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Chapter

6

Dwarf Mistletoe Surveys

Dwarf mistletoe surveys are conducted for a variety of vegetation management objectives. Various survey and sampling techniques are used either at a broad, landscape scale in forest planning or program review, or at an individual, stand, site level for specific project implementation. Standard and special surveys provide data to map mistletoe distributions and quantify disease severity. At a landscape scale, extensive surveys assess regional impacts, estimate mistletoe occurrence, intensity, and effects, and estimate future growth and yield. Intensive surveys evaluate stands, campgrounds, and other sites to design projects and monitor treatments.

Numerous variations and combinations of techniques such as aerial survey and photography, forest inventory, road and plot survey, transects and grid survey, and permanent plots are used to obtain dwarf mistletoe information for program and project management (table 6-1). Only a few studies compare alternative survey and sampling methods (Drummond 1978, Hildebrand and others 1997, Mathiasen

Table 6-1—Surveys for mapping the distribution and quantifying the effects of dwarf mistletoes.

Technique	Objective(s)	Reference Example
Aerial survey	Landscape assessments	Brandt and others 1998
Aerial photography	Landscape assessments	Baker and French 1991
Forest inventory plots	Landscape assessments	Hildebrand and others 1997
Road and plot surveys	Landscape assessments	Thomson and others 1997
Transects and grids	Landscape assessments	Maffei and Arena 1993
Permanent plots	Detailed assessments Project monitoring	Hawksworth and Marsden 1990 Lightle and Hawksworth 1973
Project area assessment	Management prescription Stand or Land Unit examination Recreation management Wildlife habitat	Tkacz 1989 Vásquez 1994 Scharpf and others 1988 Parks and others 1999

and others 1996b, Vázquez 1993b, 1994a). Effective and efficient sampling benefits from use of explicit objectives recognizing the resources of interest (such as timber, recreation, wildlife), specification of statistical standards, and consideration of cost and safety issues (Tkacz 1989, and see assistance provided at Forest Service 2002). In this chapter, we identify the major types of dwarf mistletoe surveys, uses of that data, and subjects for research and development.

General Requirements and Procedures

Before selecting or adapting one or more methods, a user should carefully consider and articulate the purpose and scope of the proposed survey. Almost all the available methods for estimating mistletoe occurrence and effects can be adapted to a variety of purposes including timber management, vegetation inventory, recreation, and wildlife management. Many techniques can be adapted to a range of scales from regional or forest landscapes to individual stands or sites. For any management decision, a wide variety of information from numerous sources on various subjects is needed. In areas with significant dwarf mistletoe infestations, data on mistletoe extent, severity, and potential make an important contribution to the decision process (Stage and others 1986, Tkacz 1989). Given the variety of objectives and constraints encountered by managers, only general guidelines can be stated here. The benefits of proposed treatment in each particular case should be evaluated for expected costs and benefits, impacts to other resources, and conflicts with other objectives. Assessments for landscape-scale management usually require only extensive, relatively broad information on dwarf mistletoe occurrence and effects. A general strategy for dwarf mistletoe management in areas of significant occurrence may be sufficient. At the level of particular stands and sites, however, management prescription may require detailed information on resource and ecological conditions and specific data for mistletoe distribution and abundance. Site prescriptions also require consideration of the general principles for managing infested stands (see chapters 7 and 8) as well as local issues and forest-level management objectives.

Several Provinces and States require a professionally certified evaluation of young forests to ensure that damages from insects and diseases are less than specified levels. This is especially important where the previous stand had been infested by dwarf mistletoe because the regeneration process may have left an infected, residual overstory that allowed spread to the seedlings (Alfaro 1985). In British Columbia, evaluations assess whether the young stand is free-growing and contractor obligations satisfied (British Columbia Ministry of Forests 1995); in other regions, this standard is described as producing adequate stocking of healthy seedlings.

Several existing data sources are available for general information on regional occurrence and potential impacts of dwarf mistletoes. These include Forest Inventory and Analysis (2002), Forest Health Monitoring Program (1994), Current Vegetation Survey (2002, Gregg and Michaels Goheen 1997), and the Canadian Forest Insect and Disease Survey (Cerezke and Emond 1989, Moody 1992, Myren and Gross 1977, Wood 1986). Use of these kinds of data is reviewed by Bolsinger (1978), Drummond (1982); limitations are described by Drummond (1978), Hildebrand and others (1997), and Marsden and others (1990).

If archive, large-scale data are either lacking or not sufficient, other established forest management plots are available from standard resource inventories. Data for dwarf mistletoes are relatively easily determined, as described below (see Forest Inventory Plots). For landscape-level surveys, several techniques such as road surveys or aerial photography can be used separately or in conjunction with inventory plots.

Surveys of dwarf mistletoes on a landscape or large geographic area are undertaken to determine the overall returns from a national or regional program or to compare returns from standard operational treatments applied to a large forest area. More frequently, landscape surveys are used to substantiate the general extent and effects of mistletoes and rank areas for treatment priority. Exercises range from botanical surveys for detection and identification of dwarf mistletoe species (for example, Hernandez 1991) to large-scale, annual programs for tracking broad forest health conditions and trends (Forest Health Monitoring Program 1994). Large-scale surveys have been conducted for Canada (Moody 1992, Myren and Gross 1977), the Southwestern States (Andrews and Daniels 1960, Maffei and Beatty 1988), and California (Byler 1978).

Occasionally, there is a need for a detailed dwarf mistletoe survey on a land unit for a specific purpose such as determining disease impacts to forest ecology, stand structure, productivity, or treatment effectiveness. Generally, detailed analyses are feasible only if foresters or specialists have access to agency-endorsed methods or models for analysis of forest growth and dwarf mistletoe effects (for example, British Columbia Ministry of Forests 2000, Forest Management Service Center 2001). These models are useful in developing detailed prescriptions for harvesting, silvicultural treatment, and other management objectives such as visual quality, wildlife, and recreation management. Use of models to predict the effects of dwarf mistletoe damage and analyze benefits from silvicultural treatments is described in chapter 8.

For intensive surveys such as silvicultural inspections and timber cruising, several tree stand attributes related to dwarf mistletoe status are useful. These include dwarf mistletoe species (see chapter 4), extent of infested area, mistletoe incidence as percent of host trees that are infected, and a measure or rating of disease severity such as DMR (fig. 6-1) or other rating for intensity of infection within trees.

Dwarf Mistletoe Surveys

Dooling (1978) summarizes several methods suitable for dwarf mistletoe surveys. The most commonly used methods and recent examples (table 6-1) are briefly described in the following sections.

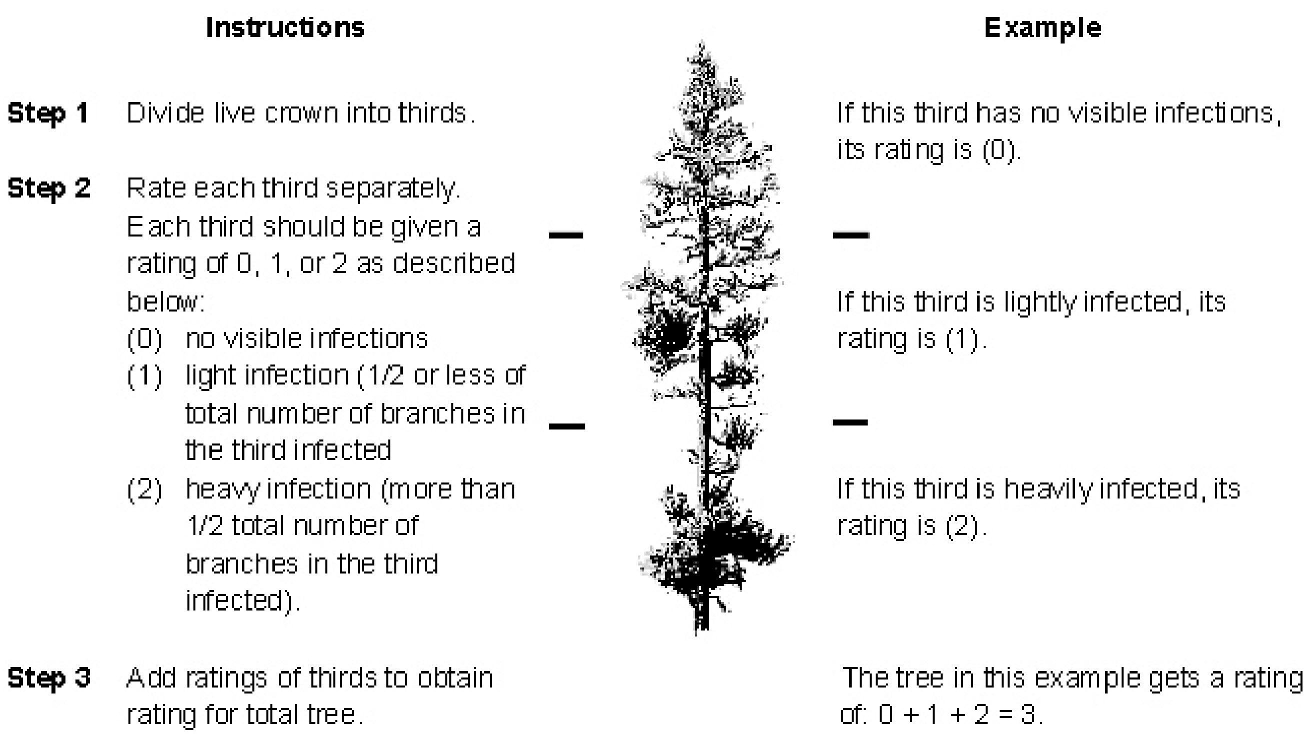

Figure 6-1—Dwarf mistletoe rating system (DMR).

Aerial Surveys

A major technique or approach used for extensive examinations is aerial survey. This technique is described for dwarf mistletoe (*A. americanum*) on jack pine (Robins 1972) and lodgepole pine (Brandt and others 1998), and Eastern spruce dwarf mistletoe (*A. pusillum*) on black spruce (Baker and others 1992). Aerial survey observers can best detect severe infestations by the distinct infection centers associated with heavy mortality and brooming. Total extent and incidence are under estimated. Aerial survey is most practical over low-relief terrain, but rotary-wing aircraft have been used successfully over mountainous areas (Brandt and others 1998, Schwandt and Page 1978). Flight lines are run parallel at intervals of 5 to 10 km (or wider) through areas of susceptible forest types. Fixed, overhead-wing aircraft can be used on clear, bright days at ground speeds of 150 km per hour. One observer alone or one observer on each side of the aircraft draws or sketches the extent of each mistletoe-infested area on an appropriate map (which may be a topographic, forest type, or inventory base map). In some surveys, a lap-top computer with a digital map display of topographic and forest-type features is used with a global positioning system (GPS) to sketch-map directly on the computer screen; this method is in development (L. Rankin, 1999 personal communication). Geographic positions of infested stands can also be located with a GPS-receiver (Brandt and others 1998, Zavala and Zavala 1993). Information is eventually incorporated into a GIS-database. Brandt and others (1998) demonstrate the capability of this technique for mapping the severe damage caused by dwarf mistletoe to jack pine and lodgepole pine for an area of over 28 million ha in Central Canada (Alberta, Saskatchewan, Manitoba).

Aerial Photography

Aerial photography is routinely used for vegetation and forest inventory typing, classification, and sampling. Aerial photography is feasible, however, for landscape dwarf mistletoe surveys only where there are highly distinctive features such as mortality or infection centers. These occur in Central to Eastern, North American forests of black spruce (Baker and French 1991) and jack pine (Muir and Robins 1973). Especially in young infestations, mistletoe infections are often most common in the lower crown and obscure to aerial view. Large-scale aerial photography can be used for individual stands to detect infected trees with large witches' brooms or to identify susceptible tree species and suspect individuals based on various crown attributes.

Forest Inventory Plots

Vegetation or forest inventory sampling is the commonly accepted means of describing and quantifying the forest resource, and it is often the only acceptable data source for projecting dwarf mistletoe impacts on forest growth. Established inventory plots ensure an acceptable sampling scheme and avoid the expense of recollecting associated tree data. Dwarf mistletoe data from routine inventories, however, may have low or uncertain reliability because inventory crews may lack the experience to recognize mistletoe presence and damage (Drummond 1978, Marsden and others 1990). Where inventory plots are reexamined to obtain mistletoe specific data, trained personnel and check cruises are appropriate (Hildebrand and others 1997). Forest inventory plots are often situated by a stratification scheme that if not properly accounted may lead to biased estimates. Nonetheless, this is described and used by several authors including Caballero (1970), Filip and others (1993), DeMars (1980), Gregg and Michaels Goheen (1997), Hildebrand and others (1997).

Surveys for dwarf mistletoes using an existing inventory plot system can be relatively simple and easy to conduct. Each sample tree on the inventory plot is examined and a rating (such as DMR) is recorded. Wide-field, high-quality binoculars (for example, 8x40) are useful; yellow-tinted eyeglasses are not used because they obscure dwarf mistletoe shoots (B. Geils 1999, personal communication). Training and quality checks are appropriate to maintain quality and consistency (Shaw and others 2000).

Growth impacts are calculated from tree data and information for mistletoe severity using the sample design of the inventory (Marsden and others 1990). In many situations, covariate factors are useful. For example, Thomson and others (1997) point out that for lodgepole pine, stand density (number of stems per hectare) has a major effect on tree volume and should be used to adjust estimates. Supplemental data can determine the correlations between radial growth, DMR, tree age, and stand density.

Road and Plot Surveys

Roadside surveys for dwarf mistletoes are popular and suitable for many forests in Western North America with reasonably extensive road access (Andrews and Daniels 1960, Johnson and others 1981, Maffei and Beatty 1988, Merrill and others 1985, Mathiasen and others 1996b, Thomson and others 1997). Good results are obtained in forests of almost pure, even-aged stands of trees at least 20 years old. A vehicle driver and an observer traverse roads through susceptible forest stands at a low speed (say, 30 to 40 km per hour) and rate levels of infestation in segments or fixed intervals (such as 100 to 200 m) along the roads. Data are recorded on inventory maps with cover type information.

Tree infection along roads is usually rated using percentage incidence categories: nil or 0, no infection visible; low, 1 to 33 percent of trees infected; medium, 34 to 66 percent infected; and severe, 67 to 100 percent infected. These data are converted to DMR by correlating roadside incidence ratings with plot DMR. A more direct and probably more efficient method is to directly estimate average DMR along roadsides rather than estimating percentage incidence.

To obtain inventory tree data, fixed-radius or prism plots are established at intervals of 5 to 10 km along roads at a distance 50 m back from the road. On each plot the usual inventory tree measurements are taken for each tree, including DMR (fig. 6-1). Although it is suspected that road development or some forest practices might have increased incidence of dwarf mistletoe at roadside units, Merrill and others (1985) found that incidence at roadsides was similar to that in the adjacent stand (also see Maffei and Beatty 1988).

Although a roadside survey is relatively easy to conduct and produces estimates of growth impacts, it is often difficult to reconcile these results with forest inventory data. Locating plots along roads introduces a sampling bias that may result in substantial discrepancies of tree species volumes and growth estimates between roadside plots and standard inventory plots. Data from a roadside survey as area infested or percent of trees infected cannot be readily incorporated into forest inventory record systems. A potentially more accurate and cost-effective alternative is to move directly to resampling already established forest inventory plots that also have a history of tree growth and mortality.

Transects and Grids

Sample plots systematically distributed as either strip transects or on a gird are another approach for surveying dwarf mistletoe. Transects and grid sampling have been used for landscape-scale surveys (Hawksworth and Lusher 1956, Maffei and Arena 1993), but they are more frequently applied to individual stands. Their use has been largely superseded by vegetation or inventory plots (for example, Current Vegetation Survey 2002).

Permanent Plots

Another type of dwarf mistletoe survey technique is the permanent sample plot system. Hawksworth and Marsden (1990) catalogue a number of these installations. Permanent sample plots are also established to monitor efficacy of management projects (Lightle and Hawksworth 1973). These plots typically are much larger than routine forest inventory plots, have fixed boundaries, and include a map of the position of all plot trees. Given the relatively high costs of establishment and remeasurements, relatively few permanent sample plots have been established recently or are currently being maintained. They are, however, extremely valuable for measuring spatial aspects of dwarf mistletoe spread and intensification and as benchmark stands used to validate simulation models (Taylor and Marsden 1997).

Project Area Assessments

Several methods or techniques for dwarf mistletoe surveys are used primarily to assess stands or sites for a variety of objectives including developing management prescriptions and management of recreation areas and wildlife habitat.

Developing Management Prescriptions—Detailed surveys of stands are used to develop management prescriptions (Tkacz 1989) and for general stand examinations (Mathiasen 1984, Vázquez 1994a).

For dwarf mistletoe infested sites, distribution and severity data are used to assess management options (Hawksworth 1978a, Parmeter 1978, van der Kamp and Hawksworth 1985). The expected effects of a treatment, for example, such as leaving dwarf mistletoe-infected trees on partially or selectively cutover areas, can be evaluated in the specific context in which it is to be applied. These effects can be projected with data representing the actual stand of interest and using the agency-supported growth model or simulation program (for example, PrognosisBC or Forest Vegetation Simulator). The data required from the survey are determined by the requirements of the selected model. Generally these include tree data, DMR (see fig. 6-1), and some ecological classification describing site productivity. Data are usually collected using a grid or series of prism plots or fixed-radius plots according to prescribe methods of the agency (DeMars 1980). Baker and Durham (1997) describe a transect survey for mistletoe in young jack pine and a model to simulate expansion of infection or mortality centers. Marsden and others (1993) evaluate management options for Southwestern ponderosa pine stands with Armillaria root disease and dwarf mistletoe with data from a systematic grid of inventory plots and the Forest Vegetation Simulator. Chapter 8 provides further information on use of models to evaluate silvicultural treatments.

When dwarf mistletoe sanitation practices are planned or have been undertaken, an important consideration is to determine both the potential and realized benefits. In many regions of Western North America, sanitation treatments after harvesting have been a common practice for several years or even decades. Postcontrol or postsuppression surveys and evaluations have been undertaken in several regions (Hawksworth and Johnson 1989b, Knutson and Tinnin 1986, Van Sickle and Wegwitz 1978).

The spatial pattern of infected trees and spatial autocorrelation of mistletoe are important in some situations (Robinson and others 2002). Infected young trees may be clustered around residual infected trees left as blocks, strips, or groups trees. Patterns that deviate greatly from random or uniform toward clusters have significant consequences for sampling design and model projections. The spatial pattern of infected trees and the spatial autocorrelation of mistletoe can be computed from a stem map of the stand of interest or selected from another stand with a similar appearance.

Assessing complex stands—that is, those consisting of two or more tree species, age classes, and height classes — often involves making a compromise between number of locations visited and the detail recorded at each location. Because the dynamics and effects of dwarf mistletoes vary by tree size, it is important that surveys provide data on incidence and severity by tree size class. This can be accomplished by recording DMR and either tree diameter or height for each sample tree and later computing class averages. Alternatively, trees can be grouped into classes and assigned average incidence and severity ratings while the observer is at the plot. With training and experience, observers are able to retain data quality and increase productivity. Vegetation structural stages such as described in table 6-2 or other classification schemes can be used to group trees into size classes. The criteria for determining classes vary by situation but represent canopy structure classes meaningful to the manager. Where there are several mistletoe species with different host tree species, mistletoe incidence and severity should be estimated by structure class for each susceptible tree species.

Assessments of Recreation Areas and Wildlife Habitat—Dwarf mistletoe effects on trees (chapter 5)—including suppression of tree growth, formation of large witches' brooms, and increased mortality—can be important considerations for management of recreation sites and for wildlife habitat. Occasionally, dwarf mistletoe surveys are required for evaluating the need for, or efficacy of, silvicultural treatments (see chapter 8) for these types of management.

Trees in recreation sites are regularly inspected for defects and evaluated for potential hazard to users and facilities (Hadfield 1999, Lightle and Hawksworth 1973, Scharpf and others 1988). Dwarf mistletoe infection is usually included in the inspections. In some areas, as described in chapter 8, infected trees are replaced with other less susceptible tree species. Severely infected trees are pruned to maintain tree vigor. Tree data generally recorded are DMR and an estimate of broom size if these are to be pruned. Infected trees are usually inspected annually or more frequently.

Surveys for dwarf mistletoe in conjunction with wildlife habitat are used for management (Marshall and others 2000) and research (Bennetts and others 1996, Parker 2001, Parks and others 1999a, Reich and others 2000). Information collected about mistletoe includes DMR and usually additional information on broom type, size, and location (Garnett 2002, Hedwall 2000, Tinnin 1998, Tinnin and Knutson 1985).

Table 6-2—Vegetation Structural Stages (VSS), an example of a classification system for describing dwarf mistletoe incidence and severity. (Table excludes VSS class 1, nonforested.)

VSS class	Size class (cm of d.b.h.)	Description
2	2–12.5	Seedlings/saplings
3	12.5–30	Young trees
4	30–45	Mid-age trees
5	45–60	Mature trees
6	60+	Old trees

Evaluations Using Dwarf Mistletoe Survey Data

After a survey is conducted to determine forest-level damage caused by dwarf mistletoe, one or more of several methods are used to project forest growth under different management regimes and evaluate impacts and potential benefits of management programs for dwarf mistletoes (see Power and D'Eon 1991).

One example of this type of evaluation is use of a whole-forest model such as FORPLAN or MUSYC. These models predict timber supplies and possibly other outputs such as wildlife habitat in infested stands under various management regimes. They determine potential returns and benefits of dwarf mistletoe control programs. Landscape or forest-level yield models require both extensive data on dwarf mistletoe occurrence and severity, and response curves based on individual land units or stands, similar to those proposed by Stage and others (1986) for root diseases.

To our knowledge, forest-level evaluations of dwarf mistletoe effects have not yet been reported but they should, however, be relatively simple to develop. Average curves can be developed for average stand conditions, using stand-level models with dwarf mistletoe effects. Growth curves for lodgepole pine infected by dwarf mistletoe are reported by Hawksworth and

Johnson (1989a) and van der Kamp and Hawksworth (1985) and are included in a review of forest growth models by Eav and Marsden (1988).

In evaluating effects of dwarf mistletoe, data used to construct the baseline or "healthy" stand growth curves should be examined. If temporary plot data were used, and plots were located without bias, then empirical growth curves may already include mistletoe effects. Stands that have been treated for dwarf mistletoe, therefore, should grow more than the baseline stands. Growth and yield data for landscape-level analyses, however, are often derived from remeasured plots selected to avoid dwarf mistletoe and other disturbances. If growth curves from these stands were used to represent operational conditions, they represent the growth of "healthy" stands or what is expected when dwarf mistletoe infestations are suppressed. In most analyses, these types of growth curves are usually reduced using one or more "operational adjustment factors" to account for unstocked or unproductive areas (such as swamps or rocky knolls). Tree volumes are also reduced using factors for waste and breakage during harvesting and internal wood decay in live trees. All of these factors and assumptions should be checked and verified as to the manner by which mistletoe effects were incorporated.

Another potentially important use of dwarf mistletoe survey data is to evaluate potential benefits of controlling or preventing effects of dwarf mistletoe on site productivity. Site productivity is one of the major factors affecting sustainability of the forest resource. For an example with lodgepole pine, mistletoe infection at moderate to severe intensities generally reduces growth to such an extent that a forest inventory based on mature trees would underestimate the site index or productivity. Foresters might not be particularly interested in dwarf mistletoe as such. If it were shown, however, that the productivity of the forest land base were substantially underestimated and underutilized and that it could be increased with sanitation, interest may rise.

Further Needs for Surveys and Evaluations

Large-scale, forest-growth projection methods need to be used and modified to accommodate analyses of the actual or potential benefits of dwarf mistletoe control programs. In many regions, more or supplementary data will have to be collected by well-trained personnel in conjunction with forest inventory sampling to provide a more credible basis for determining dwarf mistletoe effects and defining treatment opportunities.

On an individual stand basis, information on spatial patterns of trees and autocorrelation of mistletoe need to be employed in more assessments (Robinson and others 2002). For many stands with complex structures and heterogeneity (see Reich and others 2000), an average DMR does not properly represent conditions where wildfire, windthrow, bark beetles, and mistletoe infestation have created a mosaic of canopy and gaps. Infected trees often occur in or at the edges of residual stands, strips, or patches, or as scattered individual trees; and spread of dwarf mistletoe from these sources is unlike that across a uniform stand (Muir 2002, Edwards 2002).

Detailed dwarf mistletoe surveys of land units are essential for determining effects on forest ecology, stand structure, and productivity or analyzing effectiveness and benefits of silvicultural treatment. These surveys and evaluations, however, are feasible only if foresters or specialists have access to methods or models endorsed by their agencies. Given the increasing complexity of forest management issues, comprehensive and detailed stand-level models are now essential to develop detailed prescriptions for harvesting and silvicultural treatments. These models are needed to ensure that forest ecosystems are managed sustainably and that these treatments do not detrimentally affect other management objectives such as visual quality, wildlife habitat, and recreation management. Although there have been considerable improvements in models in recent years, there is a continuing need for model development for new management scenarios. Access to several models is available from the British Columbia Ministry of Forests (2000) and Forest Health Technology Enterprise Team (2002); other vegetation management tools are at Forest Service (2002). Access to and support for various models are still needed for field foresters to conduct surveys and analyze potential benefits of treatment programs. This is particularly urgent with the increasing need to consider a wide array of effects and objectives such as wildlife and fuel reduction.

Finally, the increasing imperative to manage uneven-aged forest stands infested by dwarf mistletoe necessitates development of indices or measures of tree-to-tree variation of incidence and infection severity of dwarf mistletoe. New or drastically improved models are required to analyze the effects of dwarf mistletoes on trees and the efficacy of silvicultural treatments (including deployment of biological control agents) in these complex situations. Measurements of dwarf mistletoe occurrences and quantitative projections of effects of various forest and stand-level management regimes are essential to guide and help resolve the various, often-conflicting views of desirable forest-resource management strategies.