The Incidence of Dwarf Mistletoe in Minnesota Black Spruce Stands Detected by Operational Inventories

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ABSTRACT

We surveyed black spruce stands within 0.5 miles of US Forest Service Forest Inventory and Analysis (FIA) plots and compared dwarf mistletoe status with that of the FIA and Minnesota Department of Natural Resources (DNR) forest inventories. Our results differed from FIA results in 3 of 16 stands with FIA plots, with FIA most often not recording dwarf mistletoe in infested stands. The infestation status of 140 of 202 surrounding stands was the same as recorded for the nearby FIA plot. Minnesota DNR forest inventory identified dwarf mistletoe in only 26 of 112 infested stands. Using only the most recent FIA plot data, 8% of FIA plots were recorded as infested. Considering an FIA plot to be infested if it was infested at any time in its history raises the percentage of infested FIA plots to 11%. Of the stands we surveyed, 112 of 202 (55%) were infested, but spatial autocorrelation may bias our sample. For the infested stands, dwarf mistletoe is projected to infest 20% of the stand area and reduce timber volume by at least 14% in the current rotation.

Keywords: disease survey

The eastern spruce dwarf mistletoe (*Arceuthobium pusillum*) causes the most important black spruce (*Picea mariana*) disease throughout the range of the species. Anderson (1949) estimated that 3–11% of the black spruce type in the Big Falls Management Unit in Minnesota was out of production because of dwarf mistletoe. This estimate was conservative in that he could only reliably delineate areas of mortality on the aerial photographs, not the entire area of infestation. Further contributing to an underestimate, Anderson was certain that 3% of the area was infested and that another 16% of the area was "questionably" infested. He arbitrarily added half of the questionable class to the 3% to arrive at the 11% figure. However, all of the areas in both classes that he field checked were infested, so the area of mortality could have been as great as 19%. In other surveys of black spruce stands in the Lake States, Anderson and Mosher (1976) found dwarf mistletoe in 17% of stands in the upper peninsula of Michigan, and they later (Anderson and Mosher 1977) reported that an average of 15% of black spruce stands on six national forests were infested. On the Chippewa and Superior National Forests, both in Minnesota, 13 and 11% of stands were infested, respectively.

These pest-specific surveys provide a wealth of information about the overall condition of the resource but are costly in time and resources. Shrinking budgets prevent management agencies from executing many such surveys. Many periodic forest inventories collect information about disease and insect occurrence on inventory plots. Although pathogen and insect data collected from forest in-

ventory plots are often unreliable (See Muir and Moody 2002 and references therein), in at least one case dwarf mistletoe incidence collected by inventory crews was reasonably accurate (Drummond 1978). If inexperienced observers can collect accurate information for any pest, eastern spruce dwarf mistletoe would be among the best candidates. In black spruce stands, this parasite causes large witches' brooms and rapidly kills trees, causing damage that can be obvious to anyone with minimal training (Anderson and Kaufert 1959, Baker and French 1981). The highly aggregated nature of these symptoms makes it difficult to miss dwarf mistletoe damage and to confuse it with other types of damage.

A casual examination of US Forest Service Forest Inventory and Analysis (FIA) data for plots with a pest code of dwarf mistletoe suggested that the parasite occurs on only 5% of black spruce plots in northern Minnesota, which appeared low in light of the studies cited above. The objective of this project was to examine the accuracy of FIA data on incidence of dwarf mistletoe in Minnesota black spruce stands.

Methods

We identified 19 FIA plots on federal, state, or county land in northern Minnesota with >10 ft^2 basal area of black spruce and either dwarf mistletoe or a witches' broom on at least one tree. We also identified the black spruce plot without dwarf mistletoe or witches' brooms nearest to each infested plot. Because of confidentiality requirements, each plot's true location was specified only to
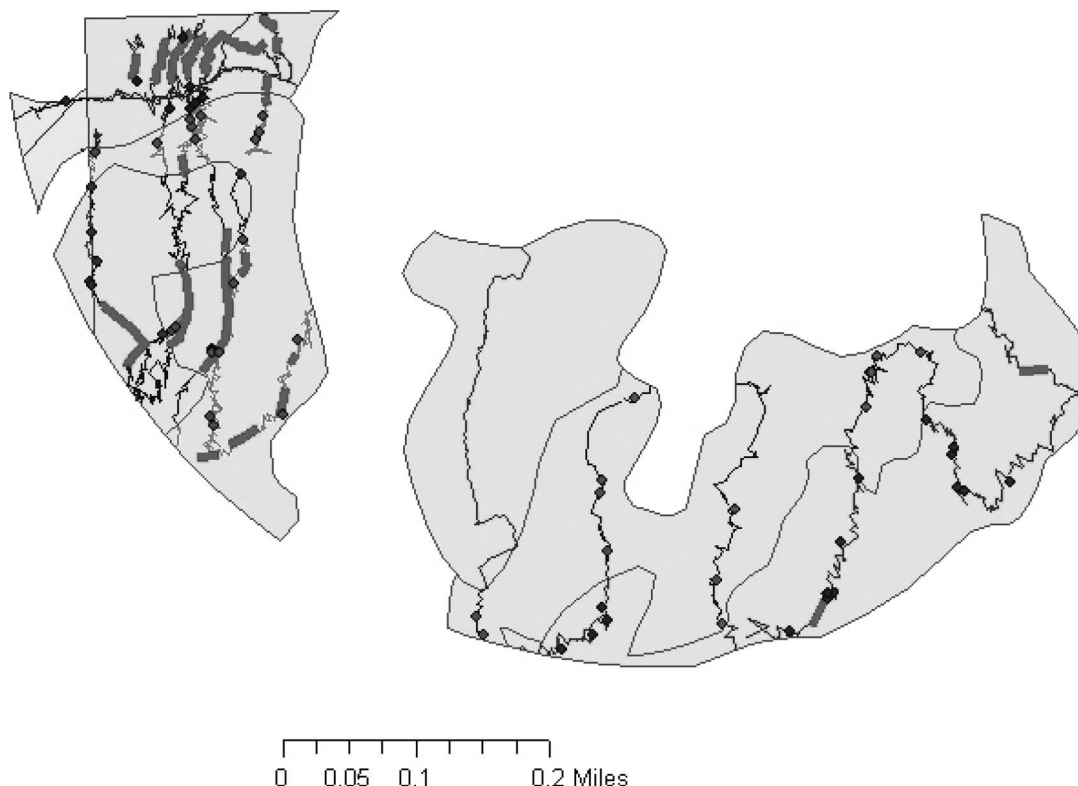
Figure 1. Cluster of black spruce stands within 0.5 miles of approximate US Forest Service Forest Inventory and Analysis (FIA) plot location. The lightest lines represent stand and/or cluster boundaries; light, irregular lines represent survey lines; heavy lines represent parts of survey line with dwarf mistletoe within 100 yards of the survey line; and points represent small groups of infested trees within 100 yards of the survey line.

within 0.5 miles. We used ArcMap (ESRI, Inc., Redlands, CA) to map the given (but deliberately inaccurate) plot locations, and then, using a file containing all black spruce polygons in Minnesota obtained from the Minnesota Department of Natural Resources (MN DNR), we identified all of the black spruce stands within 0.5 miles of each specified point. This group of stands was roughly circular and is called a cluster. We then created transect chords more or less parallel to the north-south diameter of the circle and approximately 200 yards apart, The end points of each chord on the circular cluster boundary represented the beginning and end of survey lines. Points were adjusted to avoid surveying nonhost types and efficiently traverse the stands, and these points were saved into a GPS unit. In the field, we navigated along the transect chords and through the stands within the cluster, recording dwarf mistletoe incidence along the way. If within 100 yards of either side of the transect we observed an infestation, as evidenced by witches' brooms and/or mortality of broomed trees, we recorded (with the GPS unit) when the infestation was perpendicular to the transect and when it was no longer so, giving an infected segment between two waypoints on the chord. If we passed a small group of infested trees, we recorded a single point (Figure 1).

GPS data were differentially corrected and further edited with ArcMap. Prior to analysis, FIA provided accurate locations for each FIA plot. Data were analyzed with ArcMap or SPSS (SPSS Inc., Chicago, IL).

To understand the importance of dwarf mistletoe in the infested stands, we projected the volume losses to a rotation age of 110 years for all infested stands using DMSIM (Baker et al., unpublished data). DMSIM is a modernized version of DMLOSS (Baker et al.

1982) written in Python for use in ArcGis to project spatially explicit impacts of dwarf mistletoe over a rotation. We used infestation data collected during stand surveys to model current dwarf mistletoe location. Stand information was taken from the MN DNR stand shape file. For stands older than 110 years, we calculated only current impacts.

Results and Discussion

We surveyed clusters of stands within 0.5 mi of 31 FIA plots with black spruce. A warm winter prevented freezing of winter roads, limiting access to seven clusters selected for survey. Only 16 of the 31 clusters had FIA plots in a spruce stand we surveyed. This could be due to minor GPS errors or to differing definitions of black spruce stands between FIA and MN DNR. Witches' brooms and dead, broomed trees were easily observed at distances greater than 100 yards. Therefore, we assumed that the survey results represent the actual mistletoe status of the stand. Because we wished to evaluate the accuracy of dwarf mistletoe detection on FIA inventory plots, an important question was how often FIA mistletoe status agreed with our results. The infestation status of three stands with FIA plots differed between our survey and FIA data for a disagreement rate of 18% (Table 1). For all clusters, the disagreement rate was similar, at 20%. Disagreement between survey status and FIA status does not necessarily indicate errors in the FIA survey; it may indicate that the FIA plot was located in uninfested portions of a stand. However, an FIA status of infested and a survey status of uninfested likely indicates a false detection of dwarf mistletoe by FIA crews. False detections were rare, occurring half as often as cases when the survey found dwarf mistletoe but FIA did not.

Table 1. Comparison of survey and US Forest Service Forest Inventory and Analysis (FIA) dwarf mistletoe status for stands with FIA plots and for all clusters.

| | Survey dwarf mistletoe status | | | |
| | Stands | | Clusters | |
FIA plot status	Infested	Uninfested	Infested	Uninfested
Infested	8	1	20	2
Uninfested	2	5	4	5

Table 2. Dwarf mistletoe status of stands within clusters by US Forest Service Forest Inventory and Analysis (FIA) plot status.

| | Survey dwarf mistletoe status | |
FIA plot status	Infested	Uninfested
Infested	97	47
Uninfested	15	43

Table 3. Damage code recorded by Minnesota Department of Natural Resources inventory crews compared with survey dwarf mistletoe infestation status determined in this study.

| | Damage code | | | |
Survey dwarf mistletoe status	None	Dwarf mistletoe	Other	Total
Infested	66	26	20	112
Uninfested	60	10	20	90
Total	126	36	40	202

Table 4. Comparison of Minnesota Department of Natural Resources (MN DNR) and US Forest Service Forest Inventory and Analysis (FIA) dwarf mistletoe status in surveyed stands with FIA plots.

| | MN DNR infestation status | |
FIA plot mistletoe status	Infested	Uninfested
Infested	5	4
Uninfested	1	6

Table 5. Damage code recorded by Minnesota Department of Natural Resources inventory crews compared with dwarf mistletoe infestation status of the nearby US Forest Service Forest Inventory and Analysis (FIA) plot.

| | Damage code | | | |
FIA plot mistletoe status	None	Dwarf mistletoe	Other	Total
Infested	85	30	29	144
Uninfested	41	6	11	58
Total	126	36	40	202

We surveyed parts of 202 black spruce stands, and 112, or 55%, had dwarf mistletoe; 144 of the 202 stands occurred in clusters with at least one dwarf mistletoe–infested stand. Of 144 stands within 0.5 miles of a plot that FIA considered infested, 97 were infested (67%) (Table 2). Conversely, only 15 of 58 (26%) stands within 0.5 miles of an uninfested FIA plot were infested. Of all the stands surveyed, the mistletoe status of 69% of stands agreed with that of the nearby FIA plot. When there was disagreement between survey and FIA dwarf mistletoe status, stands were three times more likely to be infested than uninfested. Thus, if dwarf mistletoe is present on an FIA plot, there is a 67% chance that dwarf mistletoe is present in a stand within 0.5 mi; if dwarf mistletoe is not recorded on an FIA plot, only 26% of nearby stands are likely to be infested. This finding suggests that infestations of dwarf mistletoe are spatially autocorrelated at a scale larger than individual stands. We might expect this from a pathogen with relatively limited dispersal. In another study, we measured statistically and biologically significant spatial autocorrelation for the presence of dwarf mistletoe (Hanks et al., in press).

We also examined the agreement between survey dwarf mistletoe status and pest status as determined from the MN DNR inventory data. MN DNR crews identified dwarf mistletoe in about 23% of the stands we identified as infested (Table 3). This low level of detection is not likely due to miscoding the pests, as most of the disagreement occurred in stands with no pest coded. Considering that we did not survey the entire stand, but only the part that fell within the cluster, we cannot address the situation where our survey failed to detect dwarf mistletoe and the MN DNR inventory did detect it. However, when the survey considered a stand uninfested, MN DNR status agreed 89% of the time, so it appears that MN DNR crews rarely record dwarf mistletoe when it is absent. Twenty stands in the MN DNR inventory were not surveyed by field crews;

excluding these did not appreciably affect the rate of successful classification. Comparing MN DNR data for stands with FIA plots did not improve the accuracy of detecting dwarf mistletoe, and the two surveys agreed 69% of the time (Table 4). Although the sample size was small, MN DNR inventory appeared to be less likely than FIA to detect dwarf mistletoe in infested stands with FIA plots. For all stands in clusters containing an FIA plot, the MN DNR inventory mistletoe status agreed with the status of the FIA plot 41% of the time (Table 5). Agreement was best when FIA considered a plot uninfested. When the FIA plot was considered infested, MN DNR reported dwarf mistletoe in only 21% of the cluster's stands, underestimating dwarf mistletoe incidence. The MN DNR inventory identified 4,688 of 46,755 (10%) stands as infested, but the actual rate must be considerably greater given this evidence that infested stands were under-counted.

During this study we struggled to define what is an infested FIA plot. Ultimately, we arrived at the definition of a plot with >10 ft^2 basal area of black spruce and with a damage agent code for dwarf mistletoe or damage type code for brooms at least once in its history of observation. The requirement for >10 ft^2 of black spruce basal area eliminated plots where dwarf mistletoe may have killed all the trees. Of 835 FIA plots in Minnesota with >10 ft^2 basal area of black spruce, 86 were considered infested, and only 5 were considered infested twice. FIA crews can record dwarf mistletoe as a pest code, and/or record witches' brooms as damage (US Forest Service 2003). Our query of the FIA data in 2005 looked only at current data and only for plots with dwarf mistletoe coded as a pest. Not including witches' brooms or considering all past observations would have lowered our 2005 estimate of the proportion of infested FIA plots. This analysis is further complicated by a change in FIA plot design in 1999 and a varying number of different FIA plots examined each year. Since 2000, the number of plots examined has ranged from 101 to 181. In any one year, the proportion of infested plots ranged from 3 to almost 16%, with an average of about 7%. Whether this is due to randomness, the abundance of dwarf mistletoe in the area sampled, or variability of FIA inventory crew recognition of the disease is unknown.

Once dwarf mistletoe infests an area, it should remain infested. We had multiple observations on 460 plots, but dwarf mistletoe was

Table 6. Comparison of infestation status at initial and subsequent observations for US Forest Service Forest Inventory and Analysis (FIA) plots with multiple observations after 2003 and with dwarf mistletoe indicated at least once.

	Status prior to 2004	
Status after 2003	Uninfested	Infested
Uninfested	389	35
Infested	15	5

Figure 2. Percentage of volume loss by age for surveyed dwarf mistletoe–infested black spruce stands.

observed more than once on only 5 of 55 infested plots with multiple observations, which seems unlikely. There are four potential classes resulting from comparison of the status of a plot before a certain year with its status in subsequent observations: uninfested plots may remain uninfested, uninfested plots may become infested, infested plots remain infested, and infested plots may become uninfested. We cannot detect errors in the first three categories, but plots in the last category suggest failure to recognize dwarf mistletoe in subsequent observations. In many years, two to three times as many FIA plots became uninfested as became infested. For example, 40 plots were considered infested before 2004, only 5 of those were considered infested after 2003 (Table 6). This suggests that crews do not always record dwarf mistletoe when visiting infested plots. Thus, to determine whether a plot is infested, one should examine all records available for that plot.

The presence of dwarf mistletoe does not necessarily indicate extensive losses in infested stands. To quantify impact, we projected volume losses in infested stands to a rotation age of 110 years or quantified current losses if stands were older. We found that 20% of the stands' area was infested, and volume losses were at least 14% of the rotation volume. Volume loss was less in some stands that were beyond rotation age (Figure 2). These stands may not have been harvested because they were marginally productive sites to begin with, and dwarf mistletoes may have reduced their volume enough that a harvest was not economically feasible.

Conclusions

Based on a comparison with ground surveys, FIA plots underestimate the incidence of dwarf mistletoe in black spruce stands. Considering an FIA plot to be infested if it has a damage agent code for dwarf mistletoe or a damage type code for witches' brooms coded at any time in its past can help increase the reliability of this assessment, even if subsequent visits record the plot as infestation-free. Using these criteria, 11% of FIA plots were infested. Compared with the ground survey, the MN DNR inventory also underestimated dwarf mistletoe infestation, finding about 10% of stands with dwarf mistletoe. Our ground survey found dwarf mistletoe in 55% of black spruce stands. Our sample size was small and was rendered less effective because we did not know the exact location of FIA plots prior to fieldwork. Spatial autocorrelation may bias our estimate of
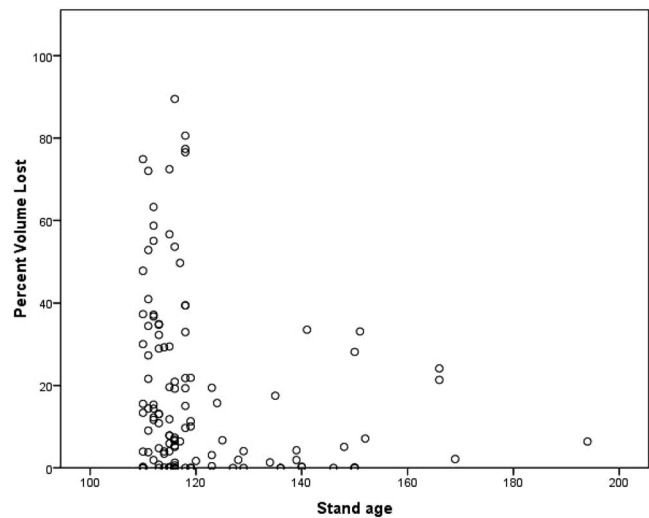
dwarf mistletoe incidence. As more FIA plots are remeasured, the reliability of the infestation level estimated from FIA plots will increase, providing land management agencies with useful information. Knowing the dwarf mistletoe status of these stands is important. In sampled infested stands, at least 14% of the volume will be lost during the current rotation. Errors in inventory dwarf mistletoe assessments and the potential volume losses in infested stands must be considered when determining allowable timber harvest.

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