16 Relationship of Ponderosa Pine Diameter Growth Potential to DMR.

Other species similarly affected by dwarf mistletoe which also use the ponderosa pine percentages are:

- mountain hemlock,
- blue spruce, and
- Jeffrey pine.

After diameter growth is calculated in FVS, it is altered to account for dwarf mistletoe, as in the following equation:

$$ADG = NDG * DGP * CL / 10.0$$

where:

ADG = altered diameter growth, in inches
NDG = normal diameter growth, in inches
DGP = dwarf mistletoe diameter growth potential based on DMR (taken from Exhibit 2.16, where percent is converted to a decimal, or supplied by the MISTGMOD keyword)
CL = cycle length (converted from 10-year period to user input length)

The data used to formulate the relationship between DMR and diameter growth potential (Exhibit 2.16) are presented with sources in Exhibit 2.17 (all entries were translated from the original source into percent potential growth in 10 years and then averaged together for the model):

Dwarf Mistletoe Rating	Region 6-Values(1) (%)	Age 55 Stand Mescalero-Apache, NM(2) (%)	Age 140 Stand Mescalero-Apache, NM(2) (%)	Grand Canyon, AZ(3) (%)
0	100	100	100	100
1	100	100	100	100
2	100	100	100	100
3	100	100	100	90
4	85	100	86	71
5	70	81	74	65
6	50	65	48	35

Sources:

A. Maffei 1989; Childs and Edgren 1967; and Shea 1964.
B. Hawksworth 1961.
C. Lightle and Hawksworth 1973.

Exhibit 2.17 Data and Sources for Exhibit 2.16.

Exhibit 2.18 is a graph of the diameter growth modification equation for ponderosa pine with mistletoe infection (black points) and the data used to formulate the relationship between DMR and diameter growth (white points).

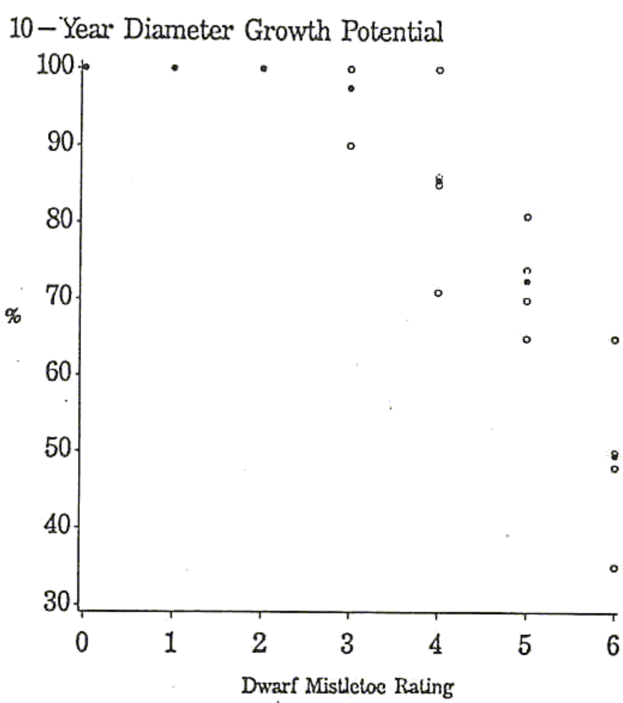

Exhibit 2.18 Ponderosa Pine Diameter Growth Potential vs. DMR.

2.5 How Mortality is Calculated

There are four different mortality equations: one for lodgepole pine, one for ponderosa pine, one for Douglas-fir, and one for true firs. All other species whose mortality is affected by dwarf mistletoe infection are currently represented by one of these four equations.

Mortality caused by dwarf mistletoe is calculated in the DMIM system on a tree-by-tree basis. This mortality is determined using the following information for each tree: FVS variant, species, density of the stand (in trees per acre), DMR, cycle length, a site factor, DBH and a user input multiplier (if one was supplied). Using this information, the DMIM system calculates what percentage of the tree record would die due to the severity of the current mistletoe infection. This percentage is then compared with background mortality and the larger of the two values is retained as the mortality for that tree record in the current cycle. Mortality caused by dwarf mistletoe is generally larger than background mortality, especially in cases of severe infection, and this will be displayed in various forms in the mistletoe statistical output tables (discussed in later sections of this manual).

Probability of mortality of infected trees is calculated using a quadratic equation which was derived from a least-squares fit of individual tree mortality measured over 10 years, stratified by DMR. The data used in deriving the mortality equations were collected from across the western U.S. The mortality model equations and resulting 10-year percentages are presented by species in the following four sections. There is an equation to model each of these species: lodgepole pine, ponderosa pine, Douglas-fir, and true firs. Any other species native to a given area which is affected by mistletoe is emulated by one of the four models listed above, based on which species it is more closely related to in terms of how it is affected by mistletoe.

Only sample trees with a DMR of 1 or greater at the start of the cycle are considered infected. No change in mortality is calculated by this model for sample trees that are not infected (DMR=0) at the start of the cycle.

See Appendix C for a list of tree species by FVS variant which are susceptible to dwarf mistletoe- induced mortality in the model.

2.5 How Mortality is Calculated

2.5.1 The Lodgepole Pine Mortality Equation

This section includes the data used to build the lodgepole pine mistletoe mortality equation which is also used to emulate other species similarly affected by dwarf mistletoe.

The 10-year mortality rate (in percent) for lodgepole pine with dwarf mistletoe infections is calculated as in the following equation:

PM = (.00112 + .0217 * DMR - .00171 * DMR**2) * UIM * 100.0

where:

PM = percent mortality due to mistletoe
DMR = dwarf mistletoe rating
UIM = user input multiplier (supplied using the MISTMORT keyword)

This rate is multiplied by 1.2 if the DBH of the tree is less than 9 inches. Upper bounds on percent mortality in a 10-year period due to mistletoe are set at 71% for trees with DBH less than 9 inches, and 50% for trees with DBH greater than or equal to 9 inches. The mortality probabilities are adjusted for cycle lengths other than 10 years.

This mortality percentage is then converted to TPA (trees per acre) and compared to background mortality to determine the larger of the two values. Other species similarly affected by dwarf mistletoe and also use the lodgepole pine mortality equation are:

- sugar pine,
- white pine,
- limber pine,
- whitebark pine, and
- western hemlock.

Resulting 10-year mortality percentages for lodgepole pine based on DMR and DBH are given in Exhibit 2.20.

Dwarf Mistletoe Rating	0	1	2	3	4	5	6
% mortality, small trees (DBH <9 inches)	0.0	2.5	4.5	6.1	7.3	8.0	8.4
% mortality, large trees (DBH >=9 inches)	0.0	2.1	3.8	5.1	6.1	6.7	7.0

Exhibit 2.20 Lodgepole Pine 10-Year Mortality Percentages.

The data used to formulate the relationship between DMR and mistletoe mortality rates (Exhibit 2.20), and also used to generate the lodgepole pine mortality equation are presented with sources in Exhibit 2.21 (all entries were translated from the original source into 10-year percent mortality):

DMR	Region 6 Values(1) (%)	Study from Roosevelt (CO), Medicine Bow (WY), and Bighorn (WY) National Forests (2, 3) (%)
0	0.0	0.0
1	3.0	1.9
2	3.0	3.7
3	6.0	4.8
4	6.0	5.8
5	7.0	6.4
6	7.0	7.0

Sources:

A. Maffei and Hessburg, personal communication; and Hawksworth and Hinds 1964
B. Hawksworth and Johnson 1989
C. Hawksworth 1958

Exhibit 2.21 Data and Sources for Exhibit 2.20.

Exhibit 2.22 is a graph of the large-tree mortality equation for lodgepole pine with mistletoe infection (curve) and the data used to formulate the relationship between DMR and tree mortality (white points).

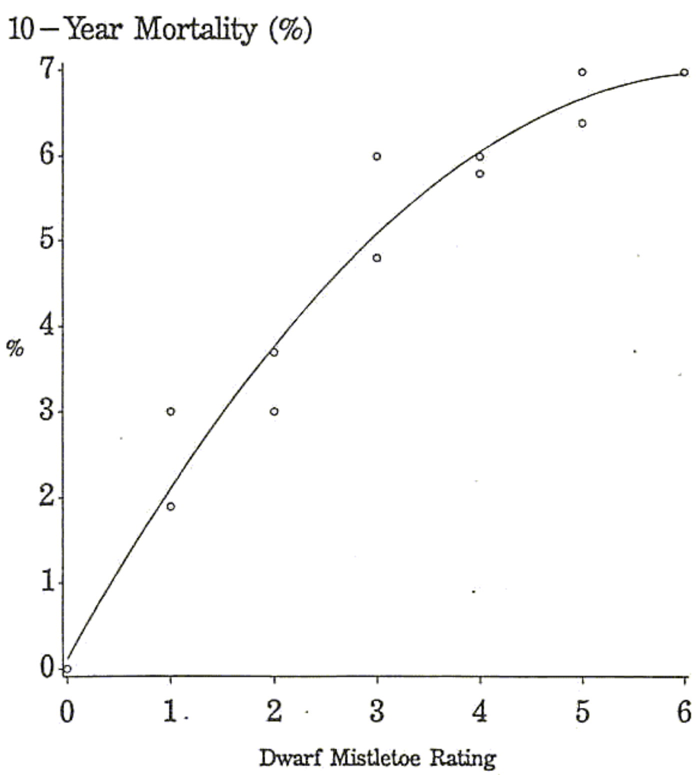

Exhibit 2.22 Lodgepole Pine Mortality vs. DMR.

2.5 How Mortality is Calculated

2.5.2 The Ponderosa Pine Mortality Equation

This section includes the data used to build the ponderosa pine mistletoe mortality equation which is also used to emulate other species similarly affected by dwarf mistletoe.

The 10-year mortality rate (in percent) for ponderosa pine with dwarf mistletoe infections is calculated as in the following equation:

PM = (.00681 - .00580 * DMR + .00935 * DMR**2) * UIM * 100.0

where:

PM = percent mortality due to mistletoe
DMR = dwarf mistletoe rating
UIM = user input multiplier (supplied using the MISTMORT keyword)

This rate is multiplied by 1.2 if the DBH of the tree is less than 9 inches. Upper bounds on percent mortality in a 10-year period due to mistletoe are set at 71% for trees with DBH less than 9 inches, and 50% for trees with DBH greater than or equal to 9 inches. The mortality probabilities are adjusted for cycle lengths other than 10 years.

This mortality percentage is then converted to TPA (trees per acre) and compared to background mortality to determine the larger of the two values. Other species that are similarly affected by dwarf mistletoe and also use the ponderosa pine mortality equation are:

- Jeffrey pine,
- blue spruce,
- western hemlock, and
- mountain hemlock.

Resulting 10-year mortality percentages for ponderosa pine based on DMR and DBH are given in Exhibit 2.23.

Dwarf Mistletoe Rating	0	1	2	3	4	5	6
% mortality, small trees (DBH <9 inches)	0.0	1.2	3.9	8.8	16.0	25.4	37.0
% mortality, large trees (DBH >=9 inches)	0.0	1.0	3.3	7.4	13.3	21.2	30.9

Exhibit 2.23 Ponderosa Pine 10-Year Mortality Percentages

The data used to formulate the relationship between DMR and mistletoe mortality rates (Exhibit 2.23), and also used to generate the ponderosa pine mortality equation are presented with sources in Exhibit 2.24 (all entries were translated from the original source into 10-year percent mortality):

DMR	A (%)	B (%)	C (%)	D (%)	E (%)	F (%)	G (%)
0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	3.5	0.0	2.0	3.1	0.9	1.3	0.0
2	7.0	4.0	3.0	10.3	3.1	2.6	0.0
3	10.0	11.5	4.0	17.8	5.3	5.0	0.0
4	13.0	16.5	8.0	22.5	11.6	9.8	0.0
5	16.5	19.0	12.0	27.2	20.9	19.1	34.5
6	19.0	29.5	38.0	31.3	29.7	37.3	34.5

Sources:

A. 3053 plots in AZ and NM (Andrews and Daniels 1960)
B. South rim of Grand Canyon, AZ (Lightle and Hawksworth 1973)
C. 4013 plots on Mescalero-Apache Reservation, NM (Hawksworth and Lusher 1956)
D. 17.1 acres in Grand Canyon Natl. Park - small trees (Hawksworth and Geils 1990)
E. 17.1 acres in Grand Canyon Natl. Park - large trees (Hawksworth and Geils 1990)
F. CA and NV forest recreation areas (Scharpf *et al.* 1988)
G. Region 6 values (Maffei 1989; and Pringle Falls unpublished data, L.F. Roth)

Exhibit 2.24 Data and Sources for Exhibit 2.23.

Exhibit 2.25 is a graph of the large-tree mortality equation for ponderosa pine with mistletoe infection (curve) and the data used to formulate the relationship between DMR and tree mortality (white points).

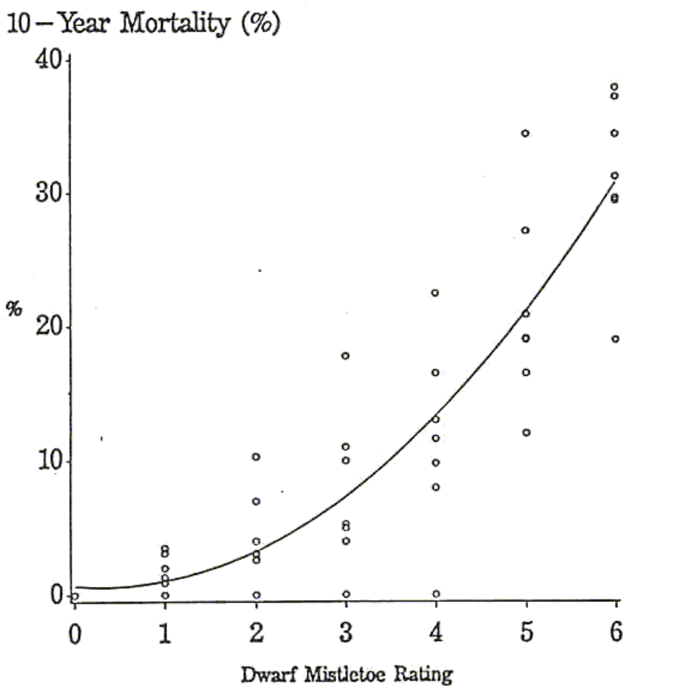

Exhibit 2.25 Ponderosa Pine Mortality vs. DMR.

2.5 How Mortality is Calculated

2.5.3 The Douglas-Fir Mortality Equation

This section includes the data used to build the Douglas-fir mistletoe mortality equation which is also used to emulate other species similarly affected by dwarf mistletoe.

The 10-year mortality rate (percent) for Douglas-fir with dwarf mistletoe infections is calculated as in the following equation:

PM = (.01319 - .01627 * DMR + .00822 * DMR**2) * UIM * 100.0

where:

PM = percent mortality due to mistletoe
DMR = dwarf mistletoe rating
UIM = user input multiplier (supplied using the MISTMORT keyword)

This rate is multiplied by 1.2 if the DBH of the tree is less than 9 inches. Upper bounds on percent
mortality in a 10-year period due to mistletoe are set at 71% for trees with DBH less than 9 inches, and 50% for trees with DBH greater than or equal to 9 inches. The mortality probabilities are adjusted for cycle lengths other than 10 years.

This mortality percentage is then converted to TPA (trees per acre) and compared to background mortality to determine the larger of the two values. Other species that are similarly affected by dwarf mistletoe and also use the Douglas-fir mortality equation are:

- western larch,
- larch, and
- Engelmann spruce.

Resulting 10-year mortality percentages for Douglas-fir based on DMR and DBH are given in Exhibit 2.26.

Dwarf Mistletoe Rating	**0**	**1**	**2**	**3**	**4**	**5**	**6**
% mortality, small trees (DBH <9 inches)	0.0	0.6	1.6	4.6	9.6	16.5	25.4
% mortality, large trees (DBH >=9 inches)	0.0	0.5	1.4	3.8	8.0	13.7	21.1

Exhibit 2.26 Douglas-fir 10-Year Mortality Percentages.

The data used to formulate the relationship between DMR and mistletoe mortality rates (Exhibit 2.26), and also used to generate the Douglas-fir mortality equation are presented with sources in Exhibit 2.27 (all entries were translated from the original source into 10-year percent mortality):

DMR	A (%)	B (%)	C (%)	D (%)	E (%)	F (%)
0	0.0	0.0	0.0	0.0	0.0	0.0
1	0.0	0.0	1.0	---	5.1	2.0
2	0.5	0.0	1.0	6.4	9.4	3.0
3	0.0	0.0	1.0	6.5	4.0	8.0
4	0.6	0.0	1.4	19.2	15.4	12.0
5	3.0	2.4	7.9	21.0	5.1	23.0
6	9.8	10.5	7.9	29.1	38.5	44.0

Sources:

A. Northwest Douglas-fir, 2,269 trees (unpublished data, B.Geils)
B. Southwest Douglas-fir, 452 trees (unpublished data, B.Geils)
C. Region 6 values (Knutson and Tinnin 1986; Pierce 1960)
D. S.W. mixed conifer, 21,885 Douglas-fir trees (unpublished data, B.Geils)
E. S.W. mixed conifer, 441 5-year remeasure trees (unpublished data, B.Geils)
F. 4,013 plots on Mescalero-Apache Reservation, NM (Hawksworth and Lusher 1956)

Exhibit 2.27 Data and Sources for Exhibit 2.26.

Exhibit 2.28 is a graph of the large-tree mortality equation for Douglas-fir with mistletoe infection (curve) and the data used to formulate the relationship between DMR and tree mortality (white points).

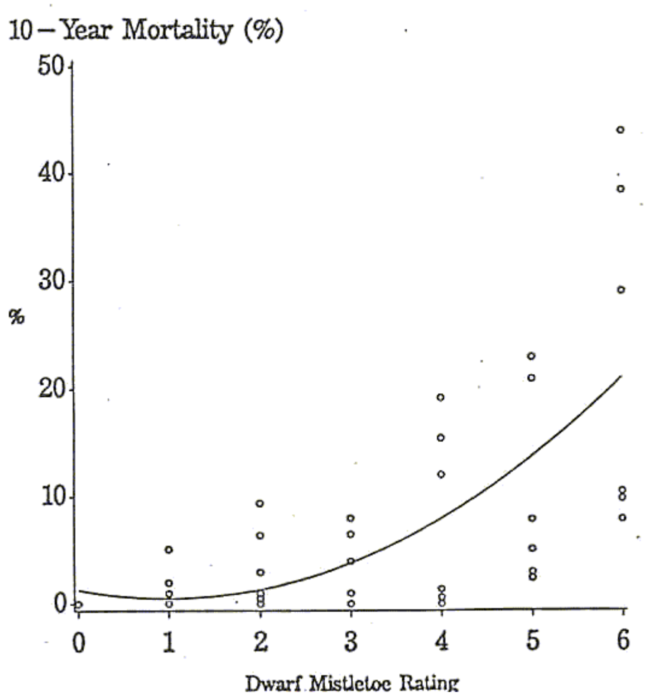

Exhibit 2.28 Douglas-fir Mortality *vs.* DMR.

2.5 How Mortality is Calculated

2.5.4 The True Fir Mortality Equation

This section includes the data used to build the true fir mistletoe mortality equation which is also used to emulate other species similarly affected by dwarf mistletoe.

The 10-year mortality rate (in percent) for true firs with dwarf mistletoe infections is calculated as in the following equation:

PM = (.00159 * DMR + .00508 * DMR**2) * UIM * 100.0

where:
PM = percent mortality due to mistletoe
DMR = dwarf mistletoe rating
UIM = user input multiplier (supplied using the MISTMORT keyword)

This rate is multiplied by 1.2 if the DBH of the tree is less than 9 inches. Upper bounds on percent mortality in a 10-year period due to mistletoe are set at 71% for trees with DBH less than 9 inches, and 50% for trees with DBH greater than or equal to 9 inches.

This mortality percentage is then converted to TPA (trees per acre) and compared to background mortality to determine the larger of the two values. Other species that are similarly affected by dwarf mistletoe and also use the true fir mortality equation are:

- alpine fir,
- grand fir,
- red fir,
- white fir,
- noble fir,
- Pacific silver fir, and
- corkbark fir.

Resulting 10-year mortality percentages for true firs based on DMR and DBH are given in Exhibit 2.29.

Dwarf Mistletoe Rating	0	1	2	3	4	5	6
% mortality,small trees (DBH <9 inches)	0.0	0.8	2.8	6.1	10.5	16.2	23.1
% mortality, large trees (DBH >=9 inches)	0.0	0.7	2.3	5.0	8.8	13.5	19.2

Exhibit 2.29 True Fir 10-Year Mortality Percentages.

The data used to formulate the relationship between DMR and mistletoe mortality rates (Exhibit 2.29), and also used to generate the true fir mortality equation are presented with sources in Exhibit 2.30 (all entries were translated from the original source into 10-year percent mortality):

Dwarf Mistletoe Rating	1281 Small Red/White Fir Trees in Lassen National Forest (%)
0	0.0
1	3.5
2	6.3
3	6.3
4	10.5
5	7.5
6	28.6

Source: unpublished data, D. Hart

Exhibit 2.30 Data and Sources for Exhibit 2.29.

Exhibit 2.31 is a graph of the small-tree mortality equation for true fir with mistletoe infection (curve) and the data used to formulate the relationship between DMR and tree mortality (white points).

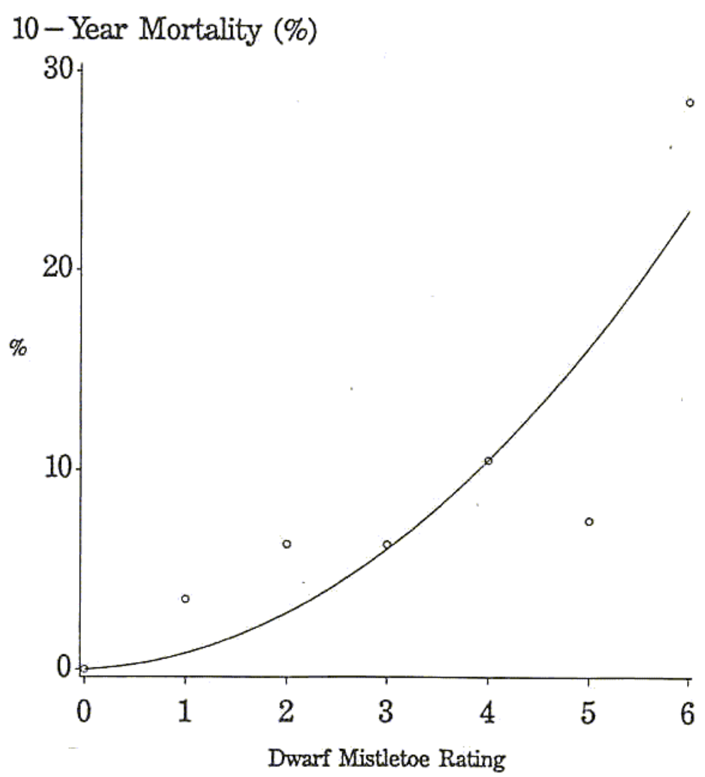

Exhibit 2.31 True Fir Mortality *vs.* DMR.

Chapter 3

Using the Model

3.1 Accessing the Dwarf Mistletoe Model from FVS

Linked with the Dwarf Mistletoe Impact Modeling (DMIM) system, FVS will automatically access the dwarf mistletoe model to determine the effects of dwarf mistletoe infections, if present in the stand, for 14 different variants of FVS.

The DMIM system runs in conjunction with the FVS Growth and Yield Model for 14 different variants of FVS. The variants that are now available with dwarf mistletoe effects included are:

- Blue Mountains
- Central Idaho
- Central Rockies
  - Black Hills
  - Lodgepole Pine
  - Southwest Mixed Conifer
  - Southwest Ponderosa Pine
  - Spruce-Fir
- East Cascades
- Eastern Montana
- Inland Empire
- KooKanTL
- Northern California (Klamath Mountains)
- SE Alaska
- SORNEC
- Tetons
- Utah
- WESSIN
- West Cascades

When the FVS and dwarf mistletoe models are linked together, the effects of dwarf mistletoe will automatically be present in a run of FVS without having to do anything at all as long as mistletoe damage/severity codes are input with the tree data. In FVS, it is possible to have up to three pairs of damage/severity codes for each tree record, and any one of these pairs can be encoded with dwarf mistletoe damage/severity codes. Valid dwarf mistletoe 2-digit damage codes are as follows:

31 lodgepole pine mistletoe
32 western larch mistletoe
33 Douglas-fir mistletoe
34 ponderosa pine mistletoe, and
30 dwarf mistletoe on any species other than the four listed above

Valid dwarf mistletoe severity codes range are two-digit numbers from 00 to 06, depending on the intensity of the infection (based on the Hawksworth 6-point Dwarf Mistletoe Rating Scale: Hawksworth 1977), where 00 implies no mistletoe infection anywhere on the tree, and 06 implies heavy mistletoe infection spread over the entire tree.

Another way to introduce dwarf mistletoe infections into a stand without having to type damage and severity codes into your tree-data file is to use the MISTPINF keyword. Use of this keyword will be covered in more detail in later sections of this manual along with other mistletoe-related keywords.

The sample tree-data file in Exhibit 3.1 shows how mistletoe infections are coded in the tree input data.

```
Codes:     AAA       BBBB  C  DD  EE F    GGHII  JJKK   LLL
   1       190 0 2   2000  1  LP  1  0 0  00 0          100    0
   1       190 0 1   1000  1  LP  13 0 0  01 0          100    0
   1       190 0 1   1000  1  LP  36 7 0  06 0          100    4
   1       190 0 1   1000  1  LP  39 0 0  0073          100    0
   1       190 0 1   1000  1  LP  48 0 0  03 0          100    5
   1       190 0 1   282   1  LP  51 0 0  393 0  3101   100    1
   1       190 0 1   261   1  LP  53 0 0  422 0  3102   100    1
   1       190 0 1   261   1  LP  53 0 0  441 0  3103   100    0
   1       190 0 1   252   1  LP  54 0 0  422 0  3104   100    0
   1       190 0 1   121   1  LP  55 0 0  380 0  3105   100    0
   1       190 0 1   226   1  LP  57 0 0  413 0  3106   100    2
   1       190 0 1   226   1  LP  57 6 0  413 0         100    0
   1       190 0 1   218   1  LP  58 0 0  461 0         100    0
   1       190 0 1   204   1  LP  60 0 0  47173         100    0
   1       190 0 1    71   1  LP  72 0 0  430 0         100    0
```

Designator codes:

A = Plot identification
B = Tree count (trees per 10 acres)
C = Tree history code
D = Species
E = DBH (tenths of inches)
F = Diameter increment (tenths of inches)
G = Height (in feet)
H = Crown ratio code
I = Tree damage code
J = Mistletoe damage code
K = DMR
L = Tree value code

Exhibit 3.1 An example of how mistletoe infections are coded in the tree input data.

Please refer to the User's Guide to the Stand Prognosis Model (Wykoff *et al*. 1982, and Wykoff *et al*. 1991) for details on running the FVS Model, including how to set up keyword files and tree data files. The example above includes six lodgepole pine tree records with mistletoe infections ranging from DMR 1 to DMR 6. The labels are based on the TREEFMT (treeformat) codes shown in Exhibit 3.2 below.

3.2 Using Keywords to Tailor the Model to Your Application

With keywords, you can alter the level of impact dwarf mistletoe will have upon a tree, alter the form and presence of statistical output tables, or tell the model to ignore the effects of dwarf mistletoe altogether.

Even though the DMIM system will run from FVS automatically without the help of any mistletoe keywords, sometimes it is necessary to modify the functionality of the mistletoe model to tailor it to your own personal applications. This is where the dwarf mistletoe impact model keywords will come into play. Mistletoe keywords can be used to alter the behavior of processes such as mistletoe spread and intensification, growth modification, and mortality rates. They can also be used to alter cutting preference to remove mistletoe-infected trees, to switch on or off the printing of mistletoe statistical output tables, change the destination of mistletoe statistical output tables, introduce mistletoe infections into a stand, and indicate whether or not to ignore the effects of dwarf mistletoe altogether.

These options will be covered in more detail in the following sections that describe the individual keywords, including definitions, valid input ranges, default values, variant and species-specific options, and examples of each. Mistletoe keywords and their subsequent input values must be included in the same file as other FVS keywords and are set apart from other FVS keywords with the use of the MISTOE and END keywords. Most mistletoe keywords begin with either the letters MIST or DM. Each keyword requires a line of its own in the FVS keyword file. The keyword itself must be the first item on the line (blank filled up to 10 spaces). It may be followed by 0 to 7 fields, where each field is also 10 spaces long and is right-justified in the field. The keywords that allow subsequent lines of input in the keyword file will be noted as such.

Exhibit 3.2 is an example of a FVS keyword file, including a block of mistletoe keywords.

```
STDIDENT
2404-0
DESIGN         0       1    99.9      16
STDINFO      601     999      60       0       1      51      47
INVYEAR     1980
BAMAX                                         587
TREEFMT
(T16,I4,T70,I1,T25,F5.1,I2,T34,A3,F3.1,F2.1,
T45,F3.0,T70,F3.0,T70,F3.1,T48,I1,6I2,I3,T70,I1,T58,I1)
NUMCYCLE
MISTOE
MISTPREF    1980       7       4
MISTPREF    2000       7       0
MISTMULT    1990      10     1.5       1
MISTMULT    2010      10       1       1
MISTMORT    2040       7     1.8
MISTMORT    2050       7       1
MISTGMOD    2040       7     .75
MISTGMOD    2050       7       1
MISTPINF    2000       4     .50       2       0
MISTPINF    2000       7     .25       4       0
MISTPRT     2080       1
MISTPRT     2100       0
MISTFILE       1       1
dm_species.out dm_stand.out
dm_dbh.ou
dm_spec_dbh.out dm_nul.out
MISTABLE    1990      4
MISTABLE    1990      7
MISTABLE    2000      4
MISTABLE    2000      7
MISTABLE    2010      4
MISTABLE    2010       7
END
PROCESS
STOP
```

Exhibit 3.2 An example of an FVS keyword file, including a block of mistletoe keywords.

Please refer to the *User's Guide to the Stand Prognosis Model* (Wykoff *et al.* 1982) for more information on setting up and executing FVS keyword files. The example above includes a block of mistletoe keywords beginning with the MISTOE keyword and ending with the END keyword.

3.2 Using Keywords to Tailor the Model to Your Application

3.2.1 Using the MISTOE/END Keywords

The MISTOE/END keywords signal the FVS keyword reader that dwarf mistletoe keywords are present.

These keywords signal that mistletoe extension keywords are present. Mistletoe extension keywords can be used to alter embedded mistletoe spread and intensification, growth modification, and mortality rates. They are also used to alter cutting preference to remove mistletoe-infected trees, switch on and off the printing of mistletoe output tables, alter the destination of mistletoe output tables, introduce mistletoe infections in a stand, and indicate whether or not to ignore the effects of mistletoe altogether.

The MISTOE/END keywords do not have any associated fields.

Note: The mistletoe extension keyword sequence *must* begin with the MISTOE keyword and end with the END keyword. All keywords contained within this sequence are considered mistletoe keywords. In total, the valid mistletoe keywords are:

MISTOE/END	DMCRTHRD
COMMENT/END	DMOPAQ
MISTOFF	DMOPQMLT
MISTPREF	DMLIGHT
MISTGMOD	DMDEATH
MISTMULT	DMFLOWER
MISTMORT	DMCAP
MISTABLE	DMCLUMP
MISTFILE	DMAUTO
MISTPRT	DMSED
MISTPINF	DMKTUNE
NEWSPRED	DMETUNE
	DMITUNE
	DMSTUNE

Exhibit 3.3 is an example of a MISTOE keyword segment.

```
MISTOE
MISTPREF        1980         7         4
MISTPREF        2000         7         0
MISTMULT        1990        10       1.5         1
MISTMULT        2010        10         1         1
MISTMORT        2040         7       1.8
MISTMORT        2050         7         1
MISTGMOD        2040         7       .75
MISTGMOD        2050         7         1
MISTPINF        2000         4       .50         2         0
MISTPINF        2000         7       .25         4         0
MISTPRT         2080         1
MISTPRT         2100         0
MISTFILE           1         1
dm_species.out
dm_stand.out
dm_dbh.out
dm_spec_dbh.out
dm_nul.out
MISTABLE        1990         4
MISTABLE        1990         7
MISTABLE        2000         4
MISTABLE        2000         7
MISTABLE        2010         4
MISTABLE        2010         7
END
```

Exhibit 3.3 An example of a MISTOE keyword segment.

The MISTOE keyword is used in this example to signal that all keywords following will be mistletoe-related, until an END keyword is encountered.

3.2 Using Keywords to Tailor the Model to Your Application

3.2.2 Using the MISTOFF Keyword

Use this keyword to tell the model whether or not to ignore all effects of dwarf mistletoe.

This keyword tells FVS and the DMIM system to ignore all effects of dwarf mistletoe, whether or not any are present in the stand (i.e. run as if the stand is not infected). The MISTOFF keyword is only validbetween a MISTOE and an END keyword. Only one MISTOFF keyword may be used per sequence.

The MISTOFF keyword does not have any associated fields.

The model defaults to processing with the effects of dwarf mistletoe in the absence of this keyword, when there is at least one tree record with a mistletoe infection. MISTOFF does not override other keywords: it only ignores the effects of mistletoe infections in the initial stand data. You may use this keyword to remove the effects of mistletoe from a stand without having to edit (sometimes) large numbers of FVS tree data input records. The model continues to function, and new infections may be introduced with the MISTPINF keyword.

Exhibit 3.4 is an example of a MISTOFF keyword segment.

```
MISTOE
MISTOFF
END
```

Exhibit 3.4 An example of a MISTOFF keyword segment.

In this example, all effects of dwarf mistletoe are turned off for this run of FVS, even if mistletoe infections are present in the tree data input file.

3.2 Using Keywords to Tailor the Model to Your Application

3.2.3 Using the MISTPREF Keyword

The MISTPREF keyword is used to alter the removal preference of dwarf mistletoe-infected trees.

This keyword adds removal preference values based on DMR to previously computed values based on other factors, tree-by-tree, before certain thinning keywords (THINABA, THINATA, THINBBA, THINBTA) are applied. These other factors include species, tree condition, and DBH. Once an overall preference for each tree is computed, trees with the highest preference values are cut first, until cutting targets are reached. This keyword does not affect the use of the THINBH keyword (see the *Users Guide to the Stand Prognosis Model*). This keyword is only valid between a MISTOE and END keyword. More than one MISTPREF keyword may be used per sequence.

field 1: Date (calendar year or cycle number) in which removal preference change is implemented. The change remains in effect until replaced by a subsequent preference change. Range: 4-digit calendar year or 0 to 40 for cycle number. A "0" will cause the activity to be performed in every cycle.

field 2: Species abbreviation or number whose removal preference is to be changed.

Fields 3-7 are not used.

Required Supplemental Record: Preference values for DMR 1, DMR 2, and so on, through DMR 6. Format: Six numeric values are required starting in any column and separated by blanks. Range: none.

Defaults by fields:

Variant	1	2	3	4	5	6	7
All Variants	all	*	not used	not used	not used	not used	not used

* Field 2 requires a valid 2-character species code; a valid numeric code, 1-39; or a "0"; which will default to all species in the variant, listed in Exhibit 3.5.

Variant	Affected by Mistletoe	Not Affected by Mistletoe
Inland Emire, KooKan Tl	L,DF,LP,PP	WH,C,S,WP,GF,AF,MH
SORNEC	WP,SP,DF,WF,LP,AF,PP	IC,ES,J
Urah	WB,LM,DF,WF,LP,AF,PP	AS,ES
Teton	WB,LM,DF,LP,AF	AS,ES
SE Alaska	SF,MH,WH,LP,AF	WS,RC,YC,SS,HD
Eastern Montana	WB,DF,LP	WH,C,S,PP,WL,GF,AF
WESSIN	SP,DF,WF,JP,RF,PP	OC,GS,JC,BO,TO
Blue Mountains	WL,DF,LP,PP	MH,ES,WP,GF,AF
East Cascades	WP,WL,DF,SF,GF,LP,AF,PP	RC,ES
Central Idaho	WP,WL,DF,GF,LP,AF,PP	WH,RC,ES
Klamath Mountains	SP,DF,WF,RF,PP	OC,M,JC,BO,TO,OH
CR-SW Mixed Conifer	DF,BS,ES,PP	WP,OS,WF,OH,AS,AF,PJ
CR-SW Ponderosa Pine	DF,BS,PP	WP,OS,WF,OH,AS,OA,,P,J
CR-SW Black Hills	LP	CW,OS,DF,OH,AS,WS,PP,JJ
CR-Spruse-Fir	DF,LP	OS,OH,AS,ES,AF
CR-Lodgepole Pine	DF,LP	OS,OH,AS,ES,AF,PP
West Cascades	AF,RF,LP,DF,WH,MH	all others

Exhibit 3.5 Species defaults by variant.

Exhibit 3.6 is an example of a MISTPREF keyword segment.

```
MISTOE
MISTPREF        1980        7
     0    0    0    4000  5000  6000
MISTPREF        1990        3
     0    0    0    0     0     6000
MISTPREF        2000        ALL
     0    0    0    0     0     0
END
```

Exhibit 3.6 An example of a MISTPREF keyword segment.

In this example, beginning in 1980, trees of species 7 will be removed by cutting trees with DMR 6 first, DMR 5 next, and then DMR 4. Trees with DMRs of 3 or less will be cut last, and differences in DMR will not affect the cutting preferences of these trees.

In the year 1990, trees of species 3 with DMR=6 will have very high preferences. This would be combined with a reduced cutting efficiency (using, for example, a value of 0.50 in a THINABA or THINATA keyword, so that some DMR 6 trees would be retained for special wildlife habitat.

In the year 2000, the cutting preference for all species will be set back to 0, meaning that there will be no removal preference due to mistletoe from the year 2000 on.

3.2 Using Keywords to Tailor the Model to Your Application

3.2.4 Using the MISTGMOD Keyword

The MISTGMOD keyword is used to alter the existing effects of dwarf mistletoe on diameter growth.

This keyword provides diameter growth modification values by DMR classes. Diameter growth modifiers are real number values representing proportional loss of diameter growth due to mistletoe infection based on the intensity of the infection for that tree. This keyword is only valid between a MISTOE and an END keyword. More than one MISTGMOD keyword may be used per sequence.

field 1: Date (calendar year or cycle number) in which diameter growth proportions are applied. The proportions remain in effect until replaced by subsequent proportions. Range: 4-digit calendar year or 0 to 40 for cycle number. A "0" will cause the activity to be performed in every cycle.

field 2: Species abbreviation or number to which proportions are applied.

Fields 3-7 are not used.

Supplemental Record:

Diameter growth modification proportions by DMR for the cycle and species listed above. Format: Six real numbers are required, starting in any column and separated by blanks, the first for DMR = 1, the second for DMR = 2, and so on. Range: 0.0 to 1.0; a value near 0.0 causes extreme diameter growth impact and a value of 1.0 causes no diameter growth impact.

Defaults by fields:

Variant	1	2	3	4	5	6	7
All variants	all	*	not used	not used	not used	not used	not used

* Field 2 requires a valid 2-character species code; a valid numeric code, 1-39; or a "0", which will default to all species in the variant, listed in Exhibit 3.7.

Variant	Affected by Mistletoe	Not Affected by Mistletoe
Inland Empire, KooKanTL	L,DF,LP,PP	WH,C,S,WP,GF,AF,MH
SORNEC	WP,SP,DF,WF,MH,LP,RF,PP	IC,ES,J
Utah	WB,LM,DF,WF,LP,AF,PP	AS,ES
Teton	WB,LM,DF,LP,AF	AS,ES
SE Alaska	SF,MH,WH,LP,AF	WS,RC,YC,SS,HD
Eastern Montana	WB,DF,LP	WH,C,S,PP,WL,GF,AF
WESSIN	SP,DF,WF,JP,RF,PP	OC,GS,IC,BO,TO
Blue Mountains	WL,DF,LP,PP	MH,ES,WP,GF,AF
East Cascades	WP,WL,DF,SF,GF,LP,AF,PP	RC,ES
Central Idaho	WP,WL,DF,GF,LP,AF,PP	WH,RC,ES
Klamath Mountains	SP,DF,WF,RF,PP	OC,M,IC,BO,TO,OH
CR-SW Mixed Conifer	DF,BS,ES,PP	WP,OS,WF,OH,AS,AF,PJ
CR-SW Ponderosa Pine	DF,BS,PP	WP,OS,WF,OH,AS,WS,PP,J
CR-Black Hills	LP	CW,OS,DF,OH,AS,WS,PP,J
CR-Spruce-Fir	DF,LP	OS,OH,AS,ES,AF
CR-Lodgepole Pine	DF,LP	OS,OH,AS,ES,AF,PP
West Cascades	AF,RF,LP,DF,WH,MH	all others

Exhibit 3.7 Species Defaults by Variant.

Exhibit 3.8 is an example of a `MISTGMOD` keyword segment.

```
MISTOE
MISTGMOD         1990          7
1.0  1.0  1.0  .83  .65  .49
MISTGMOD         2080          7
END
```

Exhibit 3.8 An example of a `MISTGMOD` keyword segment.

In this example, beginning in 1990 until 2080, trees of species 7 with a DMR of 6 will have only 49 percent of normal diameter growth due to mistletoe infection. The same species with a DMR of 5 will have 65 percent of normal growth, and DMR 4 trees will have 83 percent of normal diameter growth. After the year 2080, diameter growth modification due to mistletoe will return to normal for that species, i.e., the values programmed in the model).

3.2 Using Keywords to Tailor the Model to Your Application

3.2.5 Using the MISTMULT Keyword

The MISTMULT keyword is used to alter existing mistletoe spread and intensification probabilities for the nonspatial spread and intensification model.

This keyword provides multipliers that can be used to alter the default rate of dwarf mistletoe spread and intensification through a stand. This keyword is only valid between a MISTOE and an END keyword, and is applied only to the nonspatial model (the DM-TUNE group of keywords modifies spread rate for the spatial model). More than one MISTMULT keyword may be used per sequence.

field 1: Date (calendar year or cycle number) in which multipliers are applied. A multiplier remains in effect until replaced by a subsequent multiplier. Range: 4-digit calendar year or 0 to 40 for cycle number. A "0" will cause the activity to be performed in every cycle.

field 2: Species abbreviation or number to which multiplier is applied.

field 3: Multiplier for changing the probability of DMR increasing. A value greater than 1 will increase this probability, and a value of less than 1 will decrease this probability. Range: greater than 0.

field 4: Multiplier for changing the probability of DMR decreasing value greater than 1 will increase this probability, and less than 1 will decrease this probability. Range: greater than 0.

Fields 5-7 are not used.

Defaults by fields:

Variants	1	2	3	4	5	6	7
All Variants	all	*	1	1	not used	not used	not used

* Field 2 requires a valid 2-character species code; a valid numeric code, 1-39; or a "0", which will default to all species in the variant, listed in Exhibit 3.9.

Variant	Affected by Mistletoe	Not Affected by Mistletoe
Inland Empire, KooKan TL	L,DF,LP,PP	WH,C,S,WP,GF,AF,MH
SORNEC	WP,SP,DF,WF,MH,LP,RF,PP	IC,ES,J
Utah	WB,LM,DF,WF,LP,AF,PP	AS,ES
Teton	WB,LM,DF,LP,AF	AS,ES
SE Alaska	SF,MH,WH,LP,AF	WS,RC,YC,SS,HD
Eastern Montana	WB,DF,LP	WH,C,S,PP,WL,GF,AF
WESSIN	SP,DF,WF,JP,RF,PP	OC,GS,IC,BO,TO
Blue Mountains	WL,DF,LP,PP	MH,ES,WP,GF,AF
East Cascades	WP,WL,DF,SF,GF,LP,AF,PP	RC,ES
Central Idaho	WP,WL,DF,GF,LP,AF,PP	WH,RC,ES
Klamath Mountains	SP,DF,WF,RF,PP	OC,M,IC,BO,TO,OH
CR-SW Mixed Conifer	DF,BS,ES,PP	WP,OS,WF,OH,AS,AF,PJ
CR-SW Ponderosa Pine	DF,BS,PP	WP,OS,WF,OH,AS,OA,P,J
CR-Black Hills	LP	CW,OS,DF,OH,AS,WS,PP,J
CR-Spruce-Fir	DF,LP	OS,OH,AS,ES,AF
CR-Lodgepole Pine	DF,LP	OS,OH,AS,ES,AF,PP
West Cascades	AF,RF,LP,DF,WH,MH	all others

Exhibit 3.9 Species defaults by variant.

Exhibit 3.10 is an example of a MISTMULT keyword segment.

```
MISTOE
MISTMULT        1990        7        2.0        0.5
MISTMULT        1990       10        0.5        2.0
MISTMULT        2080        7          1          1
MISTMULT        2080       10          1          1
END
```

Exhibit 3.10 An example of a MISTMULT keyword segment.

In this example, the probability of a DMR increase will be multiplied by a factor of 2 for species 7 for all cycles between 1990 and 2080, while the probability of a DMR decrease will be lowered by a factor of 0.5. For species 10, the probability of a DMR increase will drop by a factor of 0.5 and probability of a DMR decrease will be multiplied by a factor of 2 during this same interval. From the year 2080 on, the probability of DMR increase and decrease for both species will return to normal.

3.2 Using Keywords to Tailor the Model to Your Application

3.2.6 Using the MISTMORT Keyword

The MISTMORT keyword is used to alter the existing percentage of mortality on a tree record due to dwarf mistletoe infection.

This keyword provides a multiplier used to alter mistletoe mortality. This keyword is only valid between a MISTOE and an END keyword. More than one MISTMORT keyword may be used per sequence.

field 1: Date (calendar year or cycle number) in which multipliers are applied. A multiplier remains in effect until replaced by a subsequent multiplier. Range: 4-digit calendar year or 0 to 40 for cycle number. A "0" will cause the activity to be performed in every cycle.

field 2: Species abbreviation or number to which multiplier is applied.

field 3: Multiplier for changing mistletoe mortality; greater than 1 will increase mortality rate, and less than 1 will decrease mortality rate. Range: greater than 0.

Fields 4-7 are not used.

Defaults by fields:

Variant	**1**	**2**	**3**	**4**	**5**	**6**	**7**
All variants	all	*	1	not used	not used	not used	not used

* Field 2 requires a valid 2-character species code; a valid numeric code, 1-39; or a "0" , which will default to all species in the variant, listed in Exhibit 3.11.

Variant	Affected by Mistletoe	Not Affected by Mistletoe
Inland Empire, KooKan TL	L,DF,LP,PP	WH,C,S,WP,GF,AF,MH
SORNEC	WP,SP,DF,WF,MH,LP,RF,PP	IC,ES,J
Utah	WB,LM,DF,WF,LP,AF,PP	AS,ES
Teton	WB,LM,DF,LP,AF	AS,ES
SE Alaska	SF,MH,WH,LP,AF	WS,RC,YC,SS,HD
Eastern Montana	WB,DF,LP	WH,C,S,PP,WL,GF,AF
WESSIN	SP,DF,WF,JP,RF,PP	OC,GS,IC,BO,TO
Blue Mountains	WL,DF,LP,PP	MH,ES,WP,GF,AF
East Cascades	WP,WL,DF,SF,GF,LP,AF,PP	RC,ES
Central Idaho	WP,WL,DF,GF,LP,AF,PP	WH,RC,ES
Klamath Mountains	SP,DF,WF,RF,PP	OC,M,IC,BO,TO,OH
CR-SW Mixed Conifer	DF,BS,ES,PP	WP,OS,WF,OH,AS,AF,PJ
CR-SW Ponderosa Pine	DF,BS,PP	WP,OS,WF,OH,AS,OA,P,J
CR-Black Hills	LP	CW,OS,DF,OH,AS,WS,PP,J
CR-Spruce-Fir	DF,LP	OS,OH,AS,ES,AF
CR-Lodgepole Pine	DF,LP	OS,OH,AS,ES,AF,PP
West Cascades	AF,RF,LP,DF,WH,MH	all others

Exhibit 3.11 Species defaults by variant.

Exhibit 3.12 is an example of a `MISTMORT` keyword segment.

```
MISTOE
MISTMORT        1990                1.5
MISTMORT        2000                1.0
MISTMORT        2080        10     1.25
END
```

Exhibit 3.12 An example of a `MISTMORT` keyword segment.

In this example, mistletoe mortality will be 1.5 times larger than normal in cycle 1990 for all species affected by mistletoe in the current variant. If the variant is SORNEC, for example, this would affect these eight species: WP, SP, DF, WF, MH, LP, RF, and PP. Mistletoe mortality will then return to normal for all these species from the year 2000 on, except for species 10 (which in SORNEC is PP: ponderosa pine) which will have mistletoe mortality increased 1.25 times from cycle 2080 through the last cycle.

3.2 Using Keywords to Tailor the Model to Your Application

3.2.7 Using the MISTABLE Keyword

The MISTABLE keyword is used to produce the detailed species/DBH (diameter breast height) class and detailed treelist statistical output tables which are not produced automatically.

Use this keyword to produce detailed mistletoe output tables stratified by species and DBH-class, for a particular year or cycle. This keyword is only valid between a MISTOE and an END keyword. More than one MISTABLE keyword may be used per sequence. If the spatial spread and intensification model is in use (see the NEWSPRED keyword), detailed infection information can be produced for the entire treelist. This keyword works in conjunction with the MISTFILE keyword

field 1: Date (calendar year or cycle number) in which to print detail taken. The tables will be pointed in this cycle only (does not carry over to subsequent cycles). Range: 4-digit calendar year or 0 to 40 for cycle number. A "0" will cause the activity to be performed in every cycle.

field 2: If the nonspatial model is in use, a valid species abbreviation or number for which the DBH class detail table is desired. If the spatial spread and intensification option is used, this field is ignored.

field 3: If the spatial spread and intensification option is used, a 1 in this field indicates that detailed treelist output is required. This detailed output is directed to the fifth output file, or the filename listed under the MISTFILE keyword. If the nonspatial spread and intensification is used, this field is ignored.

Fields 4-7 are not used.

Defaults by fields:

Variant	1	2	3	4	5	6	7
All variants	1	*	0	not used	not used	not used	not used

* When the nonspatial option is used, field 2 requires a valid 2-character species code; a valid numeric code, 1-39; or a "0", which will default to all species in the variant, listed in Exhibit 3.13.

Variant	Affected by Mistletoe	Not Affected by Mistletoe
Inland Empire, KooKan TL	L,DF,LP,PP	WH,C,S,WP,GF,AF,MH
SORNEC	WP,SP,DF,WF,MH,LP,RF,PP	IC,ES,J
Utah	WB,LM,DF,WF,LP,AF,PP	AS,ES
Teton	WB,LM,DF,LP,AF	AS,ES
SE Alaska	SF,MH,WH,LP,AF	WS,RC,YC,SS,HD
Eastern Montana	WB,DF,LP	WH,C,S,PP,WL,GF,AF
WESSIN	SP,DF,WF,JP,RF,PP	OC,GS,IC,BO,TO
Blue Mountains	WL,DF,LP,PP	MH,ES,WP,GF,AF
East Cascades	WP,WL,DF,SF,GF,LP,AF,PP	RC,ES
Central Idaho	WP,WL,DF,GF,LP,AF,PP	WH,RC,ES
Klamath Mountains	SP,DF,WF,RF,PP	OC,M,IC,BO,TO,OH
CR-SW Mixed Conifer	DF,BS,ES,PP	WP,OS,WF,OH,AS,AF,PJ
CR-SW Ponderosa Pine	DF,BS,PP	WP,OS,WF,OH,AS,OA,P,J
CR-Black Hills	LP	CW,OS,DF,OH,AS,WS,PP,J
CR-Spruce-Fir	DF,LP	OS,OH,AS,ES,AF
CR-Lodgepole Pine	DF,LP	OS,OH,AS,ES,AF,PP
West Cascades	AF,RF,LP,DF,WH,MH	all others

Exhibit 3.13 Species defaults by variant.

Exhibit 3.14 is an example of a `MISTABLE` keyword segment.

```
MISTOE
MISTABLE        1990        4
MISTABLE        1990        7
MISTABLE        1990       10
MISTABLE        2080
END
```

Exhibit 3.14 An example of a `MISTABLE` keyword segment.

In this example, in cycle 1990, mistletoe species/DBH class detail tables will be generated for species 4, 7, and 10. Then, in cycle 2080, the mistletoe species/DBH class tables will be generated for all species affected by mistletoe for the current variant. If the variant is SORNEC, for example, then there will be a table generated in this cycle for each of the following species: WP, SP, DF, WF, MH, LP, RF, and PP.

3.2 Using Keywords to Tailor the Model to Your Application

3.2.8 Using the MISTFILE Keyword

The MISTFILE keyword is used to route dwarf mistletoe statistical output tables to permanent system files.

Use this keyword to tell the model whether or not to write mistletoe output statistics tables to permanent files. This keyword is only valid between a MISTOE and an END keyword. Only one MISTFILE keyword may be used per sequence.

field 1: Filename preference. A 0 or a blank means use the default filenames. Anything else means the user will supply five filenames in supplemental records following this key word.

field 2: Heading preference. A 0 or a blank means omit the headings from the data files. Anything else means include headings.

Fields 3-7 are not used.

Defaults by fields:

Variants	1	2	3	4	5	6	7
All Variants	0	0	not used	not used	not used	not used	not used

The default filenames are:

DM1.OUT species-specific summary data
DM2.OUT stand average summary data
DM3.OUT DBH class summary data
DM4.OUT detailed species/DBH class data
DM5.OUT detailed treelist output similar to the format used by the TREELIST keyword of the base model. This includes the absolute tree ID, the number of stems per acre, DBH, DMR and height. For each crown third it gives height information, spread and intensification inputs; and immature, latent and active pool sizes. This table is available with the spatial model only.

If filenames are to be supplied in supplemental records, you must enter five names, one per line, up to 80 characters each (possibly including a path name). Unlike the summary tables (see the MISTABLE keyword), species/DBH class detail tables and treelist detail tables are not automatically produced.

Exhibit 3.15 is an example of a MISTFILE keyword segment.

```
MISTOE
MISTPRT
MISTFILE           1         1
dm_species.out
dm_stand.out
dm_dbh.out
dm_sp_dbh.out
dm_nul.out
MISTABLE        2000
END
```

Exhibit 3.15 An example of a MISTFILE keyword segment.

In this example, the mistletoe statistical output tables will be printed, with headings, to the separate Data General files listed instead of the default file names. Note that the MISTPRT keyword was included: nothing will be written to the first three Data General files unless a MISTPRT keyword is used. Note also that the MISTABLE keyword was included in this example: nothing will be written to the fourth Data General file unless a MISTABLE keyword is used to generate the detail table information. Finally, note that a `dummy' filename is used for the fifth output file. Since the nonspatial spread and intensification model is being used in this example, no detailed treelist output is available.

3.2 Using Keywords to Tailor the Model to Your Application

3.2.9 Using the MISTPRT Keyword

The MISTPRT keyword tells the DMIM system whether or not to print dwarf mistletoe statistical output tables.

Use this keyword to tell the model to print of mistletoe output statistics tables. This keyword is only valid between a MISTOE and an END keyword. Only one MISTPRT keyword may be used per sequence.

If the keyword is present, three summary tables (stand totals, species specific, and DBH class) will be printed. If it is not present, these three tables will not be printed. Note that the MISTABLE keyword requests separate detail tables (species/DBH class and treelist) be printed. The MISTFILE keyword routes files requested by MISTPRT and MISTABLE to Data General system files.

field 1: Threshold DBH in inches for trees to be counted in DMI/DMR statistics. Smaller trees will be treated as if they contain no mistletoe. Range: greater than or equal to 0.

Fields 2-7 are not used.

Defaults by fields:

Variant	1	2	3	4	5	6	7
All variants	0	not used	not used	not used	not used	not used	not used

Exhibit 3.16 is an example of a MISTPRT keyword segment.

```
MISTOE
MISTPRT            1.0
END
```

Exhibit 3.16 An example of a MISTPRT keyword segment.

In this example, the three mistletoe statistical output summary tables will be printed. Dwarf mistletoe in trees with DBH less than 1.0 inches will be ignored. DMI and DMR ratings in the statistical output tables will reflect only trees with DBH greater than or equal to 1.0 inches.

3.2 Using Keywords to Tailor the Model to Your Application

3.2.10 Using the MISTPINF Keyword

The MISTPINF keyword is used to automatically introduce mistletoe infections into a proportion of trees in a stand.

Use this keyword to automatically introduce dwarf mistletoe infections to a proportion of trees in the stand (based on individual species in the stand) that were not already infected. This keyword is only valid between a MISTOE and an END keyword. More than one MISTPINF keyword may be used per sequence.

field 1: Date (calendar year or cycle number) in which infections are to be introduced. The infection will happen in this cycle only (does not carry over to subsequent cycles). Range: 4-digit calendar year or 0 to 40 for cycle number. A "0" will cause the activity to be performed in every cycle.

field 2: Species abbreviation or number to be infected.

field 3: Proportion of that species to be infected (not including already infected trees). Range: 0.0 to 1.0.

field 4: Level of infection for that species:

1 = all selected trees will start with DMR 1
2 = all selected trees will start with DMR 1 or 2
...
6 = all selected trees will start with DMR 1, 2, 3, 4, 5, or 6

field 5: Method of infection for the stand:

0 = random infection throughout the species
1 = infection assigned beginning with the tallest and moving to the shortest trees
2 = infection assigned beginning with the shortest and moving to the tallest trees.

Fields 6-7 are not used.

Defaults by fields:

Variant	1	2	3	4	5	6	7
All variants	all	*	0	1	0	not used	not used

* Field 2 requires a valid 2-character species code; a valid numeric code, 1-39; or a "0", which will default to all species in the variant, listed in Exhibit 3.17

Variant	Affected by Mistletoe	Not Affected by Mistletoe
Inland Empire, KooKan TL	L,DF,LP,PP	WH,C,S,WP,GF,AF,MH
SORNEC	WP,SP,DF,WF,MH,LP,RF,PP	IC,ES,J
Utah	WB,LM,DF,WF,LP,AF,PP	AS,ES
Teton	WB,LM,DF,LP,AF	AS,ES
SE Alaska	SF,MH,WH,LP,AF	WS,RC,YC,SS,HD
Eastern Montana	WB,DF,LP	WH,C,S,PP,WL,GF,AF
WESSIN	SP,DF,WF,JP,RF,PP	OC,GS,IC,BO,TO
Blue Mountains	WL,DF,LP,PP	MH,ES,WP,GF,AF
East Cascades	WP,WL,DF,SF,GF,LP,AF,PP	RC,ES
Central Idaho	WP,WL,DF,GF,LP,AF,PP	WH,RC,ES
Klamath Mountains	SP,DF,WF,RF,PP	OC,M,IC,BO,TO,OH
CR-SW Mixed Conifer	DF,BS,ES,PP	WP,OS,WF,OH,AS,AF,PJ
CR-SW Ponderosa Pine	DF,BS,PP	WP,OS,WF,OH,AS,OA,P,J
CR-Black Hills	LP	CW,OS,DF,OH,AS,WS,PP,J
CR-Spruce-Fir	DF,LP	OS,OH,AS,ES,AF
CR-Lodgepole Pine	DF,LP	OS,OH,AS,ES,AF,PP
West Cascades	AF,RF,LP,DF,WH,MH	all others

Exhibit 3.17 Species defaults by variant.

If more than one MISTPINF keyword is to be used with different species in the same cycle, then the same method of infection must appear on each keyword for that cycle or it will default to the first method encountered. In other words, if species 7 is to be infected from tallest to shortest in the first cycle, then species 10 must also be infected from tallest to shortest in the first cycle. This is because method of infection requires that the entire treelist be sorted in a certain manner (either by height or randomly) so it cannot be done a different way for each species in the same cycle.

Exhibit 3.18 shows an example of a MISTPINF keyword segment.

```
MISTOE
MISTPINF        1990        7       .50       2       0
MISTPINF        1990       10       .25       4       0
MISTPINF        2000        4       .25       3       1
MISTPINF        2000        5       .10       6       1
END
```

Exhibit 3.18 An example of a MISTPINF keyword segment.

In this example, in the year 1990, 50% of the total number of not-yet-infected trees of species 7 will be infected randomly with DMRs of 1 and 2. In the same cycle, 25% of all uninfected trees of species 10 will be infected randomly with DMRs ranging from 1 to 4. Then, in the next cycle, 25% of uninfected species 4 trees will be infected with DMRs of 1, 2, or 3, starting with the tallest trees and moving toward the shortest trees of that species. Also in the year 2000, not-yet-infected species 5 trees will be infected with DMRs ranging from 1 to 6, starting with the tallest trees and moving toward the shortest trees until 10% of these are infected with mistletoe.

3.2 Using Keywords to Tailor the Model to Your Application

3.2.11 Using the NEWSPRED Keyword

The NEWSPRED keyword is used to select the method of spread and intensification that simulates the spatial relationship within crowns and between trees.

Use this keyword to switch from the default nonspatial simulation of spread and intensification to one which allows for the clumping of trees and infections. Only one NEWSPRED keyword should appear per sequence.

The NEWSPRED keyword does not have any associated fields.

Note: The keywords beginning with DM are valid only with the spatial spread and intensification model. The spatial spread and intensification model may also use any of the mistletoe model keywords listed previously in this chapter (all starting with MIST). Valid spatial spread and intensification model
keywords are:

```
COMMENT/END
DMCRTHRD
DMOPAQ
DMOPQMLT
DMLIGHT
DMDEATH
DMFLOWER
DMCAP
DMCLUMP
DMAUTO
DMSED
DMKTUNE
DMETUNE
DMSTUNE
DMITUNE
```

Exhibit 3.19 shows an example of a keyword segment containing NEWSPRED.

```
MISTOE
NEWSPRED
MISTABLE            2                   1
MISTPRT
DMAUTO              1       0.0       0.0
MISTFILE                      1
END
```

Exhibit 3.19 An example of a NEWSPRED keyword segment.

The NEWSPRED keyword is used in this example to switch from the default nonspatial spread and intensification model to the spatial model.

3.2 Using Keywords to Tailor the Model to Your Application

3.2.12 Using the DMCRTHRD Keyword

The DMCRTHRD keyword is used to alter the default assumptions about how dwarf mistletoe infections are initially located within tree canopies, when the spatial model of spread and intensification is in use.

At inventory, crown third mistletoe ratings are added together to give a whole-tree DMR score. Crown third scores are often not recorded in the final inventory. The spatial spread and intensification model needs to know the initial rating (0, 1 or 2) for *each crown third*, so that it can set up a vertical pattern of infection for each tree record. For scores in the DMR1 to DMR5 range, it may be hard to work backward and determine the crown third scores from the whole-tree score, since a given DMR can be produced from a variety of crown third scores. For example, a DMR3 tree could carry an infection that was top-heavy (2,1,0 counting top-to-bottom), bottom-heavy (0,1,2), or any other pattern that added up to three. This keyword allows users to change the default crown third pattern associated with *initial* DMR scores, to more realistically account for particular stand conditions. After the simulation begins, the model dynamically changes the amount of infection in the crown third of each tree, so this keyword only affects the starting values.

The DMCRTHRD keyword has no associated fields.

Supplemental Records:

> This keyword must be followed by five supplemental records. All five rows must be present: the first record changes the loading pattern associated with DMR1, the second changes DMR2, and so on. (DMR0 and DMR6 are all zeroes and all twos, respectively, and so are not required). On each line three columns with I10 format are used to change the default crown third DMR assignment, beginning with the upper crown third in the leftmost column. If the three fields on any line do not add up to the DMR for that line, an error occurs and the entire attempt to alter the default filling order is ignored.

The example below, Exhibit 3.20, shows the default, a "bottom first" filling order. Exhibit 3.21 shows some different possible filling orders.

```
MISTOE
NEWSPRED
DMCRTHRD
          0         0         1
          0         0         2
          0         1         2
          0         2         2
          1         2         2
 END
```

Exhibit 3.20 An example of a DMCRTHRD keyword segment.

Initial DMR	**Top First**	**Bottom First**	**Even**
0	0-0-0	0-0-0	0-0-0
1	1-0-0	0-0-1	0-0-1
2	2-0-0	0-0-2	1-0-1
3	2-1-0	0-1-2	1-1-1
4	2-2-0	0-2-2	1-1-2
5	2-2-1	1-2-2	2-1-2
6	2-2-2	2-2-2	2-2-2

Exhibit 3.21 Three possible crown-filling orders that could be described with the DMCRTHRD keyword. The "Bottom First" column is used in the example in Exhibit 3.20, and is the default.

One limitation of the DMIM system is that it applies the same filling rules to all infected trees based on their inventoried DMR. So although one record may be for one of the tallest trees in a stand, and another for a much smaller understorey tree, they will be assigned the same *initial* filling order. However, because the spatial mode is dynamic, initial wrong assumptions about the placement of dwarf mistletoe infections in the canopy, will tend to correct themselves.

3.2 Using Keywords to Tailor the Model to Your Application

3.2.13 Using the DMOPAQ Keyword

The DMOPAQ keyword is used to alter the default assumptions about the relative thickness of the canopy foliage of particular species, compared to ponderosa and lodgepole pine, when the spatial model of spread and intensification is in use.

Use this keyword to change the relative opacity (density) of foliage. Opacity is the ability of trees (crown foliage, branches and bole) to stop mistletoe seeds in flight: more open foliage will allow more seeds to pass through unintercepted, compared to the higher opacity foliage of another species. Because of uncertainties in the measurement of absolute values, opacity is expressed relative to ponderosa and lodgepole pine, which are assigned values of 1.This keyword is only valid between a MISTOE and an END keyword. More than one DMOPAQ keyword may be used per sequence.

field 1: A species abbreviation or number indicating the species for which the relative opacity is to be changed.

field 2: The relative opacity value. Range: greater than or equal to zero.

Fields 3-7 are not used.

Defaults by fields:

Variant	**1**	**2**	**3**	**4**	**5**	**6**	**7**
All variants	*	*	0	1	0	not used	not used

* Field 1 requires a valid 2-character species code; a valid numeric code, 1-39; or a "0", which will default to all species in the variant, listed in Exhibit 3.7. Field 2 default opacities are listed in Exhibit 3.23.

Exhibit 3.22 shows an example of a keyword segment containing DMOPAQ.

```
MISTOE
NEWSPRED
DMOPAQ            DF       1.1
DMOPAQ            GF       1.3
END
```

Exhibit 3.22 An example of a DMOPAQ keyword segment.

In this example douglas-fir threes are assigned an opacity value 1.1 times that of lodgepole pine. Grand fir trees are assigned a value 1.3 times that of lodgepole pine. There is not yet enough empirical data to describe the opacity of different tree species in absolute terms of "proportion extinction per meter." (The DMOPQMLT keyword describes how this may be done once this information becomes available.) However, it is possible to define relative opacity with more confidence. The table below shows these values relative to **lodgepole** and **ponderosa pine**, which are assigned a "standard" value of 1.0. Exhibit 3.23 shows the default relative opacities for all FVS variants. The keyword allows any species' relative value to be altered.

Code	Common Name	Relative Opacity
AF	subalpine fir	1.8
AS	aspen	2.0
BC	cherry	2.0
BO	black oak	2.0
BM	bigleaf maple	2.0
C	western red cedar	1.8
CO	cottonwood	2.0
DF	Douglas-fir	1.5
DG	western dogwood	2.0
ES	Englemann spruce	1.7
GC	giant chinkapin	2.0
GF	grand fir	1.8
GS	giant sequoia	2.0
HD	hardwood	2.0
HW	hawthorne	2.0
IC	incense cedar	1.8
J	juniper	2.0
JP	Jeffrey pine	1.0
KP	knobcone pine	1.0
L	western larch	0.9
LL	subalpine larch	0.9
LM	limber pine	1.2
LP	**lodgepole pine**	**1.0**
M	Pacific madrone	2.0
MH	mountain hemlock	2.0
NF	noble fir	1.8

Code	Common Name	Relative Opacity
OC	other conifer	2.0
OH	other hardwood	2.0
PB	paper birch	2.0
PP	**ponderosa pine**	**1.0**
PY	pacific yew	2.0
RA	red alder	2.0
RC	western red cedar	1.8
RF	red fir	1.8
RW	coastal redwood	2.0
S	Englemann spruce	1.7
SF	pacific silver fir	1.8
SP	sugar pine	1.2
SS	Sitka spruce	1.7
TO	tanoak	2.0
WA	white alder / white ash	2.0
WB	whitebark oak	1.2
WF	white fir	1.8
WH	western hemlock	2.0
WI	willow	2.0
WL	western larch	0.9
WO	white oak	2.0
WP	white pine	1.2
WS	white spruce	1.7
YC	Alaska cedar	1.8
--	"others"	2.0

Exhibit 3.23 Default values for relative opacities of all species found in variants.

3.2 Using Keywords to Tailor the Model to Your Application

3.2.14 Using the DMOPQMLT Keyword

The DMOPQMLT keyword is used to alter the default assumptions about the absolute thickness of the canopy foliage of ponderosa and lodgepole pine, benchmarks for other species, when the spatial model of spread and intensification is in use.

Use this keyword to change the absolute opacity (density) of the foliage of ponderosa and lodgepole pine. Changing the default value will alter the opacity of all species in a stand, since they are determined in relation to these species. This keyword is only valid between a MISTOE and an END keyword. Only one DMOPQMLT keyword should be used per sequence.

field 1: Absolute opacity value of the foliage of ponderosa and lodgepole pine. Range: greater than zero.

Fields 2-7 are not used.

Defaults by fields:

Variant	1	2	3	4	5	6	7
All variants	0.20	not used	not used	not used	not used	not used	not used

Exhibit 3.24 shows an example of a keyword segment containing DMOPQMLT.

```
MISTOE
NEWSPRED
DMOPQMLT        0.15
END
```

Exhibit 3.24 An example of a DMOPQMLT keyword segment.

The value used with the DMOPQMLT keyword has the units "proportion extinction per meter." In the example above, the default absolute opacity of lodgepole pine and ponderosa pine (0.2/meter) is changed to 0.15/meter. The opacity of any other species in the stand will also be reduced by 25%.

3.2 Using Keywords to Tailor the Model to Your Application

3.2.15 Using the DMLIGHT Keyword

When the spatial model of spread and intensification is in use, the DMLIGHT keyword is used define how light influences the transition from a latent to a flowering plant, and the suppression of flowering plants when light is diminished.

Light is one of two agents responsible for the emergence of mistletoe plants following seed germination. (Time is the other agent; see the DMFLOWER keyword.) Under conditions of high light, infections become reproductive after four years. Conversely, under low light conditions, new infections will not produce shoots and most flowering infections will lose their shoots and enter a suppressed condition. This keyword defines the functional relationships which drive the maturation of nonflowering infections into flowering plants when light is abundant, and which suppress their reproduction when light is diminished. This done by providing the DMIM system with the coordinates of forward and backward transition functions. The keyword segment in Exhibit 3.25 (graphs of the resulting functions are shown in Exhibit 3.26) alters both the *forward* and *backward* reactions for Species 3, and alters the backward reaction for species 10 only. The default forward reaction is shown for Species 10 in Exhibit 3.26. This keyword is only valid between a MISTOE and an END keyword. More than one DMLIGHT keyword can be used in a sequence.

field 1: Species abbreviation or number for which light levels are to be changed.

Fields 2-7 are not used.

Defaults by fields:

Variant	1	2	3	4	5	6	7
All variants	*	not used	not used	not used	not used	not used	not used

* Field 1 requires a valid 2-character species code or a valid numeric code, 1-39.

Required Supplemental Records:

Light levels are described with Supplemental Records, and are proportions between zero and one. When referring to light, a zero represents darkness and a one represents the available light at the top of the canopy. When referring to the proportion making a forward or backward transition, a zero means that no individuals will move in one year, and a one means that all the individuals in the life history category (see the last paragraph of Section 2.3.2) will move forward or backward in one year.

Up to four fields can be entered on each line, and up to four supplemental lines can be used. The first pair of fields describes a point on a graph of the forward transition function; the second pair of fields describes a point on the graph of the backward transition. Examples of these functions are shown below in Exhibits 3.25 and 3.26. The two pairs of fields are independent and either set can be left out, as the keyword example shows. If fewer than four lines are needed to describe the graph, then the entries must be ended with -999. Data pairs represent *x* and *y* values, where *x* is the proportion of light and *y* is the proportion of individual plants making a forward or backward transition. The points must be given in increasing order with respect to *x*, and both *x* and *y* values must lie within the 0.0 to 1.0 range. One of the default functions is shown below; they are simple graphs with slopes of +1.0 and -1.0 for the forward and backward functions, respectively. If the user-supplied data points do not include the zero and one *x* end points, the *y* values are assumed to be constant across the lower or upper interval, as shown below in the example backward reaction for Species 10. These examples are for illustration purposes only.

field 1: The *x* values for the forward transition function. These represent the proportion of available light, and must be sorted from smallest to largest and must be lie within the 0.0 to 1.0 range.

field 2: The *y* values for the forward transition function. These must be lie within the 0.0 to 1.0 range and correspond with the entries in Field 2. Typically these values will form an increasing sequence that represents the increase in the proportion of individuals moving from the Latent to Active population pool under high light conditions.

field 3: The *x* values for the backward transition function. These must be sorted from smallest to largest and must be lie within the 0.0 to 1.0 range. The meaning of the numbers is identical to Field 1.

field 4: The *y* values for the backward transition function. These must be lie within the 0.0 to 1.0 range and correspond with the entries in Field 3. Typically these values will form a decreasing sequence that represents the decrease in the proportion of individuals moving from the Active to Latent population under high light conditions.

The keywords below show an example of the syntax of `DMLIGHT`, and the resulting graphs in Exhibit 3.26 show how the model interprets the keyword and supplemental records for species 3 and species 10.

```
MISTOE
NEWSPRED
DMLIGHT           3
                 0.0       0.2       0.0       1.0
                 0.5       0.9       0.2       0.4
                 1.0       1.0       0.6       0.3
                                     1.0       0.1
DMLIGHT          10
                                     0.1       0.8
                                     0.2       0.4
                                     0.6       0.3
-999
END
```

Exhibit 3.25 An example of a `DMLIGHT` keyword segment.

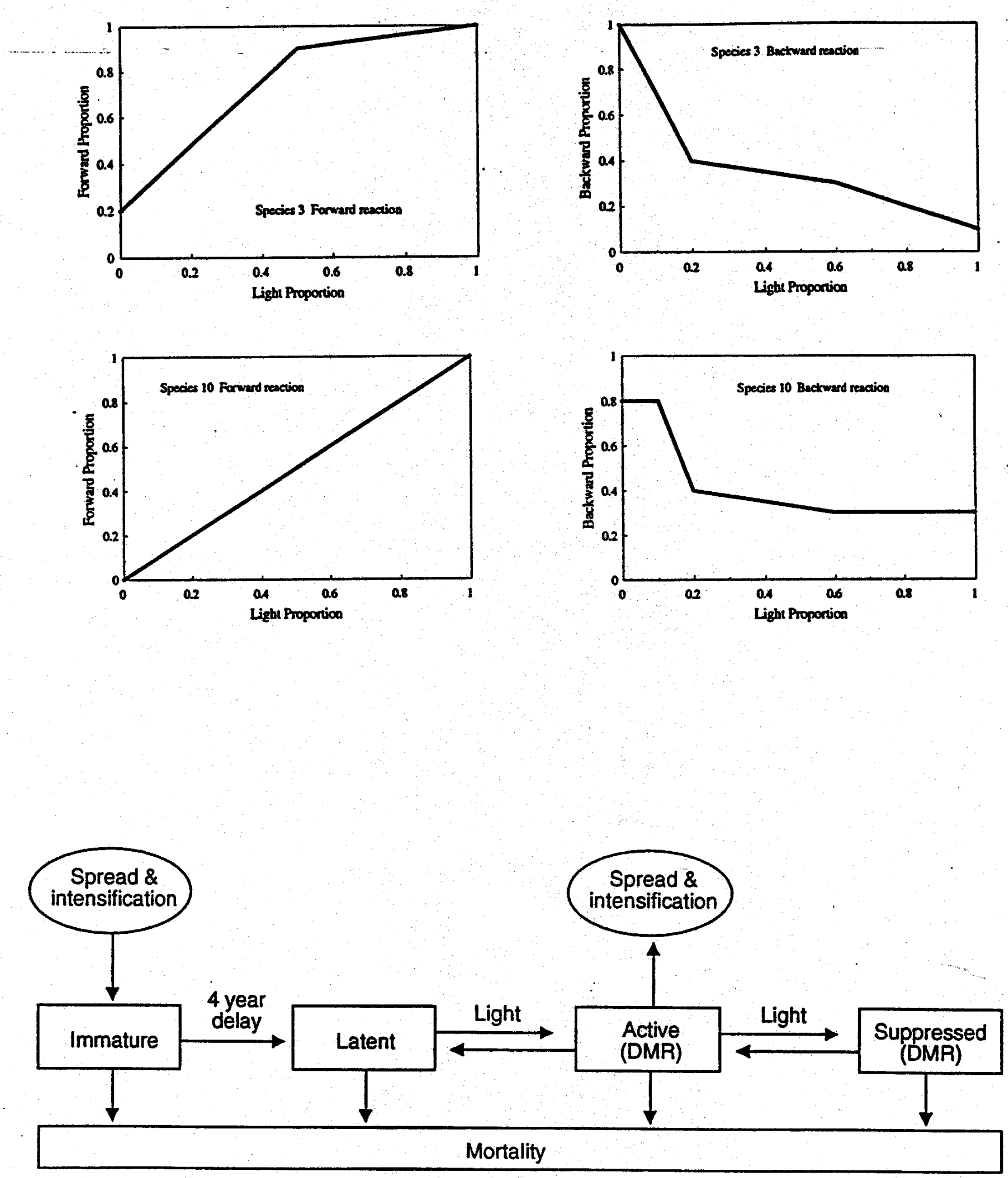

Exhibit 3.26 Examples showing how the model interprets the keyword examples for the forward and backward light reactions for species 3 and 10. The bottom panel shows how the light reactions are linked to the life history of dwarf mistletoe.

3.2 Using Keywords to Tailor the Model to Your Application

3.2.16 Using the DMDEATH Keyword

The DMDEATH keyword is used to define a death rate for mistletoe infections, independent of the death of trees or branches, when the spatial model of spread and intensification is in use.

Use this keyword to define the proportion of dwarf mistletoe infections dying within a year. This rate is applied to infections within all life stages: immature, latent, active and suppressed, and is distinct from losses due to lower crown senescence or tree death. This keyword is only valid between a MISTOE and an END keyword. More than one DMDEATH keyword can be used in a sequence, as shown in Exhibit 3.27.

field 1: Species abbreviation or number for which mistletoe infection death rate is to be changed.

field 2: A mistletoe infection mortality rate. Range: 0.0 to 1.0.

Fields 3-7 are not used.

Defaults by fields:

Variant	1	2	3	4	5	6	7
All variants	*	0.08	not used	not used	not used	not used	not used

* Field 1 requires a valid 2-characater species code; a valid numeric code, 1-39; or a "0", which will default to all species in the variant, listed in Exhibit 3.27.

Variant	Affected by Mistletoe	Not Affected by Mistletoe
Inland Empire, KooKan TL	L,DF,LP,PP	WH,C,S,WP,GF,AF,MH
SORNEC	WP,SP,DF,WF,MH,LP,RF,PP	IC,ES,J
Utah	WB,LM,DF,WF,LP,AF,PP	AS,ES
Teton	WB,LM,DF,LP,AF	AS,ES
SE Alaska	SF,MH,WH,LP,AF	WS,RC,YC,SS,HD
Eastern Montana	WB,DF,LP	WH,C,S,PP,WL,GF,AF
WESSIN	SP,DF,WF,JP,RF,PP	OC,GS,IC,BO,TO
Blue Mountains	WL,DF,LP,PP	MH,ES,WP,GF,AF
East Cascades	WP,WL,DF,SF,GF,LP,AF,PP	RC,ES
Central Idaho	WP,WL,DF,GF,LP,AF,PP	WH,RC,ES
Klamath Moutains	SP,DF,WF,RF,PP	OC,M,IC,BO,TO,OH
CR-SW Mixed Conifer	DF,BS,ES,PP	WP,OS,WF,OH,AS,AF,PJ
CR-SW Ponderosa Pine	DF,BS,PP	WP,OS,WF,OH,AS,OA,P,J
CR-Black Hills	LP	CW,OS,DF,OH,AS,WS,PP,J
CR-Spruce-Fir	DF,LP	OS,OH,AS,ES,AF
CR-Lodgepole Pine	DF,LP	OS,OH,AS,ES,AF,PP
West Cascades	AF,RF,LP,DF,WH,MH	all others

Exhibit 3.27 Species defaults by variant.

```
MISTOE
NEWSPRED
DMDEATH            3      0.07
DMDEATH           PP      0.11
END
```

Exhibit 3.28 An example of a DMDEATH keyword segment.

In this example, the (variant-dependent) species with code 3 is assigned an annual infection mortality rate of 0.07, while mistletoe infections on Ponderosa pine are assigned an annual mortality rate of 0.11.

3.2 Using Keywords to Tailor the Model to Your Application

3.2.17 Using the DMFLOWER Keyword

The DMFLOWER keyword is used to define the minimum number of years that must elapse before a new infection can produce seeds, when the spatial model of spread and intensification is in use.

Use this keyword to define the number of years that must pass before a new infection can produce seeds, under the best possible conditions. This keyword is only valid between a MISTOE and an END keyword. More than one DMFLOWER keyword can be used in a sequence, as shown in Exhibit 3.29.

field 1: Species abbreviation or number for which a flowering delay is to be changed.

field 2: A time delay minimum: Time delay in years before a new infection can produce seed.
Range: whole number greater than zero.

Fields 3-7 are not used.

Defaults by fields:

Variant	1	2	3	4	5	6	7
All variants	*	4	not used	not used	not used	not used	not used

* Field 1 requires a valid 2-characater species code; a valid numeric code, 1-39; or a "0", which will default to all species in the variant, listed in Exhibit 3.29.

Variant	Affected by Mistletoe	Not Affected by Mistletoe
Inland Empire, KooKan TL	L,DF,LP,PP	WH,C,S,WP,GF,AF,MH
SORNEC	WP,SP,DF,WF,MH,LP,RF,PP	IC,ES,J
Utah	WB,LM,DF,WF,LP,AF,PP	AS,ES
Teton	WB,LM,DF,LP,AF	AS,ES
SE Alaska	SF,MH,WH,LP,AF	WS,RC,YC,SS,HD
Eastern Montana	WB,DF,LP	WH,C,S,PP,WL,GF,AF
WESSIN	SP,DF,WF,JP,RF,PP	OC,GS,IC,BO,TO
Blue Mountains	WL,DF,LP,PP	MH,ES,WP,GF,AF
East Cascades	WP,WL,DF,SF,GF,LP,AF,PP	RC,ES
Central Idaho	WP,WL,DF,GF,LP,AF,PP	WH,RC,ES
Klamath Mountains	SP,DF,WF,RF,PP	OC,M,IC,BO,TO,OH
CR-SW Mixed Conifer	DF,BS,ES,PP	WP,OS,WF,OH,AS,AF,PJ
CR-SW Ponderosa Pine	DF,BS,PP	WP,OS,WF,OH,AS,OA,P,J
CR-Black Hills	LP	CW,OS,DF,OH,AS,WS,PP,J
CR-Spruce-Fir	DF,LP	OS,OH,AS,ES,AF
CR-Lodgepole Pine	DF,LP	OS,OH,AS,ES,AF,PP
West Cascades	AF,RF,LP,DF,WH,MH	all others

Exhibit 3.29 Species defaults by variant.

```
MISTOE
NEWSPRED
DMFLOWER          DF        5
DMFLOWER          WH        6
END
```

Exhibit 3.29 An example of a DMFLOWER keyword segment.

In this example for mistletoe-infected Douglas-fir terees it will be at least 5 years before a new infection can produce seed. For western hemlock, it will be at least 6 years before a new infection can produce seed.

It should be remembered that the delay until flowering represents the minimum time required for mistletoe development under optimal conditions. Effects such as those caused by light are handled separately, using the `DMLIGHT` keyword.

3.2 Using Keywords to Tailor the Model to Your Application

3.2.18 Using the DMCAP Keyword

The DMCAP keyword is used to define an upper limit on the density of infections required to saturate a crownthird, when the spatial model of spread and intensification is in use.

Use this keyword to constrain the amount of infection that can be carried by a unit volume of crown, expressed as a DMR-equivalent density. The default upper limit is 3.0. By comparison, a value of 2.0 constrains the maximum density of infections to be just equal to the density required to always give a crown third rating of 2. This keyword is only valid between a MISTOE and an END keyword. More than one DMCAP keyword can be used in a sequence, as shown in Exhibit 3.31.

field 1: Species abbreviation or number for which maximum density of infections is to be changed.

field 2: A capping value Range: greater than 0.0 to 3.0.

Fields 3-7 are not used.

Defaults by fields:

Variant	1	2	3	4	5	6	7
All variants	*	3.0	not used	not used	not used	not used	not used

* Field 1 requires a valid 2-character species code; a valid numeric code, 1-39; or a "0", which will default to all species in the variant, listed in Exhibit 3.31.

Variant	Affected by Mistletoe	Not Affected by Mistletoe
Inland Empire, KooKan TL	L,DF,LP,PP	WH,C,S,WP,GF,AF,MH
SORNEC	WP,SP,DF,WF,MH,LP,RF,PP	IC,ES,J
Utah	WB,LM,DF,WF,LP,AF,PP	AS,ES
Teton	WB,LM,DF,LP,AF	AS,ES
SE Alaska	SF,MH,WH,LP,AF	WS,RC,YC,SS,HD
Eastern Montana	WB,DF,LP	WH,C,S,PP,WL,GF,AF
WESSIN	SP,DF,WF,JP,RF,PP	OC,GS,IC,BO,TO
Blue Mountains	WL,DF,LP,PP	MH,ES,WP,GF,AF
East Cascades	WP,WL,DF,SF,GF,LP,AF,PP	RC,ES
Central Idaho	WP,WL,DF,GF,LP,AF,PP	WH,RC,ES
Klamath Mountains	SP,DF,WF,RF,PP	OC,M,IC,BO,TO,OH
CR-SW Mixed Conifer	DF,BS,ES,PP	WP,OS,WF,OH,AS,AF,PJ
CR-SW Ponderosa Pine	DF,BS,PP	WP,OS,WF,OH,AS,OA,P,J
CR-Black Hills	LP	CW,OS,DF,OH,AS,WS,PP,J
CR-Spruce-Fir	DF,LP	OS,OH,AS,ES,AF
CR-Lodgepole Pine	DF,LP	OS,OH,AS,ES,AF,PP
West Cascades	AF,RF,LP,DF,WH,MH	all others

Exhibit 3.31 Species defaults by variant.

```
MISTOE
NEWSPRED
DMCAP                4       1.7
DMCAP               LP       2.2
END
```

Exhibit 3.32 An example of a DMCAP keyword segment.

In this example, the (variant-dependent) species with code 4 is assigned a capping value of 1.7, and lodgepole pine infections are capped at 2.2. One interesting side effect of setting the cap lower than 2.0 is that it imparts a measure of variability in the assignment of high DMRs, since in each cycle they are always constrained to have a random component contributing to the assignment of their value.

3.2 Using Keywords to Tailor the Model to Your Application

3.2.19 Using the DMCLUMP Keyword

The DMCLUMP keyword is used to define the initial pattern of clumpiness of stems when the spatial model of spread and intensification is in use.

Use this keyword to override the sample point dispersion by providing a new dispersion parameter and cycle date. Beginning at this date and continuing forward in time, the user-supplied dispersion will replace the dispersion calculated from the sample points. This keyword's effects are calculated independently of any spatial autocorrelation between DMR classes (see the DMAUTO keyword).This keyword is only valid between a MISTOE and an END keyword. More than one DMCLUMP keyword can be used in a sequence, as shown in Exhibit 3.34.

Trees in a stand may be found in an infinite range of spatial patterns. These can affect the way in which mistletoe spreads within a stand, and can range from very regular arrangements that might be found in plantations, to very clumped arrangements that might reflect past disturbances or patchy resources in the environment. The amount and pattern of clumping observed in a stand also depends on the spatial scale of the sampling (i.e. the size of sample quadrats), but this information is rarely present in stand inventories. As a plausible intermediate step, the spatial spread and intensification module uses the variation between the total trees/acre measured at the sample points (when this information is present) to arrive at a measure of the stand dispersion. Dispersion is the ratio of the variance to the mean size of a collection of samples. Assuming that the sample points all represent stand regions having the same area, then when the dispersion is less than one, the stems are more regularly spaced; when the dispersion equals one, the stems are randomly located ("Poisson"); and when the dispersion is greater than one, the stems are clumped in the stand.

Sample quadrats for the spatial spread and intensification module are circles with a radius of 14 meters. Dispersion is measured at this spatial scale and at no other. The simulation further assumes that stem clumpiness can be modeled using three related probability distributions: the Binomial (more regular), Poisson (random) and Negative Binomial (more clumped). This distribution family has the advantage that the Binomial merges with the Poisson as the dispersion increases from zero to one; and the Poisson merges with the Negative Binomial as the dispersion increases above one. However, tree stems are not somehow compelled to be distributed according to any theoretical distribution, and may (and almost certainly do) exhibit distribution patterns that vary with the scale of observation. Some examples of different dispersion patterns are shown below in Exhibit 3.33. Although they don't give any clue about what value that should be used, they do show how the amount of dispersion can vary with the size of the sampling area. In the rightmost example, stems are quite regular within patches, but the patches themselves are clumped.

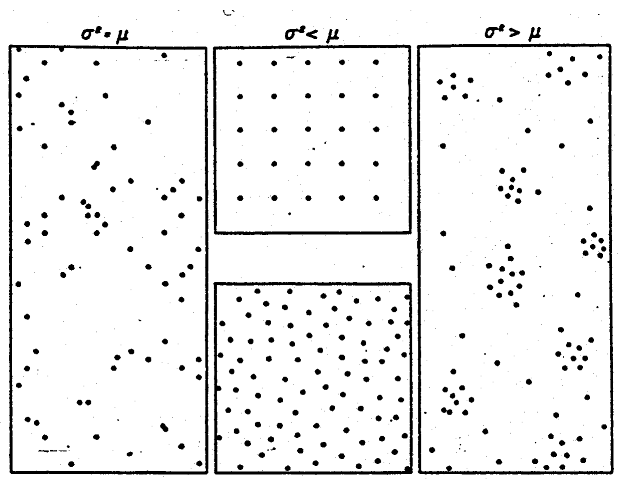

Exhibit 3.33 Three examples of dispersion illustrate some of the attributes of spatial distributions: regularity, randomness and clumpiness (from Elliott 1971; Figure 7).

field 1: Date (calendar year or cycle number) in which change is implemented. The change remains in effect until replaced by a subsequent spatial distribution in another cycle.
Range: 4-digit calendar year or 0 to 40 for cycle number. A "0" will cause the activity to be performed in every cycle.

field 2: The variance-to-mean ratio. Values less than one imply more regular spacing of stem; values equal to one are random in the Poisson sense; and values greater than one imply more clumping of stems.

Fields 3-7 are not used.

Defaults by fields:

Variant	1	2	3	4	5	6	7
All variants	1	*	not used	not used	not used	not used	not used

* The value in field 2 depends on the variance and mean of the number of stems in each inventoried sample-point.

```
MISTOE
NEWSPRED
DMCLUMP              2        1.0
DMCLUMP           1985        2.5
END
```

Exhibit 3.34 An example of a DMCLUMP keyword segment.

This example begins by assuming that beginning at cycle 2, trees in the stand are randomly placed; in 1985 the stand becomes more clumped, with a dispersion of 2.5.

3.2 Using Keywords to Tailor the Model to Your Application

3.2.20 Using the DMAUTO Keyword

The DMAUTO keyword is used to define the amount of spatial autocorrelation between stems of differing DMR classes, when the spatial model of spread and intensification is in use.

In a stand in which mistletoe infestation is concentrated in well-defined patches, it is unlikely that trees of widely differing DMR class will often be found near one another. The simulation model uses a double exponential function to adjust the density of each DMR class in the local neighborhood of other DMR classes, contingent upon stem clumping (see the DMCLUMP keyword). One term of this relationship adjusts the average stand-DMR-patchiness; the other term adjusts the patchiness within the 14 meter radius quadrant surrounding each target tree. When the first term is 0, infections are simulated as if they are evenly spread through the stand with no patches.

Use this keyword to the simulate the effect of spatial autocorrelation of DMR class in any cycle of a run. Beginning at the chosen cycle/date and continuing forward in time, the new autocorrelation terms will replace the preceding terms. This keyword is only valid between a MISTOE and an END keyword. More than one DMAUTO keyword can be used in a sequence, as shown in Exhibit 3.35.

field 1: Date (calendar year or cycle number) in which change is implemented. The change remains in effect until replaced by a subsequent autocorrection term in another cycle. Range: 4-digit calendar year or 0 to 40 for cycle number. A "0" will cause the activity to be performed in every cycle.

field 2: The stand average autocorrelation term. Range: less than zero.

field 3: The within-patch autocorrelation term. Range: less than zero.

Fields 4-7 are not used.

Defaults by field:

Variant	1	2	3	4	5	6	7
All variants	1	-2.50	-0.05	not used	not used	not used	not used

```
MISTOE
NEWSPRED
DMAUTO            1      -1.0     -0.02
DMAUTO            5      -2.5       0.0
END
```

Exhibit 3.35 An example of a DMAUTO keyword segment.

In this example, the stand-average spatial autocorrelation is reduced in cycle 1, making it more likely that trees of unlike DMR will be neighbors; within-patch autocorrelation is also reduced so that more distant neighbors within the patch may be of unlike DMR relative to the center of the patch. In cycle 5, the stand-average autocorrelation is increased, isolating DMR classes from each other; within-patch autocorrelation is set to zero, making the patch homogeneous with respect to the DMR classes of the trees found there.

3.2 Using Keywords to Tailor the Model to Your Application

3.2.21 Using the DMSED Keyword

The DMSED keyword is used to provide a different sequence of the random numbers used by the spatial spread and intensification module.

Use this keyword to change the sequence of random numbers used by the spatial spread and intensification module. Random numbers play a role in selecting the individual trees that will become simulated neighbors, and in assigning discrete DMR categories to infected trees. This keyword is only valid between a MISTOE and an END keyword, and should appear only once in a sequence, as shown in Exhibit 3.36. If this keyword is not used, the model uses a default seed value that is repeated each run.

field 1: Any large, odd-numbered integer greater than zero. If no seed is given, the model creates a seed value based on the time of day.

Fields 2-7 are not used.

Defaults by field:

Variant	1	2	3	4	5	6	7
All variants	55329	not used	not used	not used	not used	not used	not used

```
MISTOE
NEWSPRED
DMSED        231155
END
```

Exhibit 3.36 An example of a DMSED keyword segment.

In this example, the seed (initial) number supplied to the random number generator is changed. Note that the value is positive and odd.

3.2 Using Keywords to Tailor the Model to Your Application

3.2.22 Using the DMKTUNE Keyword

The `DMKTUNE` keyword is used to change the minimum DMR at which trees can spread infection onto their neighbors, when the spatial spread and intensification model is in use.

Use this keyword to change the minimum DMR at which an infected tree is allowed to spread infection onto its neighbors. Trees below this minimum value are still able to intensify and to receive infection from neighbors (with a higher DMR).

field 1: Species abbreviation or number for which minimum DMR is to be changed.

field 2: A minimum DMR. Range: 1-6.

Fields 3-7 are not used.

Defaults by field:

Variant	1	2	3	4	5	6	7
All variants	*	0	not used	not used	not used	not used	not used

* Field 1 requires a valid 2-character species code; a valid numeric code, 1-39; or a "0", which will default to all species in the variant, listed in Exhibit 3.37.

Variant	Affected by Mistletoe	Not Affected by Mistletoe
Inland Empire, KooKan TL	L,DF,LP,PP	WH,C,S,WP,GF,AF,MH
SORNEC	WP,SP,DF,WF,MH,LP,RF,PP	IC,ES,J
Utah	WB,LM,DF,WF,LP,AF,PP	AS,ES
Teton	WB,LM,DF,LP,AF	AS,ES
SE Alaska	SF,MH,WH,LP,AF	WS,RC,YC,SS,HD
Eastern Montana	WB,DF,LP	WH,C,S,PP,WL,GF,AF
WESSIN	SP,DF,WF,JP,RF,PP	OC,GS,IC,BO,TO
Blue Mountains	WL,DF,LP,PP	MH,ES,WP,GF,AF
East Cascades	WP,WL,DF,SF,GF,LP,AF,PP	RC,ES
Central Idaho	WP,WL,DF,GF,LP,AF,PP	WH,RC,ES
Klamath Mountains	SP,DF,WF,RF,PP	OC,M,IC,BO,TO,OH
CR-SW Mixed Conifer	DF,BS,ES,PP	WP,OS,WF,OH,AS,AF,PJ
CR-SW Ponderosa Pine	DF,BS,PP	WP,OS,WF,OH,AS,OA,P,J
CR-Black Hills	LP	CW,OS,DF,OH,AS,WS,PP,J
CR-Spruce-Fir	DF,LP	OS,OH,AS,ES,AF
CR-Lodgepole Pine	DF,LP	OS,OH,AS,ES,AF,PP
West Cascades	AF,RF,LP,DF,WH,MH	all others

Exhibit 3.37 Species defaults by variant.

```
MISTOE
NEWSPRED
DMKTUNE              3          2
DMKTUNE             LP          2
END
```

Exhibit 3.38 An example of a `DMKTUNE` keyword segment.

In this example the (variant-dependent) species 3 as well as lodgepole pine have a minimum spread DMR value of 2. Any trees of these species with DMR less than 2 will be able to intensify and receive infection from other (higher DMR) trees, but they will not be able to infect neighboring trees.

3.2 Using Keywords to Tailor the Model to Your Application

3.2.23 Using the DMETUNE, DMSTUNE and DMITUNE Keywords

The DMETUNE, DMSTUNE and DMITUNE keywords are used to adjust the effectiveness of mistletoe spread and intensification when the spatial spread and intensification model is in use.

These three keywords are used to change the multipliers used to modify the effectiveness of the spread and intensification process. The DMITUNE keyword is a direct multiplier for infections resulting from intensification within a tree; DMSTUNE is a multiplier for infections resulting from spread. The DMETUNE keyword is combines both infection processes, and is multiplier for infections resulting from both spread and intensification. The action of DMETUNE is multiplied by whatever terms may be in effect for DMITUNE and DMSTUNE. This keyword is only valid between a MISTOE and an END keyword, and should appear only once in a sequence, as shown in Exhibit 3.39.

field 1: Species abbreviation or number for which multipliers are to be changed.

field 2: Spread and intensification effectiveness multipliers. Range: greater than 0. Negative values are set to zero, and have the effect of turning off the spread (DMSTUNE), intensification (DMITUNE), or both (DMETUNE).

Fields 3-7 are not used.

Defaults by field:

Variant	1	2	3	4	5	6	7
All variants	*	1.0	not used	not used	not used	not used	not used

* Field 1 requires a valid 2-character species code; a valid numeric code, 1-39; or a "0", which will default to all species in the variant, listed in Exhibit 3.39.

Variant	Affected by Mistletoe	Not Affected by Mistletoe
Inland Empire, KooKan TL	L,DF,LP,PP	WH,C,S,WP,GF,AF,MH
SORNEC	WP,SP,DF,WF,MH,LP,RF,PP	IC,ES,J
Utah	WB,LM,DF,WF,LP,AF,PP	AS,ES
Teton	WB,LM,DF,LP,AF	AS,ES
SE Alaska	SF,MH,WH,LP,AF	WS,RC,YC,SS,HD
Eastern Montana	WB,DF,LP	WH,C,S,PP,WL,GF,AF
WESSIN	SP,DF,WF,JP,RF,PP	OC,GS,IC,BO,TO
Blue Mountains	WL,DF,LP,PP	MH,ES,WP,GF,AF
East Cascades	WP,WL,DF,SF,GF,LP,AF,PP	RC,ES
Central Idaho	WP,WL,DF,GF,LP,AF,PP	WH,RC,ES
Klamath Mountains	SP,DF,WF,RF,PP	OC,M,IC,BO,TO,OH
CR-SW Mixed Conifer	DF,BS,ES,PP	WP,OS,WF,OH,AS,AF,PJ
CR-SW Ponderosa Pine	DF,BS,PP	WP,OS,WF,OH,AS,OA,P,J
CR-Black Hills	LP	CW,OS,DF,OH,AS,WS,PP,J
CR-Spruce-Fir	DF,LP	OS,OH,AS,ES,AF
CR-Lodgepole Pine	DF,LP	OS,OH,AS,ES,AF,PP
West Cascades	AF,RF,LP,DF,WH,MH	all others

Exhibit 3.39 Species defaults by variant.

```
MISTOE
NEWSPRED
DMSTUNE           LP      10.0
DMIKTUNE          LP       3.5
DMETUNE            3       5.5
END
```

Exhibit 3.40 An example of a `DMETUNE`, `DMSTUNE` and `DMITUNE` keyword segment.

In this example, spread effects are magnified by ten times for lodgepole pine, while intensification effects are increased by a factor of 3.5. In the case of (variant dependent) species 3, both spread and intensification are increased by 5.5 times.

3.2 Using Keywords to Tailor the Model to Your Application

3.2.24 Using the COMMENT/END Keywords

The COMMENT/END keywords are used to enter comments in a FVS keyword file.

Use these keywords to add comments to your FVS keyword file and to your FVS Stand Output listing. The keywords and related comments will have no bearing on the FVS run.

The COMMENT/END keywords do not have any associated fields.

Any number of records can intervene between the COMMENT and the END keywords. The keyword sequence must begin with a COMMENT keyword and end with an END keyword. All lines in between will be considered comment records and will be printed out to the FVS Stand Output listing along with other mistletoe keywords and input.

Exhibit 3.41 shows an example of a COMMENT/END keyword segment.

```
MISTOE
COMMENT
The following MISTPINF keyword will cause the introduction of
dwarf mistletoe infections to 50% of all previously uninfected
ponderosa pine trees in this stand in the first 10-year cycle.
The infections will range from DMR 1 to DMR 6 and the trees
will be infected randomly.
END
MISTPINF          1        10        .50        6        0
END
```

Exhibit 3.41 An example of a COMMENT/END keyword segment.

In this example, the four lines of comments will be written to the FVS Stand Output file in the keyword section just before the MISTPINF keyword and its parameters are printed out. Note that there is an END keyword to signal the end of the comment and also an END keyword to signal the end of the mistletoe keyword sequence.

3.3 Producing Dwarf Mistletoe Statistical Output Tables

Three dwarf mistletoe impact statistical output tables will automatically be produced with every run of FVS containing the DMIM system unless you override this feature with keywords. A fourth table is available upon request, as is a fifth table if the spatial spread and intensification model is in use.

The mistletoe model will automatically append three dwarf mistletoe statistical output tables to the end of the FVS Stand Output listing for every run of FVS which was linked with the DMIM system, as long as the MISTPRT keyword is specified. Mistletoe tables will not be produced if there is no mistletoe present in the stand, or if the MSTPRT keyword is not specified. The three basic output tables are:

1. the Stand Composite Summary Table, which contains mistletoe infection and mortality information averaged over the entire stand;

2. the Species-Specific Summary Table, which contains mistletoe infection and mortality information grouped by species for the top four most-infected species in the stand; and

3. the Diameter Class Summary Table, which contains mistletoe infection and mortality information grouped by 2-inch DBH classes from 0 to 20 inches.

Using the MISTABLE keyword, a fourth dwarf mistletoe statistical output table can be produced on request: the Species/Diameter Class Detail Table. This table contains mistletoe infection and mortality information presented by cycle, by species, and by 2-inch DBH classes. This table is not printed automatically because it produces such a volume of information that might not be desired for every cycle, every species, and every 2-inch DBH class from 0 to 40 inches.

When the spatial spread and intensification model is in use (via the NEWSPRED keyword), a fifth statistical output table can be requested. This table is a modified version of the treelist that can be printed with the FVS TREELIST keyword, and contains detailed information about the infection status of the crown third of every record, as well as the amounts of infection present in immature, latent, flowering and light-suppressed categories, by crown third.

The production of the three summary tables can be requested using the MISTPRT keyword. All five tables can be written to separate Data General external files (using the MISTFILE keyword) for those who do not want the mistletoe tables attached to the FVS Stand Output listing or who want each table in a file of its own.

Please refer to the FVS Sequence of Events table (Exhibit 3.42) to understand where in each cycle the mistletoe statistical output information is gathered, calculated, and printed out. (Exhibit 3.42 duplicates Exhibit 2.2, but is repeated here for ease of reference.) The following sections should help in understanding and interpreting the mistletoe infection and mortality information presented in each table.

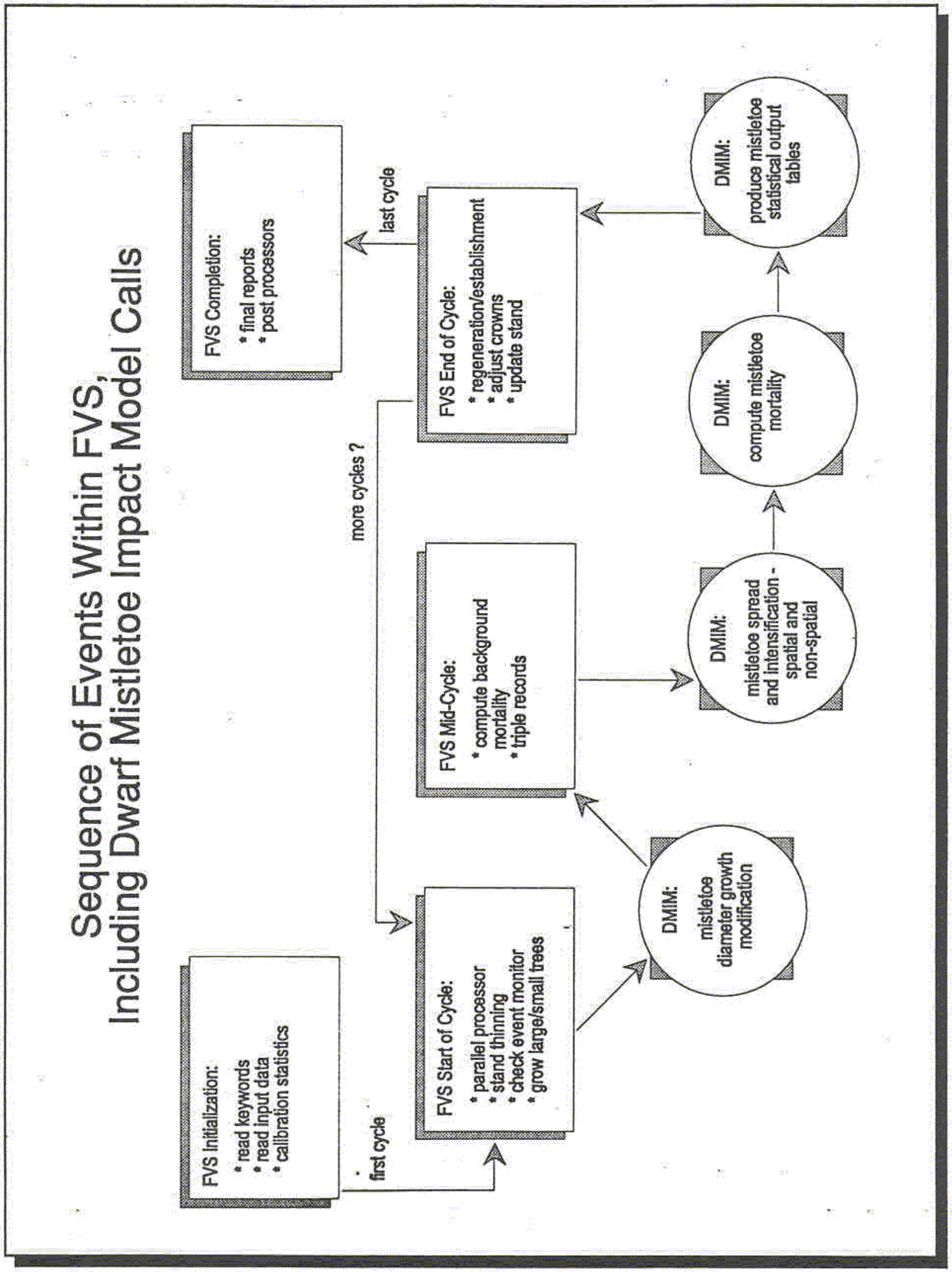

Exhibit 3.42 The sequence of events within FVS, including DMIM model calls.

3.3 Producing Dwarf Mistletoe Statistical Output Tables

3.3.1 Interpreting the Stand Average Table Data

This table contains dwarf mistletoe infection and mortality information displayed as averages over the entire stand, all species combined.

The Dwarf Mistletoe Infection and Mortality Statistics Summary Table for the Stand Composite presents mistletoe-induced infection, intensification, and mortality statistics on a trees-per-acre (TPA) basis over the entire stand, all species combined. This table is not printed unless printing is requested using the MISTPRT keyword. It can also be routed to an external file using the MISTFILE keyword. The table lists information by cycle for each of the following areas:

- stand age;
- TPA, basal area, and volume totals at the beginning of the cycle;
- TPA, basal area, and volume of total trees with mistletoe infection;
- TPA, basal area, and volume of total trees killed by mistletoe;
- percentages of TPA and volume of infected trees;
- percentages of TPA and volume of mortality trees;
- an average dwarf mistletoe rating (DMR) for the entire stand; and
- an average dwarf mistletoe rating (DMI) of infected-only trees in the stand.

Mistletoe infection and mortality totals, percentages, and average DMRs for the stand for total and infected-only trees are all calculated at the middle of a FVS cycle, whether it is the default 10-year cycle or any other length cycle. This happens after diameter growth has been modified due to mistletoe, after mistletoe has spread and intensified through the stand, and after mortality due to mistletoe infection has been calculated. Another thing to note is that stand total values, mistletoe infection values, percentages of infected trees, stand average DMR, and infected-only trees DMR all include mistletoe mortality statistics for that cycle also.

Exhibit 3.43 is an example of the Dwarf Mistletoe Stand Average Summary Table.

DWARF MISTLETOE INFECTION AND MORTALITY STATISTICS SUMMARY TABLE
(STAND COMPOSITE; PER ACRE)

Stand ID: 9108-11   Management Code: NONE   Revision Code: 950301

DMRs and DMIs calculated for trees with DBH >= .0
MEAN DMR = Average dwarf mistletoe rating for all trees in the stand.
MEAN DMI = Average dwarf mistletoe rating for infected-only trees in the stand.

		START OF CYCLE			DM INFECTION			DM MORTALITY								
YEAR	AGE	TREES /ACRE	BA SQFT	VOL CU FT	TREES /ACRE	BA SQFT	VOL CU FT	TREES /ACRE	BA SQFT	VOL CU FT	%TPA INF	%VOL INF	%TPA MORT	%VOL MORT	MEAN DMR	MEAN DMI
1980	60	1876	130	2780	203	52	1110	11	4	78	11	40	1	3	.3	2.9
1990	70	1762	147	3345	237	60	1371	12	4	90	13	41	1	3	.4	2.6
2000	80	1662	164	3958	338	65	1570	14	4	101	20	40	1	3	.4	2.2
2010	90	1573	181	4610	394	71	1812	19	5	115	25	39	1	3	.6	2.3
2020	100	1462	196	5235	395	78	2078	23	5	132	27	40	2	3	.7	2.5
2030	110	1256	202	5653	472	83	2314	30	5	146	38	41	2	3	.9	2.4
2040	120	1097	208	6065	443	90	2629	29	5	160	40	43	3	3	1.0	2.6
2050	130	971	214	6455	413	96	2910	27	6	174	43	45	3	3	1.1	2.6
2060	140	867	219	6818	381	101	3137	32	6	196	44	46	4	3	1.3	2.9
2070	150	774	225	7139	347	109	3458	30	7	215	45	48	4	3	1.5	3.3
2080	160	699	230	7426	323	118	3833	32	7	232	46	52	5	3	1.7	3.6
2090	170	632	235	7689	308	132	4344	28	8	260	49	56	4	3	1.8	3.7
2100	180	576	239	7935	281	138	4582	24	8	272	49	58	4	3	1.8	3.8
2110	190	538	245	8186	285	144	4811	21	9	287	53	59	4	4	2.0	3.7
2120	200	496	249	8363	278	153	5138	20	9	310	56	61	4	4	2.2	4.0

Exhibit 3.43 An example of the Dwarf Mistletoe Stand Average Summary Table.

3.3 Producing Dwarf Mistletoe Statistical Output Tables

3.3.2 Interpreting the Species-Specific Table Data

This table contains dwarf mistletoe infection and mortality information displayed by individual species in the stand, from the most infected to the least infected species.

The Dwarf Mistletoe Infection and Mortality Statistics Summary Table for the Top Four Most- Infected Species presents mistletoe-induced infection, intensification, and mortality statistics for the four species with the highest percentage of dwarf mistletoe-infected trees per acre. The top four most-infected species are presented from most infected to least infected, which is determined in the first cycle, and will remain in this relative order through the entire FVS run. This table is not printed unless printing is requested using the `MISTPRT` keyword. It can also be routed to an external file using the `MISTFILE` keyword. The table lists information by cycle for each of the four species, for each of the following areas:

- trees per acre (TPA) with mistletoe infection;
- TPA killed by mistletoe infection;
- TPA percentages of mistletoe-infected trees;
- TPA percentages of mistletoe mortality trees;
- an average dwarf mistletoe rating of all trees of that species;
- an average dwarf mistletoe rating of infected-only trees of that species; and
- TPA percent representation of each species in the entire stand.

Mistletoe infection and mortality totals, percentages, and average DMRs for each of the species for total and infected-only trees are all calculated at the middle of a FVS cycle, whether it is the default 10-year cycle or any other length cycle. This happens *after* diameter growth has been modified due to mistletoe, *after* mistletoe has spread and intensified through the stand, and *after* mortality figures due to mistletoe infection have been calculated. Another thing to note is that mistletoe infection values, percentages of infected trees, species average DMR, and species-infected-only DMR all include mistletoe mortality statistics for that cycle also.

Exhibit 3.44 is an example of the Dwarf Mistletoe Species-Specific Summary Table.

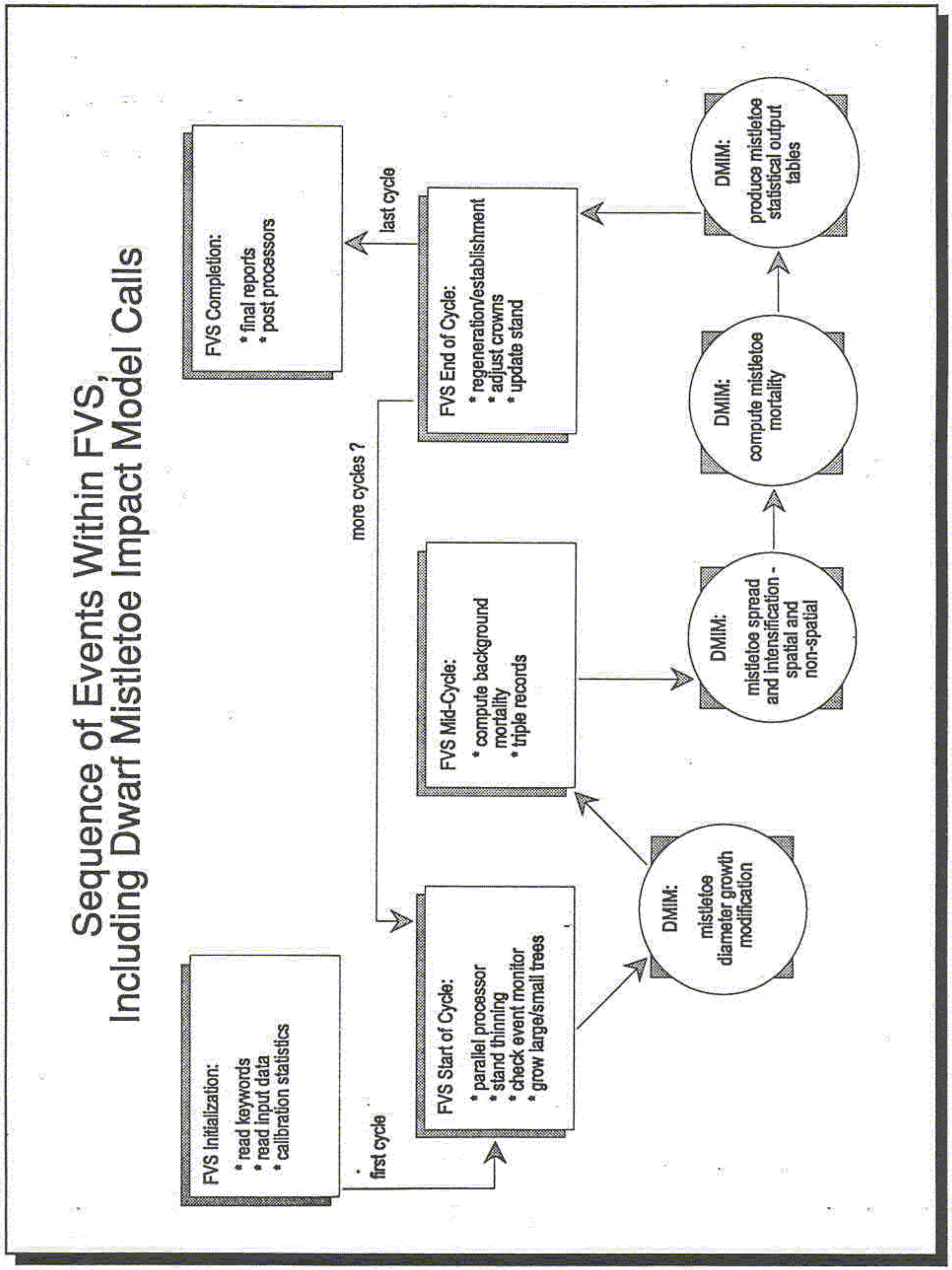

Exhibit 3.44 An example of the Dwarf Mistletoe Species-Specific Summary Table.

3.3 Producing Dwarf Mistletoe Statistical Output Tables

3.3.3 Interpreting the Diameter Class Table Data

This table contains dwarf mistletoe infection and mortality information for each diameter class in the stand, by two-inch diameter classes ranging from 2 to 20 inches.

The Dwarf Mistletoe Infection and Mortality Statistics Summary Table for 2-Inch Diameter Classes presents mistletoe-induced infection, intensification, and mortality statistics grouped by 2-inch DBH classes from 0 to 20+ inches, all species combined. This table is not printed unless the printing is requested using the `MISTPRT` keyword. It can also be routed to an external file using the `MISTFILE` keyword. The table lists information by cycle for each of the 2-inch DBH classes from 0 to 20 inches, for each of the following areas:

- trees per acre (TPA) total;
- TPA with mistletoe infection;
- TPA killed by mistletoe infection;
- an average dwarf mistletoe rating (DMR) of all trees in that DBH class; and
- an average dwarf mistletoe rating (DMI) of infected-only trees of that DBH class.

Mistletoe infection totals, mortality totals, and average DMRs for the DBH classes for total and infected-only trees are all calculated at the middle of a FVS cycle, whether it is the default 10-year cycle or any other length cycle. This happens *after* diameter growth has been modified due to mistletoe, *after* mistletoe has spread and intensified through the stand, and *after* mortality figures due to mistletoe infection have been calculated. Another thing to note is that the TPA total values, TPA with mistletoe infection values, average DMR's for the total DBH class, and average DMRs for infected-only trees of that DBH class all include mistletoe mortality statistics for that cycle also.

Exhibit 3.45 is an example of the Dwarf Mistletoe Diameter Class Summary Table.

DWARF MISTLETOE INFECTION AND MORTALITY STATISTICS SUMMARY TABLE
(BY 2 INCH DIAMETER CLASSES)

Stand ID: 9108-11 Management Code: NONE Revision Code: 950301

DMRs and DMIs calculated for trees with DBH >= .0
MEAN DMR = Average dwarf mistletoe rating for all trees of that diameter class.
MEAN DMI = Average dwarf mistletoe rating for infected-only trees of that diameter class.

YEAR		2 INCH DIAMETER CLASSES									
		0-2.9"	3-4.9"	5-6.9"	7-8.9"	9-10.9"	11-12.9"	13-14.9"	15-16.9"	17-18.9"	19 +"
1980											
	TPA	1350.0	206.2	181.2	80.1	38.0	11.7	3.5	2.3	.9	.3
	INF	43.7	6.3	95.0	35.8	12.5	4.6	1.3	1.4	.8	.2
	MRT	1.6	.2	5.7	2.5	.7	.3	.1	.1	.1	.0
	DMR	.0	.0	1.8	1.5	1.1	1.6	1.2	2.0	3.9	3.6
	DMI	1.4	1.0	3.4	3.3	3.4	4.1	3.2	3.0	4.5	6.0
1990											
	TPA	1227.5	200.0	163.6	95.6	43.9	20.6	5.5	2.0	1.0	.7
	INF	81.7	11.7	79.8	31.8	16.9	9.5	1.7	1.4	1.0	.4
	MRT	2.8	.3	4.8	2.0	1.1	.5	.1	.1	.1	.0
	DMR	.1	.1	1.7	1.1	1.5	1.5	1.1	2.5	3.9	3.0
	DMI	1.4	1.0	3.4	3.3	4.0	3.3	3.4	3.6	4.2	4.8
2000											
	TPA	1136.5	155.5	171.3	102.4	55.5	28.1	6.6	2.6	1.5	.6
	INF	186.1	11.1	67.1	33.1	23.4	11.3	2.4	1.2	1.2	.5
	MRT	4.6	.3	3.9	2.2	1.4	.7	.1	.1	.1	.0
	DMR	.2	.1	1.2	1.3	1.5	1.4	1.0	1.8	3.0	3.7
	DMI	1.2	1.0	3.2	4.0	3.6	3.6	2.8	4.1	3.9	4.6
2010											
	TPA	1055.6	115.2	176.0	106.4	68.2	33.7	10.4	3.2	2.0	.6
	INF	241.9	10.5	54.9	36.5	30.7	10.6	5.0	1.0	1.3	.6
	MRT	9.9	.3	3.0	2.5	1.6	.7	.2	.1	.1	.1
	DMR	.4	.1	.9	1.4	1.5	1.2	1.4	1.1	2.8	4.0
	DMI	1.7	1.0	2.9	4.1	3.4	3.8	3.0	3.4	4.2	4.0
2020											
	TPA	954.8	67.4	181.9	123.0	70.6	37.3	17.7	5.1	2.1	.8
	INF	243.0	4.8	41.7	48.2	30.7	14.0	8.2	1.4	1.3	.8
	MRT	14.6	.1	1.9	3.4	1.5	.8	.4	.1	.1	.1
	DMR	.5	.1	.6	1.6	1.4	1.3	1.6	1.0	2.4	4.3
	DMI	2.1	1.0	2.4	4.1	3.2	3.4	3.4	3.4	3.9	4.8

Exhibit 3.45 An example of the Dwarf Mistletoe Diameter Class Summary Table.

3.3 Producing Dwarf Mistletoe Statistical Output Tables

3.3.4 Interpreting the Species/DBH Class Table Data

This table contains dwarf mistletoe infection and mortality information for each diameter class (from 2 to 40 inches) by species and by cycle.

The Dwarf Mistletoe Infection and Mortality Statistics Detail Table by Species and by 2-Inch Diameter Class presents mistletoe-induced infection, intensification, and mortality statistics broken down first by cycle, then by species, and last by 2-inch DBH classes from 0 to 40+ inches. This table is not printed automatically with every run of FVS that includes the mistletoe model; it must be requested using the `MISTABLE` keyword, and it can be requested for any one or all of the eleven species, for any one or all cycles. Each table will then list information for 20 different 2-inch DBH classes from 0 to 40+ inches. It can be routed to an external file using the `MISTFILE` keyword. The table lists information by cycle, by species, for each 2-inch DBH class from 0 to 40+ inches for each of the following areas:

- trees per acre (TPA) total;
- TPA with mistletoe infection;
- TPA without mistletoe infection (DMR = 0);
- TPA per acre with DMR 1 or 2;
- TPA per acre with DMR 3 or 4;
- TPA per acre with DMR 5 or 6;
- TPA killed by mistletoe infection;
- an average dwarf mistletoe rating (DMR) for all trees of that species/DBH class; and
- an average dwarf mistletoe rating (DMI) of infected-only trees of that species/DBH class.

Mistletoe infection, mortality, and DMR-specific totals, and average DMR's for each class for total and infected-only trees are all calculated at the middle of a FVS cycle, whether it is the default 10-year cycle or any other length cycle. This happens after diameter growth has been modified due to mistletoe, after mistletoe has spread and intensified through the stand, and after mortality figures due to mistletoe infection have been calculated. Another thing to note is that TPA totals, TPA with mistletoe infection, TPA broken down by DMR, and average DMRs for each class (total and infected-only trees) all include mistletoe mortality statistics for that cycle also.

Exhibit 3.46 is an example of the Dwarf Mistletoe Species/DBH Class Detail Table.

DWARF MISTLETOE INFECTION AND MORTALITY STATISTICS DETAIL TABLE
(BY SPECIES, BY 2 INCH DIAMETER CLASS, BY CYCLE)

Stand ID: 9108-11 Management Code: NONE Revision Code: 950301

DMRs and DMIs calculated for trees with DBH >= .0
MEAN DMR = Average dwarf mistletoe rating for all trees of that species/DBH class.
MEAN DMI = Average dwarf mistletoe rating for infected-only trees of that species/DBH class.

Year: 1990
Species: LP

DBH CLASS	TREES/ACRE TOTAL	TREES/ACRE INFECTED	TREES/ACRE UNINFECTED	TREES/ACRE DMR 1-2	TREES/ACRE DMR 3-4	TREES/ACRE DMR 5-6	TREES/ACRE MORTALITY	MEAN DMR	MEAN DMI
0- 2.9"	1021.5	35.0	986.5	35.0	.0	.0	.9	.0	1.0
3- 4.9"	194.0	11.7	182.3	11.7	.0	.0	.3	.1	1.0
5- 6.9"	159.3	79.8	79.5	29.3	24.4	26.0	4.8	1.7	3.4
7- 8.9"	91.9	31.3	60.6	13.5	9.1	8.8	1.8	1.1	3.2
9-10.9"	42.4	15.9	26.5	4.0	4.5	7.5	.9	1.5	3.9
11-12.9"	19.7	9.2	10.5	3.3	3.2	2.8	.5	1.6	3.4
13-14.9"	5.0	1.7	3.2	.6	.6	.5	.1	1.2	3.4
15-16.9"	1.3	.9	.5	.2	.4	.3	.1	2.6	4.1
17-18.9"	.7	.6	.1	.0	.3	.4	.0	4.4	4.9
19-20.9"	.3	.2	.1	.0	.0	.2	.0	3.4	6.0
21-22.9"	.0	.0	.0	.0	.0	.0	.0	.0	.0
23-24.9"	.0	.0	.0	.0	.0	.0	.0	.0	.0
25-26.9"	.0	.0	.0	.0	.0	.0	.0	.0	.0
27-28.9"	.0	.0	.0	.0	.0	.0	.0	.0	.0
29-30.9"	.0	.0	.0	.0	.0	.0	.0	.0	.0
31-32.9"	.0	.0	.0	.0	.0	.0	.0	.0	.0
33-34.9"	.0	.0	.0	.0	.0	.0	.0	.0	.0
35-36.9"	.0	.0	.0	.0	.0	.0	.0	.0	.0
37-38.9"	.0	.0	.0	.0	.0	.0	.0	.0	.0
39- +"	.0	.0	.0	.0	.0	.0	.0	.0	.0
SUM/AVG	1536.2	186.4	1349.7	97.6	42.5	46.4	9.4	.3	2.8

Exhibit 3.46 An example of the Dwarf Mistletoe Species/DBH Class Detail Table.

3.3 Producing Dwarf Mistletoe Statistical Output Tables

3.3.5 Interpreting the Mistletoe Treelist Table Data

This table contains dwarf mistletoe infection information for every treelist record, by crown third. This information includes the amount of infection in immature, latent, flowering and light-suppressed categories.

The Dwarf Mistletoe Treelist Table begins by printing the proportion of light that is lost within the forest canopy, beginning at ground level (2 meters) and proceeding upward to 50 meters in two meter increments. Following this, a portion of the treelist information and infection status is printed, as described in the table below. The variables represent the state of the stand at the *beginning* of the cycle, before growth, spread or mortality processes have been accounted for. Column headings that can usually be requested with the `MISTFILE` keyword for the first four output files, are not available for this file. The table below summarizes the column position and content of the file. In many instances, variables are printed in triplets that represent the simulated condition within the crown thirds of trees. These variables are always printed in the order: top-, middle-, bottom-crown third. Note that there are *four* crown third breakpoints, counting from the top of the crown to the bottom of the tree.

Column	Variable	Units
1	Tree ID	
2	Treelist record number	1-1350
3	Species Code	1-11
4	Stem density	trees/acre
5	DBH	Inch
6	Height	Feet
7	DMR	0-6
8-11	Crown third breakpoints	2 meters
12-14	Newly spread infection	DMR/meter^3
15-17	Newly intensified infection	DMR/meter^3
18-20	Immature infections	DMR/meter^3
21-23	Latent infections	DMR/meter^3
24-26	Flowering infections	DMR/meter^3
27-29	Light-suppressed infections	DMR/meter^3

Exhibit 3.47 An example of the Dwarf Mistletoe Treelist Output Table.

Cycle= 1 Year= 1990
Shade 1..25:   .000   .000   .000   .013   .017   .031   .034   .055   .101   .092   .086   .097   .100

1001	1	3	3.19	18.51	104.62	3	15.697	13.866	12.035	10.203	.147	.594	.830	.000
1002	2	3	4.60	15.42	99.54	0	14.935	13.193	11.450	9.708	.995	.696	.470	.000
1003	3	3	2.59	20.56	111.62	3	16.764	14.250	11.735	9.220	.120	.455	.274	1.003
1004	4	3	4.60	15.37	101.40	2	15.240	13.970	12.700	11.430	.840	1.180	1.236	.003
2001	7	3	3.58	17.68	102.02	0	15.240	13.462	11.684	9.906	3.358	2.573	.934	.000
2003	9	3	4.60	15.37	103.41	0	15.545	14.250	12.954	11.659	.153	.560	.547	.000
2004	10	3	3.58	17.35	101.28	3	15.240	13.462	11.684	9.906	4.544	4.558	2.817	.183
2005	11	3	4.04	16.35	96.33	2	14.478	13.272	12.065	10.859	2.907	1.824	.763	.059
3002	14	3	2.59	20.48	111.46	3	16.764	13.691	10.617	7.544	2.153	7.344	3.933	2.299
3003	15	3	5.28	14.52	101.82	1	15.240	12.954	10.668	8.382	.935	2.218	1.270	.000
3004	16	3	2.85	19.34	101.20	4	15.240	12.954	10.668	8.382	2.733	5.185	3.527	1.831
4001	19	3	2.34	21.76	106.98	4	16.002	12.535	9.068	5.601	9.065	9.127	3.941	30.373
4003	21	3	2.87	19.58	101.75	0	15.240	11.938	8.636	5.334	2.388	15.947	8.344	.000
6001	27	3	4.04	16.68	87.15	3	12.954	11.011	9.068	7.125	.101	.602	1.749	.061
6008	32	3	4.60	15.39	93.49	0	14.021	12.853	11.684	10.516	1.564	1.122	.702	.000
6009	33	3	4.60	15.46	86.68	3	12.954	11.011	9.068	7.125	4.673	9.347	4.430	.078
7002	35	3	2.87	19.61	120.69	3	18.136	14.811	11.486	8.161	1.059	2.827	1.648	2.172
2002	8	7	5.28	14.41	93.40	0	14.021	12.853	11.684	10.516	.000	.000	.000	.000
2006	12	7	5.27	14.24	91.00	0	13.716	12.573	11.430	10.287	.000	.000	.000	.000
3001	13	7	5.28	14.45	102.46	0	15.393	13.597	11.801	10.005	.000	.000	.000	.000
5002	23	7	7.18	12.47	80.63	0	12.040	10.234	8.428	6.622	.000	.000	.000	.000
5003	24	7	6.12	13.48	77.62	0	11.583	9.845	8.108	6.370	.000	.000	.000	.000
6002	28	7	5.28	14.66	88.97	0	13.259	11.270	9.281	7.292	.000	.000	.000	.000
6005	29	7	6.12	13.32	93.21	0	14.021	12.853	11.684	10.516	.000	.000	.000	.000
6006	30	7	6.12	13.37	94.32	0	14.173	12.992	11.811	10.630	.000	.000	.000	.000
7004	37	7	7.18	12.32	73.26	0	10.973	10.059	9.144	8.230	.000	.000	.000	.000
7005	38	7	5.28	14.51	83.67	0	12.497	9.789	7.082	4.374	.000	.000	.000	.000
3005	17	8	10.34	10.11	92.65	0	14.021	12.853	11.684	10.516	.000	.000	.000	.000
4002	20	8	10.32	10.14	73.80	0	11.125	10.198	9.271	8.344	.000	.000	.000	.000
5001	22	8	21.05	7.10	44.72	0	6.706	5.923	5.141	4.359	.000	.000	.000	.000
5004	25	8	16.12	8.09	64.65	0	9.754	8.941	8.128	7.315	.000	.000	.000	.000
7001	34	8	21.01	7.08	61.65	0	9.297	8.522	7.747	6.972	.000	.000	.000	.000
1005	5	9	12.71	9.10	78.75	0	11.887	10.104	8.321	6.538	.000	.000	.000	.000
1006	6	9	5.26	14.10	86.83	0	13.132	11.731	10.331	8.930	.000	.000	.000	.000
3006	18	9	7.12	12.07	100.50	0	15.240	13.970	12.700	11.430	.000	.000	.000	.000
5005	26	9	7.15	12.13	72.78	0	10.973	9.693	8.413	7.132	.000	.000	.000	.000
6007	31	9	12.66	9.10	64.69	0	9.754	8.291	6.828	5.365	.000	.000	.000	.000
7003	36	9	12.69	9.12	56.74	0	8.535	6.970	5.405	3.841	.000	.000	.000	.000

.100 .089 .080 .074 .024 .003 .005 .000 .000 .000 .000 .000 .000

.142	.085	.052	.812	1.782	.007	.268	.342	.000	.596	.361	.002	1.418	.659
.000	.000	.511	.595	1.103	.071	.083	.155	.004	.008	.019	.019	.018	.028
1.043	.336	.216	.869	.774	.030	.277	.217	.001	.597	.409	.009	1.421	.607
.042	.068	.741	2.044	5.220	.103	.349	.796	.005	.230	.300	.028	.790	.721
.000	.000	1.332	1.669	1.707	.185	.233	.240	.009	.021	.029	.049	.051	.043
.000	.000	.138	.801	2.354	.019	.112	.329	.001	.008	.030	.005	.027	.072
.657	.279	1.876	3.775	5.827	.260	.683	.908	.013	.600	.410	.070	1.440	.611
.151	.065	2.274	2.570	3.152	.316	.435	.529	.022	.300	.361	.077	.720	.660
1.584	.895	.621	2.470	3.465	.086	.504	.604	.003	.600	.458	.025	1.438	.563
.000	.000	.373	1.488	2.424	.052	.209	.343	.003	.022	.045	.014	.041	.055
1.006	.437	.940	2.552	4.096	.130	.545	.690	.007	.722	.459	.035	1.316	.563
14.635	.555	3.895	4.103	2.310	.590	.787	.480	.162	.820	.529	.859	1.221	.492
.000	.000	.438	1.588	1.519	.061	.224	.217	.004	.027	.032	.015	.040	.028
13.901	.969	.073	3.913	1.424	.010	.761	.346	.001	.820	.506	.002	1.221	.514
.000	.000	1.348	1.618	2.563	.188	.226	.359	.013	.021	.039	.046	.049	.070
4.995	.618	2.443	4.391	2.789	.343	.827	.533	.037	.820	.506	.067	1.221	.516
1.581	.265	.520	1.579	1.707	.072	.354	.364	.001	.459	.458	.023	1.573	.562
.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000

Appendices

A. Tree Species Abbreviations, Common Names, and Scientific Names

B. Abbreviations and Glossary

C. Species Infested with Dwarf Mistletoe

A. Tree Species Abbreviations, Common Names, and Scientific Names

The following is a list of the tree species abbreviations used in this document, and the common and scientific names to which these abbreviations refer.

Abbreviation	*Common Name*	*Scientific Name*
AF	subalpine fir	*Abies lasiocarpa*
AS	aspen	*Populus tremuloides*
BC	cherry	*Prunus spp.*
BM	bigleaf maple	*Acer macrophyllum*
BO	California black oak	*Quercus kelloggi*
BS	blue spruce	*Picea pungens*
C	western red cedar	*Thuja plicata*
CB	corkbark fir	*Abies lasiocarpa var. arizonica*
CO	cottonwood	*Populus acuminata*
CW	cottonwood	*Populus acuminata*
DF	Douglas-fir	*Pseudotsuga menziesii*
DG	western dogwood	*Cornus sericea var. occidentalis*
ES	Englemann spruce	*Picea Englemannii*
GC	giant chinkapin	*Casanopsis chrsophylla*
GF	grand fir	*Abies grandis*
GS	giant sequoia	*Sequoiadentron gigantum*
HD	hardwood	--
HW	hawthorne	*Crataegns douglasii*
IC	incense cedar	*Libocedrus decurrens*
J	juniper	*Juniperus spp.*
JP	Jeffrey pine	*Pinus jeffreyi*
KP	knobcone pine	*Pinus attenuata*
L	western larch	*Larix occidentalis*
LL	subalpine larch	*Larix lyallii*
LM	limber pine	*Pinus flexilis*
LP	lodgepole pine	*Pinus contorta*

Abbreviation	*Common Name*	*Scientific Name*
M	Pacific madrone	*Arbunus menziesii*
MH	mountain hemlock	*Tsuga mentensiana*
NF	noble fir	*Abies procera*
OA	oak	*Quercus*
OC	other conifer	--
OH	other hardwood	--
OS	other softwood	--
P	pinyon	*Pinus edulis*
PB	paper birch	*Betula papyrifera*
PJ	pinyon-juniper	--
PP	ponderosa pine	*Pinus ponderosa*
PY	pacific yew	*Taxus brevifolia*
RA	red alder	*Alnus rubra*
RC	western red cedar	*Thuja plicata*
RF	red fir	*Abies magnifica*
RW	coastal redwood	*Sequoia sempervirens*
SF	Pacific silver fir	*Abies amiabils*
SP	sugar pine	*Pinus lambertiana*
S	Englemann spruce	*Picea englemannii*
SS	Sitka spruce	*Picea sitchensis*
TO	Tanoak	*Lithocarpus densiflorus*
WA	white alder	*Alnus rhombifolia*
WA	white ash	*Fraxinus americana*
WB	whitebark pine	*Pinus albicaulis*
WF	white fir	*Abies concolor*
WH	western hemlock	*Tsuga heterophylla*
WI	willow	*Salix spp.*
WL	western larch	*Larix occidentalis*
WO	white oak	*Quercus alba*
WP	white pine	*Pinus monticola*
WS	white spruce	*Picea glauca*
YC	Alaska cedar	*Chamaecyparis nootkatensis*

B. Abbreviations and Glossary

The following are phrases, words, and acronymns used in this document.

Abbreviation/Term	Explanation
active infection	mistletoe plant that produces seed
autocorrelation	the tendency of neighbors to be more alike one another than expected (positive), or less alike (negative), compared to a random spatial pattern
BA	basal area (usually square feet/acre)
Bionomial	a discrete probability distribution in which there are fewer cases of larger and smaller samples than expected from a random distribution; sample variance smaller than sample mean
CL	FVS (PROGNOSIS) cycle length (years)
crown third	the vertical division of a tree's canopy into three equal-height divisions
DBH	diameter at breast height (usually inches)
DG	Data General
DM	dwarf mistletoe
DMI	dwarf mistletoe rating , infected-only trees (0-6)
DMR	dwarf mistletoe rating (0-6 in Hawksworth's scale)
EXP	exponential function; exp(x) is also written e^x
DMIM	Dwarf Mistletoe Impact Model
immature infection	recently established infection that is not large enough to produce seed
INF	dwarf mistletoe infection (units vary)
latent infection	recent infection that is large enough to produce seed, but unable to do so because of low light conditions
MRT	dwarf mistletoe-induced mortality (units vary)
Negative Binomial	A discrete probability distribution in which there are more cases of larger and smaller samples than expected from a randon distribution; sample variance larger than sample mean
opacity	the species-specific capacity of foliage, branches and boles to block light and the ballistic discharge of seeds (proportion/meter)
Poisson	a discrete probability distribution often referred to as "random"; sample variance equals sample mean
TPA	trees per acre
suppressed infection	mistletoe plant that has produced seed in the past, but which is now unable to produce seed because of low light conditions
VOL	volume (units vary)

Appendix C. Species Infested with Dwarf Mistletoe

The following species in each region can serve as a host to dwarf mistletoe.

FVS Variant	*Species affected by dwarf mistletoe*	*Species not affected by dwarf mistletoe*
Inland Empire (NI) KooKan TL (KT)	larch Douglas-fir lodgepole pine ponderosa pine	western hemlock cedar spruce white pine grand fir alpine fir mountain hemlock
S. Oregon N.E. California -- SORNEC (SO)	white pine sugar pine Douglas-fir white fir mountain hemlock lodgepole pine red fir ponderosa pine	incense-cedar Engelmann spruce juniper
Utah (UT)	whitebark pine limber pine Douglas-fir white fir lodgepole pine alpine fir ponderosa pine	aspen Engelmann spruce
Teton (TT)	whitebark pine limber pine Douglas-fir lodgepole pine alpine fir	aspen Engelmann spruce
S.E. Alaska	Pacific silver fir moutain hemlock western hemlock lodgpole pine alpine fir	white spruce western redcedar Alaska-cedar Sitka spruce hardwood
Eastern Montana (EM)	whitebark pine lodgepole pine Douglas-fir	western hemlock cedar spruce ponderosa pine western larch grand fir alpine fir
Western Sierra Nevada -- WESSIN (WS)	sugar pine Douglas-fir white fir Jeffrey pine red fir ponderosa pine	other conifer giant sequoia incense-cedar black oak tanoak

FVS Variant	***Species affected by dwarf mistletoe***	***Species not affected by dwarf mistletoe***
Blue Mountains (BM)	western larch Douglas-fir lodgepole pine ponderosa pine	mountain hemlock Engelmann spruce white pine grand fir alpine fir
East Cascades (EC)	white pine western larch Douglas-fir Pacific silver fir grand fir lodgepole pine alpine fir ponderosa pine	western redcedar Engelmann spruce
Central Idaho (CI)	white pine larch Douglas-fir grand fir lodgepole pine alpine fir ponderosa pine	western hemlock cedar spruce
Klamath Mountains -- Northern California (NC)	sugar pine Douglas-fir white fir red fir ponderosa pine	other conifer madrone incense-cedar black oak tanoak other hardwood other hardwood
Central Rockies -- S.W. Mixed Conifer (CR)	Douglas-fir blue spruce Engelmann spruce ponderosa pine	white pine other softwood white fir other hardwood aspen alpine fir pinyon-juniper
Central Rockies -- S.W. Ponderosa Pine (CR)	Douglas-fir blue spruce ponderosa pine	white pine other softwood white fir other hardwood aspen oak pinyon juniper
Central Rockies -- Black Hills (CR)	lodgepole pine*	cottonwood other softwood Douglas-fir other hardwood aspen white pine ponderosa pine juniper

FVS Variant	*Species affected by dwarf mistletoe*	*Species not affected by dwarf mistletoe*
Central Rockies -- Spruce-Fir (CR)	Douglas-fir lodgepole pine	other softwood other hardwood aspen Englemann spruce alpine fir
Central Rockies -- Lodgepole Pine (CR)	Douglas-fir lodgepole pine	other softwood other hardwood aspen Engelmann spruce alpine fir ponderosa pine
West Cascades (WC)	subalpine fir red fir lodgepole pine Douglas-fir western hemlock mountain hemlock	[all others]

* Although dwarf mistletoe is not present in the Black Hills, lodgepole pine is affected if this model is used with non-Black Hills inventory data.

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Michael Marsden (DM information)
Ralph Johnson, Gary Dixon (existing FVS model)
Matt Thompson, Lance David (existing FVS model)
Brian Geils (southwest Douglas-fir mortality data)

Region 5:

Dennis Hart (true fir mortality and diameter growth data)

Region 6:

Jerry Beatty (mortality and diameter growth information)
Catherine Parks (same)
Ellen Michaels Goheen (same)
Don Goheen (same)
Kathy Sheehan (same)
Helen Maffei (same)
Tommy Gregg (same)
Paul Hessburg (same)
L.F. Roth (Pringle Falls data)

Region 10:

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