

Chapter 5. Tree Mortality

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Introduction

Tree mortality is a natural process in all forest ecosystems, but it can also be an indicator of forest health issues. On a regional scale, high-mortality levels may indicate widespread insect or disease problems. Regionally high mortality may also occur if a large proportion of the forests in an area are made up of older, senescent stands.

In previous national technical reports of the National Forest Health Monitoring (FHM) Program of the Forest Service, U.S. Department of Agriculture, mortality was analyzed using FHM data and data from the phase 3 (P3) grid from the Forest Inventory and Analysis (FIA) Program of the Forest Service. Those data spanned a relatively long time period, but the sample was not spatially intense (approximately one plot: 96,000 acres). In this report, a similar method is applied to FIA phase 2 (P2) data as a demonstration of how the more intensive P2 dataset can be used in forest health analyses.

Data

Mortality analysis was possible for areas where data were available from repeated plot measurements using consistent sampling protocols. Repeated annualized P2 plot measurements were available from Iowa, Indiana, Michigan, Minnesota, Missouri, and Wisconsin. Initial plot measurements occurred in 1999 and 2000, and plots were revisited in 2004 and 2005. Two P2 panels of remeasurement data were available for all States except Michigan and Wisconsin, where only one panel had been remeasured. In Minnesota, Michigan, Wisconsin,

and parts of Missouri the P2 plot network had been intensified two to three times, so even with only one or two panels of data, the sample was quite large. Remeasurement data were available for all six States from at least one plot per 15,000 acres. The States included in this analysis, as well as the forest cover within those States, are shown in figure 5.1.

Methods

The FIA P2 tree and sapling data were used to estimate average annual tree mortality in terms of tons of biomass per acre. The biomass represented by each tree was calculated by FIA and provided in the FIA database (version 2.0). To compare mortality rates across forest types and climate zones, the ratio of annual mortality to gross growth (MRATIO) is used as a standardized mortality indicator (Coulston and others 2005d). Exactly two measurements of each plot were available in the dataset. The gross growth and the mortality over the interval between each pair of plot measurements, in tons of biomass per acre, were calculated for each plot. Then, average growth and mortality rates were independently estimated for each ecoregion section (Cleland and others 2005) using simple linear regression.¹ MRATIOS

¹ In previous FHM reports (Coulston and others 2005a, 2005b, 2005c, 2005d) growth and mortality rates were estimated using a more complex mixed modeling procedure (Smith and Conkling 2004). The mixed model was most useful at efficient estimation using data where not all plots had been measured at the same time intervals (Gregoire and others 1995). Because the FIA P2 data used here had all plots measured on a 5-year cycle with exactly two measurements of each plot and 80 percent overlap of the time intervals between measurements, a simpler linear regression model was used.

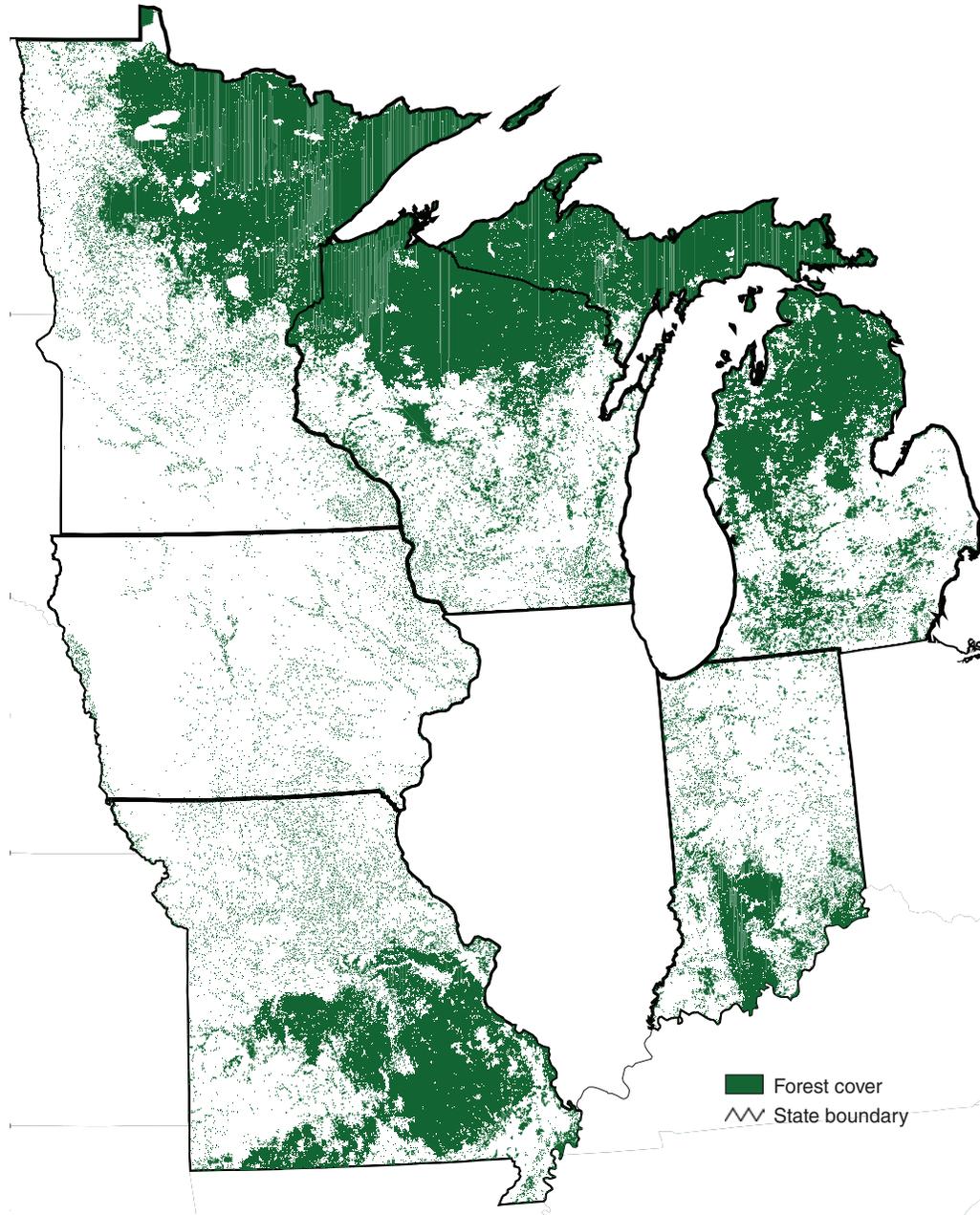


Figure 5.1—Forest cover in the States where mortality was analyzed. Forest cover was derived from Advanced Very High Resolution satellite imagery (Zhu and Evans 1994).

were then calculated from the growth and mortality rates.

The value of the MRATIO is that it normalizes mortality by growth rate, allowing a comparison of mortality rates across diverse regions of the United States. For analyses of smaller areas of the country within which growth rates are similar, it may be more useful in general to consider absolute measures of mortality. The MRATIO was used as the mortality indicator for this report even though the available data were limited to a relatively small region (fig. 5.1) as a demonstration of how this method may be applied using FIA P2 data.

The MRATIO can be large if an overmature forest is senescing and losing a cohort of older trees. If forests are not naturally senescing, a high MRATIO (> 0.6) may indicate high mortality due to some acute cause (insects or pathogens) or generally deteriorating forest health conditions. An MRATIO value > 1 indicates that mortality exceeds growth and live-standing biomass is actually decreasing.

In addition, the ratio of average dead-tree diameter to average live-tree diameter (DDL ratio) was calculated for each plot where mortality occurred. Low DDL ratios (much < 1) usually indicate competition-induced mortality typical of young, vigorous stands, while high ratios (much > 1) indicate mortality associated with senescence or some external factors such as insects or disease (Smith and Conkling 2004). Intermediate DDL ratios can be hard to interpret because a variety of stand conditions can produce such values. The DDL ratio is most

useful for analyzing mortality within regions that have high MRATIOS. High DDL values in regions with very low MRATIOS may indicate small areas experiencing high mortality of large trees or locations where the death of a single large tree, such as a remnant pine in a young hardwood stand, had produced a deceptively high DDL.

To further analyze tree mortality, the number of stems and total biomass of trees that had died were calculated by species within each ecoregion. Identifying the tree species experiencing high mortality in an ecoregion is a first step in identifying what forest health issue may be affecting the forests. Although determining particular causal agents associated with observed mortality with certainty is beyond the scope of this report, often there are well-known insects and pathogens that are “likely suspects” once the affected species are identified.

Results and Discussion

The MRATIO values are shown in figure 5.2. The highest MRATIO (1.04) occurred in ecoregion section 251G—Missouri Loess Hills (previously named 251G—Central Loess Plains; McNab and Avers 1994). Other areas of high mortality relative to growth occurred in northern Minnesota, in ecoregion sections 212L—Northern Superior Uplands, 212M—Northern Minnesota and Ontario, and 222N—Lake Agassiz, Aspen Parklands.

Results of the analysis of the relative sizes of trees that died, the DDL ratio, is shown in figure 5.3. DDL values vary widely within any

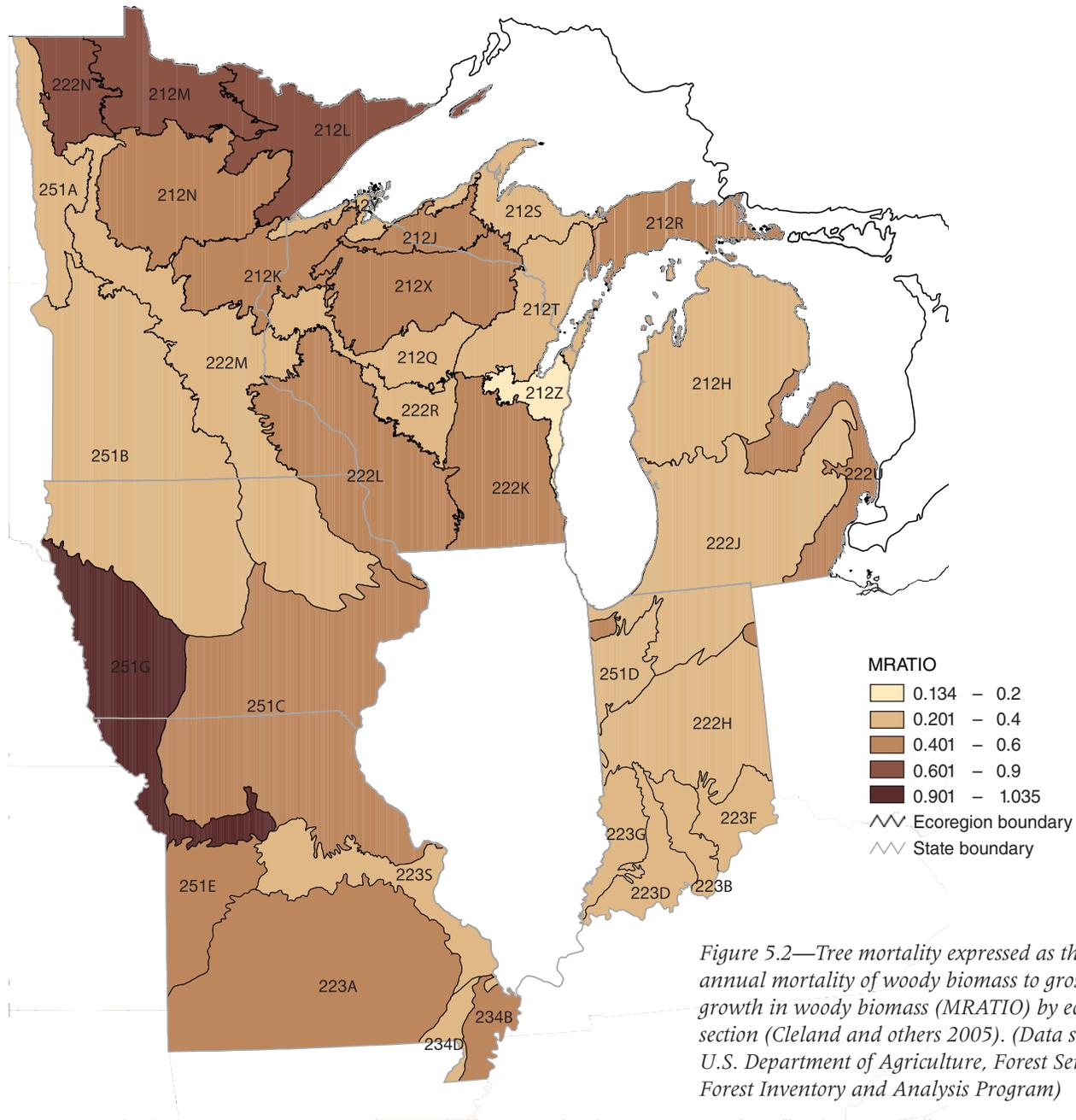
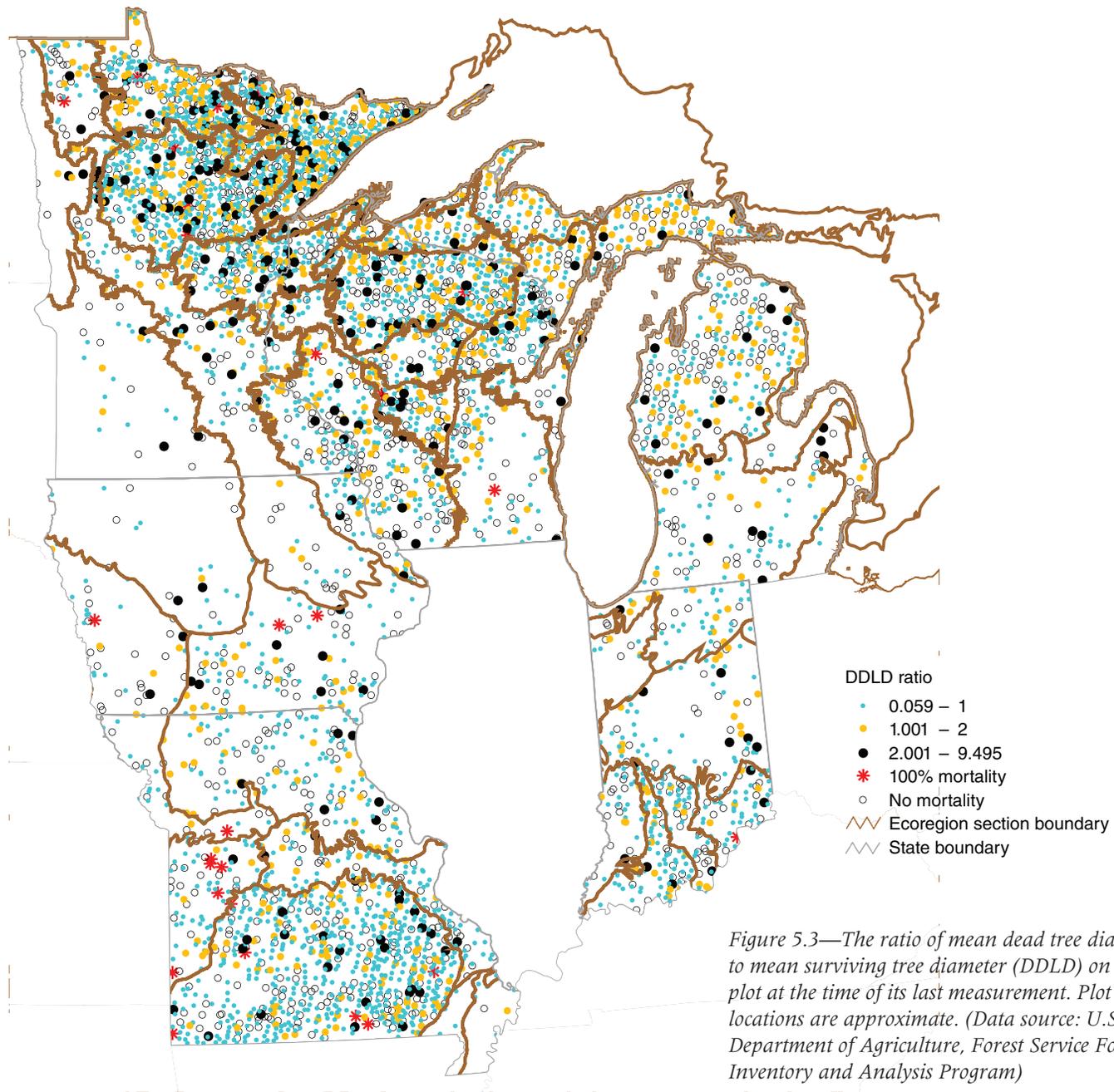


Figure 5.2—Tree mortality expressed as the ratio of annual mortality of woody biomass to gross annual growth in woody biomass (MRATIO) by ecoregion section (Cleland and others 2005). (Data source: U.S. Department of Agriculture, Forest Service Forest Inventory and Analysis Program)



given ecoregion section. Although many plots have high DDLs, often times the actual level of mortality is very low, as would be the case when remnant larger trees die, leaving young, vigorous stands behind. To focus attention on those plots where mortality was high and where mostly large trees were dying, the proportion of the plot biomass that died over the measurement cycle was calculated for each plot. Figure 5.4 shows the DDLs for only those plots where more than 30 percent of the biomass died.

In both areas having high MRATIOS, ecoregion section 251G—Missouri Loess Hills, and sections 212L—Northern Superior Uplands, 212M—Northern Minnesota and Ontario, and 222N—Lake Agassiz, Aspen Parklands (fig. 5.2), there were several plots where either all the trees died or the DDL was very high (> 1.5), while on many other plots, the DDL was in the intermediate range (0.751 to 1.5), where dying trees were about the same size as survivors. These DDL values suggest that the observed mortality was generally not all competition induced but rather associated with some acute cause(s), (e.g., insects, pathogens, extreme weather) or stand senescence.

Ecoregion section 251G—Missouri Loess Hills, where the MRATIO was highest, does not contain very much forest (figs. 5.1 and 5.2). In that ecoregion the largest amount of biomass that died was American elm (*Ulmus americana*). About 40 percent of the elms (in terms of both number of stems and biomass) died over the measurement cycle. American elm was also the

tree that had died most frequently in adjacent ecoregion sections 251B—North-Central Glaciated Plains and 251C—Central Dissected Till Plains. Elm mortality was likely due to Dutch elm disease.

The other areas of high mortality relative to growth occurred in northern Minnesota, in ecoregion sections 212L—Northern Superior Uplands, 212M—Northern Minnesota and Ontario, and 222N—Lake Agassiz, Aspen Parklands. In those ecoregions, quaking aspen (*Populus tremuloides*) was the species that died most frequently. Aspen was also the species exhibiting highest mortality (in terms of biomass) in nearby areas of Minnesota, Wisconsin, and Michigan [fig. 5.2; ecoregion sections 212H—Northern Lower Peninsula (of Michigan), 212Q—North Central Wisconsin Uplands, 212T—Northern Green Bay Lobe, 212N—Northern Minnesota Drift and Lake Plains, 212K—Western Superior Uplands, 212X—Northern Highlands, 222K—Southwestern Great Lakes Morainial, 222M—Minnesota and Northeast Iowa Morainial-Oak Savannah, 222R—Wisconsin Central Sands, and 251A—Red River Valley].

Recent “Forest Health Highlights for Minnesota and Wisconsin” describe drought (Minnesota Department of Natural Resources, Forest Service, U.S. Department of Agriculture, 2004) and major outbreaks of forest tent caterpillar (Minnesota Department of Natural Resources, Forest Service, U.S. Department of Agriculture, 2002, 2004; Wisconsin Department

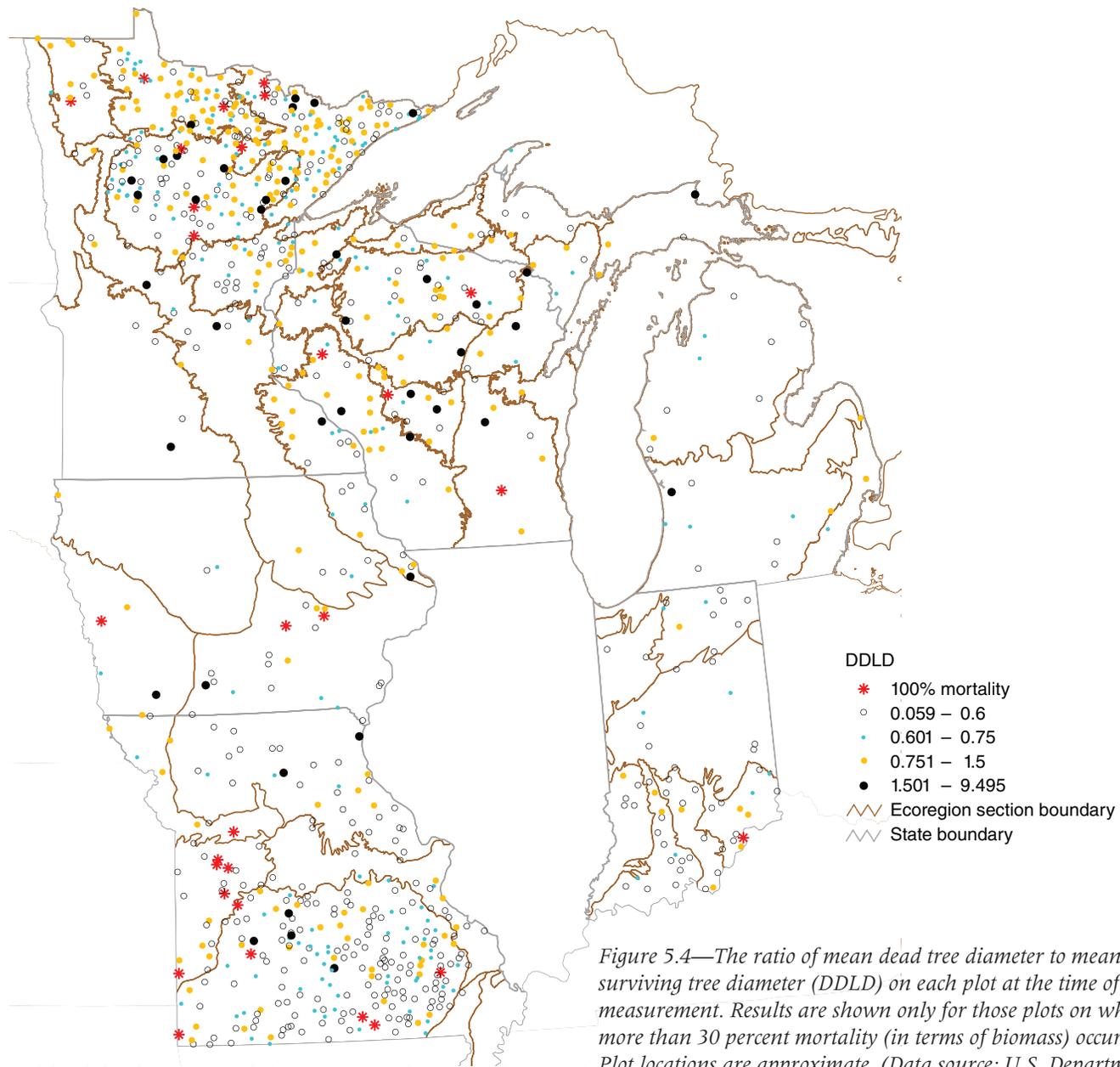


Figure 5.4—The ratio of mean dead tree diameter to mean surviving tree diameter (DDL D) on each plot at the time of its last measurement. Results are shown only for those plots on which more than 30 percent mortality (in terms of biomass) occurred. Plot locations are approximate. (Data source: U.S. Department of Agriculture, Forest Service Forest Inventory and Analysis Program)

of Natural Resources, U.S. Department of Agriculture, 2001, 2002) as causal agents that led to widespread aspen and birch mortality in the region. Gypsy moth also is present in Michigan and eastern Wisconsin (Michigan Department of Natural Resources 2004; Wisconsin Department of Natural Resources, Forest Service, U.S. Department of Agriculture, 2002) and may be contributing to aspen mortality. Mature aspen stands can experience sudden deterioration and heavy mortality over very short-time periods (Frey and others 2004). This phenomenon is not thoroughly understood, but factors that predispose aspen stands to deterioration include climate (Hogg and Hurdle 1995), age (Brandt and others 2003), and stand structure (Mueller-Dombois and others 1983), while inciting factors include drought (Hogg and others 2002) and insect defoliation (Candau and others 2002, Hogg and others 2002).

In future years, as more FIA P2 data are collected, these mortality analyses will be expanded to larger areas of the United States. The MRATIO and DDLI indicators should prove more useful as area of mortality analysis includes a greater variety of ecological regions and forest types.

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