Chapter 12. Tracking Population Loss in *Cornus florida* Since Discovery of *Discula destructiva*, Causal Agent of Dogwood Anthracnose, in Eastern North America

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Introduction

The purpose of this evaluation monitoring project was to document the losses of flowering dogwood, *Cornus florida* (L.), an important ornamental and wildlife tree that grows across much of Eastern North America. The project was prompted in 2001 by the apparent abundance of flowering dogwoods along roadsides in the Morgantown, WV, area, despite a history of severe impacts ascribed mainly to dogwood anthracnose. The native range of dogwood extends from southeastern Canada and Maine south to Florida and as far west as Kansas and Texas (McLemore 1990). However, during the past 20 to 30 years, dogwood has been suffering from the impacts of Discula destructiva (Redlin 1991), causal agent of dogwood anthracnose. This project was based on more than 20 years of cooperative work between employees and their contractors from five States—Maryland, Tennessee, Virginia, West Virginia, and North Carolina—and forest health specialists from three Federal programs—the Forest Health Protection Program of the Forest Service, U.S. Department of Agriculture; the Southern Research Station of the Forest Service; and the National Park Service, U.S. Department of the Interior.

The main objective of this project was to determine the potential impacts to dogwood following the introduction of dogwood anthracnose. Analyses were based on the spatial patterns of reductions in dogwood occurrence and the relationships to various ecological and environmental factors thought to be important in disease development, in particular aspect, elevation, and distance to streams. The purpose of this study was to use data from the Forest Inventory and Analysis (FIA) Program of the Forest Service (Miles 2005) to document the population structure of *Cornus florida* and how that has changed, if at all, after discovery of *D. destructiva* in the 1970s. After initial results from the first portion of this study were gathered, a series of transect plots were established to enhance population estimates with an estimate of tree health. The final step was to attempt to determine if there was a pattern to where dogwood still occurs and if there were differences in tree health between ecoregions.

This study comprised three separate components: (1) the estimation of regional change in dogwood population using a mixed model approach to analyze FIA data, (2) the examination of current health conditions of dogwoods on 102 transect plots, and (3) collection of data from permanent monitoring plots in North Carolina (1988–2008) to determine the role of anthracnose in dogwood mortality. Although observed mortality cannot simply be linked to dogwood anthracnose even within the permanent plots, any analyses investigating a decline for this species need to consider anthracnose as a critical factor. Other significant factors affecting dogwood health may include anthropogenic factors (e.g., pollution), other diseases, insects, but assigning cause to mortality even where positive infections for *D. destructiva* were found was outside the scope of this study.

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Methods and Results of the Three Project Components

Component 1: A Mixed Model Approach for Examining Forest Inventory and Analysis Data to Document the Decline in *Cornus florida* since Dogwood Anthracnose Appeared (1984 to 2004)

Methods and materials—For this project, FIA data for Maryland, North Carolina, Tennessee, Virginia, and West Virginia were analyzed to determine what, if any, changes have occurred with the population structure of dogwoods since the discovery of *D. destructiva*. The three most recent measurement cycles of FIA data were analyzed. Only remeasured fixed-area plots were analyzed. If the FIA plots contained no living or dead dogwood at the initial measurement, the plots were dropped from the analysis. Plots were also dropped if there were irreconcilable errors in the data, making the analysis of that plot invalid for this study (e.g., incorrect year of measurement, aspect, or elevation).

The structure of the FIA plots by ecoregion and dogwood anthracnose hazard class is listed in table 12.1. For analyses, measurement years were grouped into Cycle 1, Cycle 2, and Cycle 3. Table 12.2 lists year of inventory and whether FIA data were derived via periodic (P) or annualized (A) surveys. However, since in

Table 12.1—Data structure of the number of Forest Inventory and Analysis plots per ecoregion and the number of plots in each of the six disease hazard classes

		Disease hazard class					
Ecoregion[a]	n	None	Very Low	Low	Moderate	High	Severe
Allegheny Mountains	673	0	179	240	226	15	13
Coastal Plain	1228	0	1057	7	164	0	0
Cumberland Mountains	2479	0	962	662	700	150	5
Northern Blue Ridge	1615	0	100	337	796	199	183
Piedmont	3200	0	2046	435	688	25	6
Southern Blue Ridge	1168	4	51	117	582	125	289
Upper Gulf Coastal Plain	518	0	482	25	11	0	0
Total	10,881	4	4,877	1,823	3,167	514	496

[a] Ecoregion = Subsections
Coastal Plain = 232Aa, 232Ab, 232Ac, 232Ad, 232Ca, 232Cb, 232Ce, 232Cg, 232Ha, 232Hb, 232Hc, 232Hd, 232Ia, 232Ib, 232Jb
Piedmont = 221Da, 221Db, 221Dd, 221De, 231Af, 231Ia, 231Ib, 231Ic, 231Id, 231Ie, 231If, 231Ig
Mountains = M221Aa, M221Ab, M221Ac, M221Ba, M221Bc, M221Bd,M221Be, M221Bf, M221Ca, M221Cb, M221Cc, M221Cd, M221Ce, 221Ea, 221Eb, 221Ec, 221Eg, 221Ei, 221En, 221Ha, 221Hb, 221Hc, 221Hd, 221He, 221Ja, 221Jb, 221Jc, 222Hc, 223Fa, 223Fb, 223Fd, 231Cd, 231Cg, 231Ba

all cases the cycle covered multiple years, the number of live dogwood trees per acre was included for all years within the study period to determine the annual rate of change. Data were analyzed using a mixed model procedure [PROC MIXED SAS] (SAS Institute 1996) using the REPEATED statement. This creates a temporal covariance matrix within each ecoregion to ensure valid estimates and tests. Since the measurement years differ between States, the values for the years 1984, 1994, and 2004 are empirical Best Linear Unbiased Predictions (BLUPs) for each major ecoregion using the ESTIMATE statement as presented in figure 12.1. For establishment of 1984 as the baseline population, State forest health specialists were contacted for each of the five States to confirm or reject the assumption that data for Cycle 1 were not significantly contaminated (i.e., mortality was considered to be at the expected baseline). They concluded that dogwood anthracnose was not a significant cause of mortality affecting data from the 1980s for the five States, so the baseline was set to 1984.

Results—The number of live dogwood is decreasing in all ecoregions. A test of equal slope was made using the CONTRAST statement in PROC MIXED. The trend for mortality in the Northern Blue Ridge is significantly greater (p <0 .01) than the Piedmont and Coastal Plain (fig. 12.1). There were no significant differences in sub-regions within the three coastal plains, piedmont, and mountains ecoregions (fig. 12.2).

Table 12.2—Definition table for Forest Inventory and Analysis measurement Cycle 1, Cycle 2, and Cycle 3 of year of inventory and type (P=Periodic survey and A=annualized survey)

State	Cycle 1	Cycle 2	Cycle 3
MD	1983 (P)	1999 (P)	2004 (A)
NC	1984 (P)	1990 (P)	2000 (A)
TN	1989 (P)	1999 (P)	2003 (A)
VA	1984 (P)	1992 (P)	2004 (A)
WV	1989 (P)	2000 (P)	2004 (A)

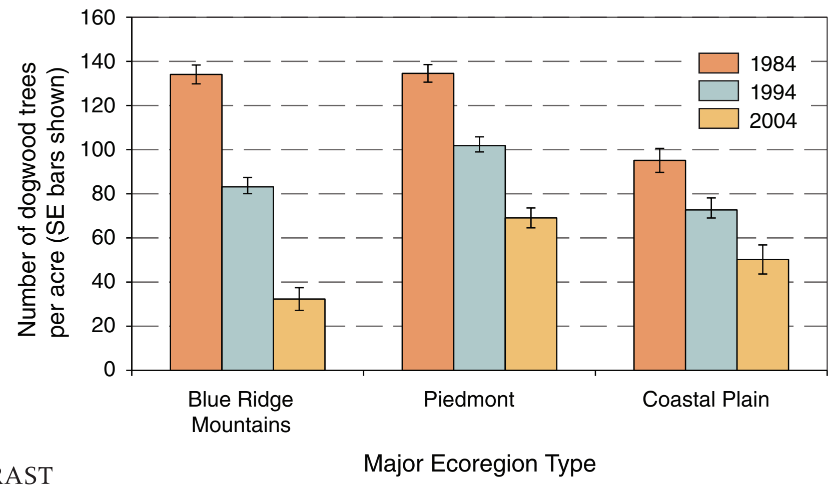

Figure 12.1—Change in the unweighted mean number of dogwoods trees per acre from Cycle 1 (1980s), Cycle 2 (1990s), and Cycle 3 (2000s) in the Coastal Plain, Piedmont, and Northern Blue Ridge Mountain ecoregions. (Data source: U.S. Department of Agriculture Forest Service, Forest Inventory and Analysis Program)

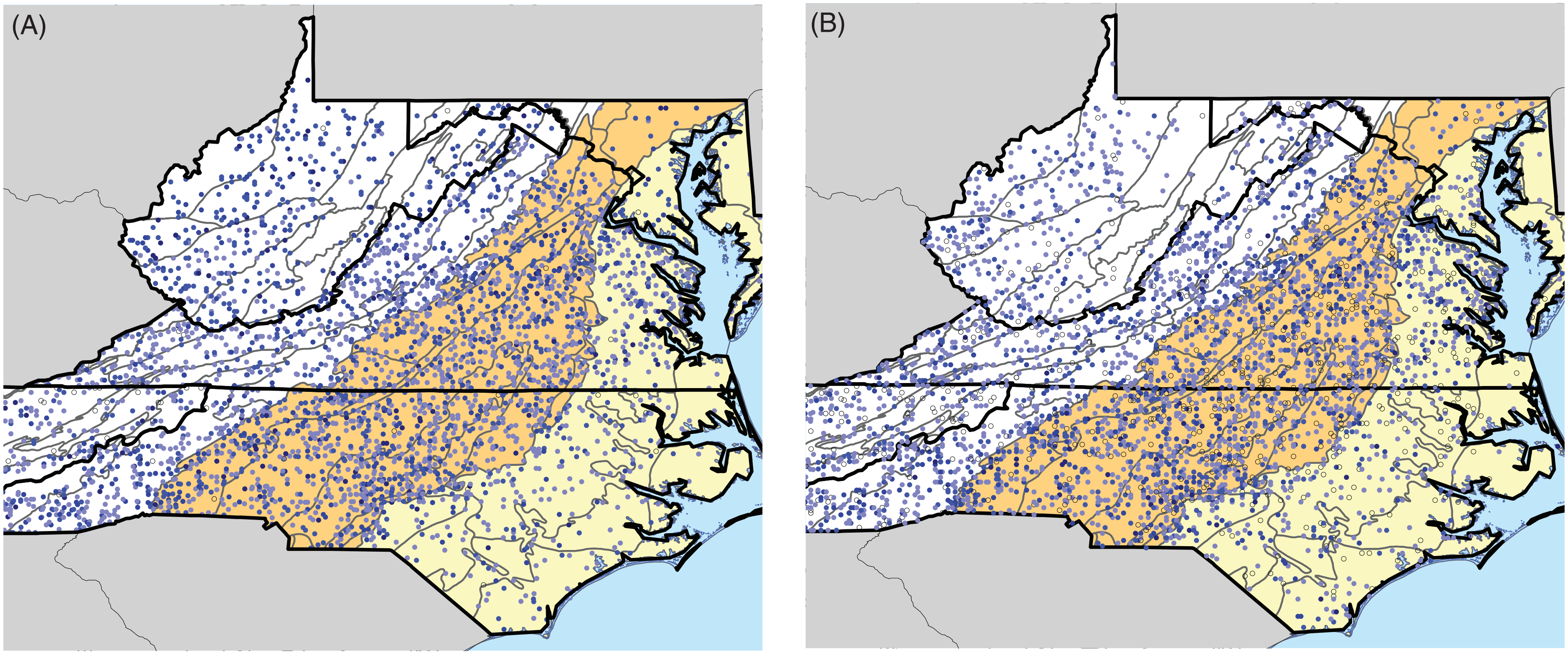

Figure 12.2—Change in the number of dogwood trees per acre from the past three Forest Inventory and Analysis (FIA) measurements, Cycle 1 (A), and Cycle 2 (B). The regions are identifed as: mountains—white background; piedmont—tan background; coastal—yellow background. Plot locations are approximate. *(continued on next page)*

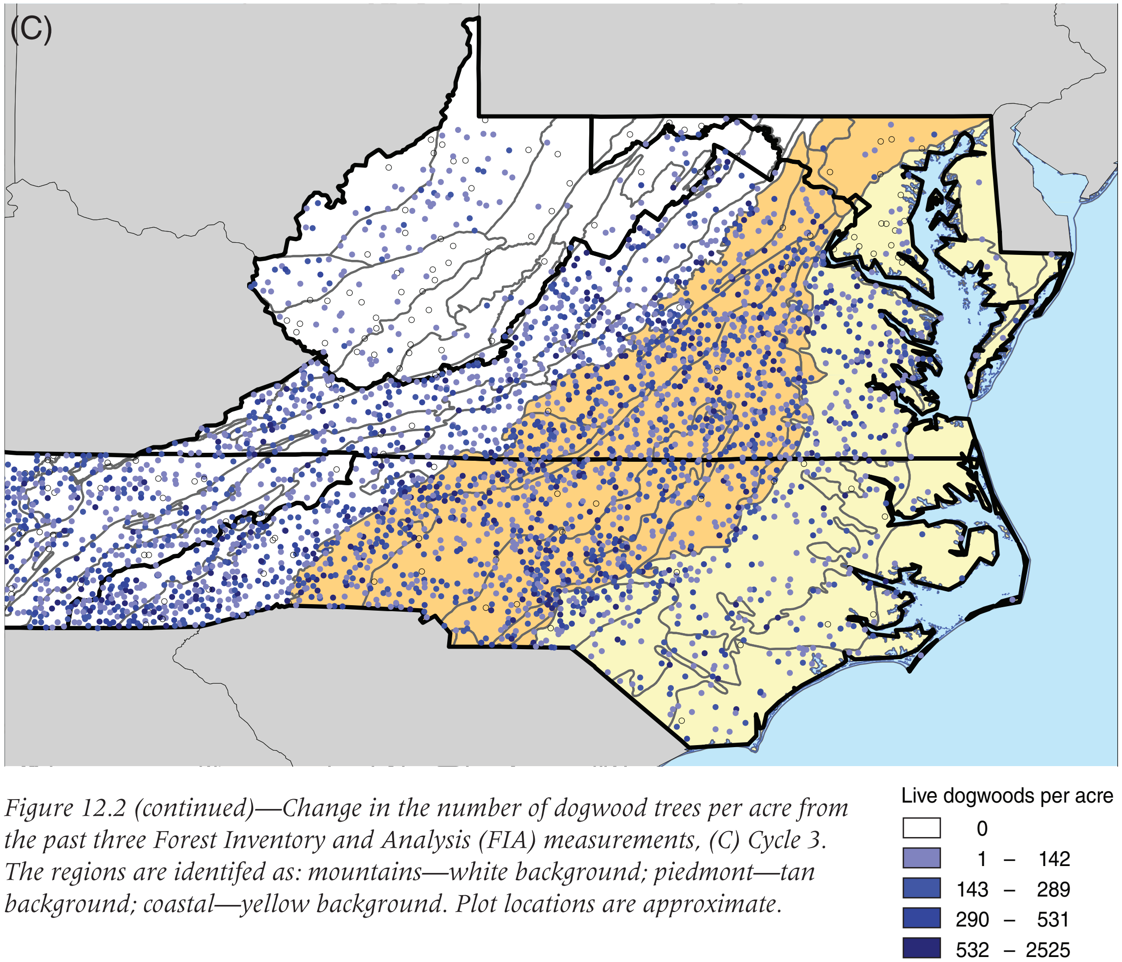

Figure 12.2 (continued)—Change in the number of dogwood trees per acre from the past three Forest Inventory and Analysis (FIA) measurements, (C) Cycle 3. The regions are identifed as: mountains—white background; piedmont—tan background; coastal—yellow background. Plot locations are approximate.

Component 2: Transect Data

Methods and materials—During the spring and summer of 2006, 102 transect plots were established in North Carolina and Tennessee to evaluate dogwood condition, crown position, and tree health. Plots consisted of four transects in the cardinal directions (north, south, east, and west) that were 5 feet wide and 330 feet long. All dogwoods with tree center falling on or within transects were tallied. The distance from transect origin, diameter at breast height (d.b.h.), (inches) and the tree's status as live or dead was recorded. For live trees additional information was collected including: presence of stem cankers, percent of anthracnose-diseased foliage (including attached and dead foliage), percent of fine-twig dieback, percent crown transparency, percent crown density, crown position in canopy, crown light exposure (CLE), and the distance and direction from base of tree to a large canopy opening (feet).

Results—A total of 453 live and 300 dead dogwood (39.8 percent) were intercepted on the 102 transect plots. Using an area expansion for each plot, the mean number of live dogwood trees per acre was 27.7 (SE 4.3) trees per acre. The mean number of dead dogwood trees per acre intersected was 16.4 (SE 3.2) dead trees per acre. Live dogwood were small understory trees with a mean diameter of 2.3 inches (SE 0.1).

On average, the coarse tree health measurements were: 70.1 percent of live trees possessing stem cankers, 20.1 percent (SE 0.1 percent) of crowns impacted by foliar infections, and crowns possessing 20.2 percent (SE 0.7 percent) mean crown dieback. In terms of crown health ratings, approximately 50 percent of the dogwood was classified as "unhealthy" (> 25 percent foliar crown infections). On only two occasions was dogwood regeneration (trees too small to have a d.b.h. but fell on transect) intercepted by transects, a rate of only one dogwood per 15.1 miles of transect.

Component 3: Permanent Dogwood Monitoring Plots Maintained in North Carolina (1988–2006)

***Methods and materials*—**From 1988 to 2006, the North Carolina Division of Forest Resources maintained permanent monitoring plots to track the condition of flowering dogwood, particularly in the mountainous western parts of the State. The methods and data forms used to collect data were previously published (Knighten and Anderson 1993) but the results from 1993 through 2006 have not been previously reported.[4] Plots consisted of the closest 10 flowering dogwood trees to a plot center located on a random stratified 15-minute grid system. Locations were determined with the aid of topographic maps. If fewer than 10 trees could be located near plot centers the locations were retained, but if no dogwood were present in a 1-mile radius of the plots, they were abandoned. If all 10 trees died, plots were also abandoned and not revisited. The total number of trees tracked in North Carolina was 293 trees on 31 plots. These 31 plots were part of a larger regional project involving 210 plots across seven States in the Southeastern United States, but only North Carolina has visited plots continuously since 1993 on a yearly basis.

The basic tree health information collected between 1993 and 2005 was dieback class, diameter (d.b.h.), height, infection presence, and whether a leaf sample was obtained to culture *Discula*. Once a tree was laboratory-confirmed as being *Discula*-positive, that tree was maintained as "positively infected" in the database but no longer resampled to culture the fungus. Crown ratings were based on a six-point scale from 0 to -5 based on the Mielke-Langdon dieback classes (Mielke and Langdon 1984):

0 = tree dead
1 = greater than 75 percent of foliage affected
2 = 51–75 percent of foliage affected
3 = 26–50 percent of foliage affected
4 = less than 25 percent of foliage affected
5= healthy

***Results*—**Approximately 80 percent of dead trees had confirmed *D. destructiva* infections. As of 2006, 245 of the 294 (85 percent) flowering

[4] NCDFR. Unpublished data. 1993–2006. On file: NCDFR, 1616 Mail Service Center, Raleigh, NC 27699-1616.

dogwoods in the permanent plots had died. Of the dead trees, 67 percent (196 trees) died after being confirmed as positive for infection. However, of the 43 trees still alive as of 2006, 79 percent had also been confirmed as positively infected by anthracnose. Since 2000, mean crown rating for living trees has remained relatively constant. Prior to 2000, mean crown rating had declined steadily from a high of 5.0 in 1989 to a low of 2.3 in 2002. As of 2000, no trees were rated "healthy," or a crown rating equal to five. Of surviving trees, those infected during the secondary peak infection year of 1999 were in the poorest health.

Conclusions

A breakdown of mortality by ecoregion showed there were some significant differences, but there were reductions in all ecoregions examined ranging from -2.3 percent to -6.3 percent of the trees per year. Rather than an indication that disease pressure has been reduced via significant host plant reductions, the rate of mortality has increased in the past 10 years compared to the previous decade (fig. 12.1). With nearly 2 billion trees dying per decade, the rate and scale of mortality from dogwood anthracnose is akin to other North American forest pandemics including chestnut blight (causal agent: *Cryphonectria parastitica*) and Dutch elm disease (causal agent: *Ophiostoma novo ulmi*).

Although this project was prompted by the observation of abundant dogwoods flowering along roadsides in areas of Maryland and West Virginia, an analysis of population trends show that dogwoods have been significantly impacted and further decreases can be expected. This project has demonstrated the utility of FIA data to document wide-scale population declines and the need for more site-specific studies. Although dogwood does not appear to have been eliminated from any portion of its range, there is currently little understanding of the role dogwood trees play as an associate forest species. We conclude that dogwood has been significantly impacted throughout the study area.

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