Open Journal of Forestry
2012. Vol.2, No.2, 41-53
Published Online April 2012 in SciRes (http://www.SciRP.org/journal/ojf)
http://dx.doi.org/10.4236/ojf.2012.22006

An Assessment of Flowering Dogwood (*Cornus florida* L.) Decline in the Eastern United States

Christopher M. Oswalt[1], Sonja N. Oswalt[1], Christopher W. Woodall[2]
[1]Forest Inventory and Analysis, United States Department of Agriculture Forest Service Southern Research Station, Knoxville, USA
[2]Forest Inventory and Analysis, United States Department of Agriculture Forest Service Northern Research Station, St. Paul, USA
Email: soswalt@fs.fed.us

Received February 19th, 2012; revised March 23rd, 2012; accepted March 31st, 2012

Cornus florida L. is one of the most numerous tree species in the Eastern United States (US). Multiple studies have reported localized declines in *C. florida* populations following the introduction of the destructive fungus *Discula destructiva* Redlin (dogwood anthracnose), but few, if any, have documented changes in *C. florida* populations across the species' entire natural range. Thus, a current assessment of the *C. florida* population in the Eastern US and implications for future sustainability is warranted. Our study's goal was to present *C. florida* population estimates across the natural range of the species (Little, 1971) in the Eastern US for two periods based on state-level forest land inventories conducted by the US Department of Agriculture Forest Service, Forest Inventory and Analysis (FIA) program. Rangewide, *C. florida* populations declined by approximately 49% over the time periods studied. At the State level, population declines occurred in 17 out of 30 states and biomass declines occurred in 20 out of 30 states studied. While declines were widespread in the substate units surrounding the Appalachians, the largest declines appeared to be centered within the Appalachian ecoregion.

Keywords: Forest Inventory; Population Decline; Tree Disease; *Discula destructiva*

Introduction

Cornus florida L. (flowering dogwood) is widely distributed across the eastern landscape of the United States (US) and is one of the most common understory trees in North America (Jenkins & White, 2002). Little (1971) describes the *C. florida* geographical distribution as covering the majority of the Eastern US from northern Florida and the Gulf Coast to southern Michigan and New England and extending as far west as eastern Oklahoma and eastern Texas. Although *C. florida* is an important member of the eastern deciduous forest, the species has been and is currently experiencing localized and regional declines. *Cornus florida* declines have largely been attributed to an imported fungus (Britton, 1994). The fungus *Discula destructiva* Redlin (dogwood anthracnose) (Mielke & Langdon, 1986; Redlin, 1991; Chellimi et al., 1992) has been identified as responsible for considerable *C. florida* mortality throughout the East, particularly in the Appalachian ecoregion (Oswalt & Oswalt, 2010).

Botanical surveys conducted throughout the 20th Century have documented the abundance of *C. florida* in the Eastern US (Hiers & Evans, 1997). Measures of high relative density and elevated importance values prior to *D. destructiva* infestation were reported by Hannah (1993) in North Carolina, Quarterman et al. (1972) in Tennessee, Muller (1982) in Kentucky, Carr and Banas (2000) in Virginia, and Sherald et al. (1996) in Maryland. Moreover, *C. florida* has been documented as a common component of second-growth hardwood stands (Orwig & Abrams, 1994; Jenkins & Parker, 1998), as an important understory component of old-growth forests (McCune et al., 1988; Goebel & Hix, 1996), and is also reported to be a significant source of calcium, in the form of leaf litter, in the surface horizons of some forest soils (Thomas, 1969; Hepting, 1971).

Multiple studies (Hiers & Evans, 1997; Schwegman et al., 1998; Williams & Moriarty, 1999; McEwan et al., 2000) have reported substantial *C. florida* mortality at local scales across its natural biological range following local colonization by *D. destructiva*, the causal agent for dogwood anthracnose (Redlin, 1991). While numerous studies have quantified local losses of *C. florida* (Sherald et al., 1996; Hiers & Evans, 1997; Schwegman et al., 1998; Williams & Moriarty, 1999; Carr & Banas, 2000; McEwan et al., 2000) specifically attributed to *D. destructiva*, few, if any, studies have quantified large-scale losses across the entire range of *C. florida*. Given that *C. florida* is one of the most numerous tree species in the Eastern U.S. (Woodall et al., 2010), a current assessment of the *C. florida* population in the Eastern US and implications for future sustainability is warranted. While *D. destructiva* is a known pathogen that has had documented negative impacts on *C. florida* populations, the decline of *C. florida* is ultimately a combination of numerous causal agents, including inter-and intra-specific competition, defoliators, and a lack of management or restoration of the species. Setting aside the complexities of abiotic and biotic decline agents, much can be gained from a strategic-scale assessment of *C. florida* population changes known to be experiencing localized declines using comparisons of large-scale forest inventories. Hence, our study's goal was to present *C. florida* population estimates across the natural range of the species (Little, 1971) in the Eastern US for two periods based on state-level forest land inventories conducted by the US Department of Agriculture (USDA) Forest Service, Forest Inventory and Analysis (FIA) program. Our specific objectives were to: (1) quantify current *C. florida* populations in the Eastern US, (2) quantify change, if any, in *C. florida* populations for the period beginning in the early 1980s to 2007 and (3) identify regional and spatial trends in *C. florida* population shifts for the same period.

Materials and Methods

Data

The forest inventory conducted by FIA is a year-round effort to collect and disseminate information and statistics on the extent, condition, status and trends of forest resources across all ownerships (Smith, 2002). In the late 1990s, FIA began a transition from irregular and asynchronous periodic inventories to annual inventories (Bechtold & Patterson, 2005). Before 2000, most inventories were periodic; since 2000 most states *have been inventoried annually. FIA applies a nationally consistent sampling protocol using a quasisystematic design covering all ownerships in the entire Nation* (Bechtold & Patterson, 2005). For this study, data was collected across 41 FIA regional units among 13 states. Fixed-area plots were installed in locations with accessible forest land cover (Bechtold & Patterson, 2005). Field crews collected data on >300 variables, including land ownership, forest type, tree species, tree size, tree condition, and other site attributes (e.g., slope, aspect, disturbance, land use) (Smith, 2006; US Department of Agriculture, 2004). Plot intensity for field collected data was approximately one plot for every 2400 ha (6000 acres) of land (125,000 plots nationally).

The design for FIA inventory plots consists of four 7.3 m fixed-radius subplots spaced 36.6 m apart in a triangular arrangement with one subplot in the center (Bechtold & Patterson, 2005). All trees with a diameter at breast height (d.b.h.) of at least 12.7 cm are inventoried on forested subplots. A 2.1 m radius microplot, offset 3.7 m from subplot center, is established within each subplot. All live tree seedlings are tallied according to species within each microplot. Conifer seedlings must be at least 15.2 cm in length with a root collar diameter < 2.54 cm to qualify for measurement. Hardwood seedlings must be at least 3.5 cm in length with a root collar diameter < 2.54 cm to qualify for measurement.

Data were assembled from the USDA Forest Service, FIA database (FIADB) version 3.0 in May 2009 (US Department of Agriculture, 2006). The FIADB contains both current and historic inventory data related to the forest resources of the US (Reams et al., 2005). County level estimates of *C. florida* populations (number of all live trees > 2.54 cm d.b.h.) and total *C. florida* biomass (tons of all live trees > 2.54 cm d.b.h.) were generated for all states (except Oklahoma) within the historic range of *C. florida* (Little, 1971) from FIA plot data for two periods in time and labeled time 1 and time 2 (**Table 1**). Perfect alignment of inventory dates was not possible due to the nature of past periodic inventories and variability in transition times between periodic and annual inventory designs (Bechtold & Patterson, 2005). Similarly, county-level population estimates were necessary because of the lack of complete plot alignment due to an altered plot design (variable radius to fixed radius) between periodic and annual inventory implementation. The data labeled time 1 ranged from 1983 in Nebraska to 1995 in Arkansas and Maine (**Table 1**) roughly corresponds to the time around which *D. destructiva* was first identified as a causal agent for dogwood anthracnose (Mielke & Langdon, 1986; Redlin, 1991; Chellemi et al., 1992), and represents a time period early in the spread of the disease. The data labeled time 2 was less variable and ranged from 2005 to 2007. Individual counties were assigned to FIA substate units that correspond to both political and ecological boundaries (**Figure 1**).

Table 1.
State and inventory data selected for analysis by time period grouping.

State	Time 1	Time 2
	periodic	*annual*
Alabama	1990	2007
Arkansas	1995	2007
Connecticut	1985	2006
Delaware	1986	2006
Florida	1987	2007
Georgia	1989	2007
Illinois	1985	2007
Indiana	1986	2007
Iowa	1990	2007
Kansas	1994	2007
Kentucky	1988	2006
Louisiana	1991	2005
Maine	1995	2006
Maryland	1986	2006
Massachusetts	1985	2006
Michigan	1993	2007
Minnesota	1990	2007
Mississippi	1994	2006
Missouri	1989	2007
Nebraska	1983	2007
New Jersey	1987	2006
New York	1993	2006
North Carolina	1984	2006
Ohio	1991	2006
Pennsylvania	1989	2006
Rhode Island	1985	2006
South Carolina	1986	2007
Tennessee	1989	2007
Texas	1992	2007
Virginia	1984	2007
West Virginia	1989	2006

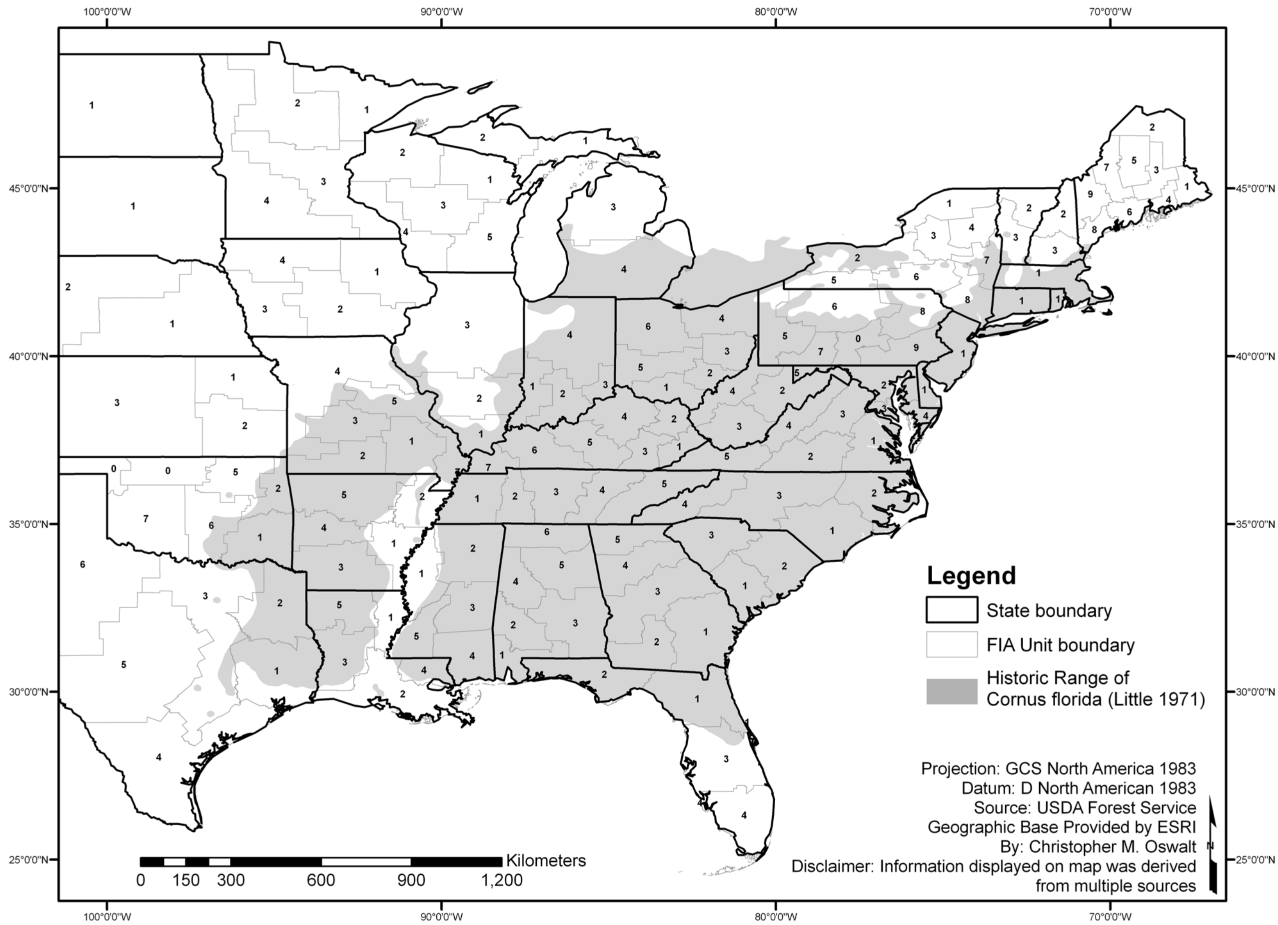

Figure 1.
Historic range of *Cornus florida* (L.) shown with state boundaries and Forest Inventory and Analysis (FIA) units (see **Table A5** for unit code descriptions).

Analysis

Absolute change, percent change and annual change was calculated for each county. Annual change was calculated by dividing the difference between times 1 and 2 for each county by the remeasurement period. Paired *t*-tests pairing county-level estimates at times 1 and 2 using R (R Development Core Team, 2009) were used to identify significant changes in *C. florida* tree populations and total biomass rangewide and within states and regional (FIA) units between times 1 and 2. Additional paired *t*-tests were used to test for significant changes in tree populations and total biomass within 5.1 cm diameter classes rangewide. Biomass estimates were converted to metric equivalents post-analysis.

Results

Rangewide

No *C. florida* stems were sampled in the states of Vermont, New Hampshire or Wisconsin for the two periods represented in this study. The rangewide *C. florida* population in the Eastern US declined approximately 49% ($P < .0001$) from an estimated 9.3 billion trees at time 1 to an estimated 4.7 billion trees at time 2 (**Table A1**). Mean annual change among all states within the historic range of *C. florida* equates to losses of approximately 8.6 million trees·year^{-1} over the period of this study. Total biomass (Mg) declined approximately 58% (P < .0001) from 10.0 million Mg to 41.8 million Mg from time 1 to time 2, respectively (**Table A1**). Mean annual change was approximately –112,418 Mg·year^{-1} among all states. All *C. florida* stems sampled in times 1 and 2 were in the 35.6 cm diameter class or smaller (**Table A2**). Significant declines in the total number of *C. florida* stems occurred between time periods for the 5.1, 1.2, 15.2, and 2.3 cm (2, 4, 6 and 8 in.) diameter classes (P < .0001, < .0001, < .0001, < .0001, respectively), while significant declines in biomass were identified in the 5.1, 1.2, 15.2, 2.3, and 25.4 cm (2, 4, 6, 8, and 10 in.) diameter classes (P < .0001, < .0001, < .0001, < .0001, = .0075, respectively). The relative declines in biomass were slightly larger than declines in the number of stems for each of the 5.1 cm (2 in.) diameter classes (**Table A3**). What appeared to be large relative increases in the 35.6 cm (14 in.) diameter class were not significant for either number of stems or dry biomass (P = .1507 and = .2489, respectively).

State Level

Seventeen out of 30 eastern states experienced significant declines in *C. florida* populations, while 20 states experienced significant declines in dry biomass (**Table A4**). The largest absolute declines in numbers of stems, calculated as mean county change, occurred in Alabama, followed by West Virginia, Virginia, North Carolina and Tennessee with losses of 8.1, 7.5, 6.0, 5.8 and 5.0 million trees, respectively (all p values < .0001). *Cornus florida* biomass declines were also largest in Alabama (**Table A4**). Maryland (P = .0038) was the only state where a significant increase in biomass was observed. No significant increases in numbers of trees were observed. *Cornus florida* was sampled only for time 1 in Kansas, Maine and Nebraska and, therefore, relative losses appeared to be 100% (**Table A1**), although not significant (**Table A4**). The largest relative declines in numbers of trees from time 1 to time 2 were observed in West Virginia (–73%; P < .0001), Ohio (–71%; P < .0001), Maryland (–66%; P = .0043) and Pennsylvania (–64%; P < .0001) (**Table A1**). The largest significant relative declines in biomass occurred in New York (–71%; P = .0194), Ohio (–70%; P < .0001), Mississippi (–69%; P < .0001), Virginia (–68%; P < .0001) and North Carolina (–67%; P < .0001) (**Table A1**).

Substate Level

Cornus florida stems were recorded in 107 FIA units in either times 1 or 2 or at both times (**Table A5**). Significant declines in numbers of stems were observed in 57 units (53%). Dry biomass declined in 55 (51%) of the 105 FIA units. Significant declines in both numbers of stems and dry biomass were detected in 48 units (45%). The largest regional declines in number of stems were in southwest-north Alabama (–16.4 million trees·county^{-1}, P = .0035) and southern West Virginia (–13.9 million trees·county^{-1}, P < .0001). Biomass loss was greatest in southwest-north Alabama (–244,723 Mg·county^{-1}, P = .0105) and west central Alabama (–188,035 Mg·county^{-1}, P < .0023). Losses, both in terms of number of stems and biomass, appeared to be heaviest within the Appalachian Mountains and surrounding area. Interestingly, significant regional increases in number of stems (P = .0280) and biomass (P = .0294) were observed in the South Delta unit in Louisiana which is outside of the geographic distribution delineated by Little (1971).

The largest substate declines relative to the time 1 population occurred in New York. The Adirondack and South-central Highlands units experienced a 100% loss of *C. florida* stems (P = .0419 and = .0233, respectively). Sixteen percent of all substate units experienced calculated declines of >75%. Calculated relative declines in excess of 50% were recorded in 53% of all FIA units. Relative increases in stem numbers, regardless of statistical significance, were observed in 16% of units. Significant increases in numbers of stems were observed in the Southwestern Ozarks of Missouri (P = .0193) and in the South Delta of Louisiana (P = .0280).

Discussion

The results of this investigation suggest that *C. florida* populations have declined significantly across the Eastern US Declines in absolute numbers of trees have been particularly noticeable in the Appalachians and in the South. Losses relative to population levels during the period of 1983-1995 (time 1) appeared larger in the North. One reason for this may be that the majority of the data for time 1 was collected in the late 1980s and early 1990s. Symptoms of what was once labeled "lower branch dieback" (Daughtrey & Hibben, 1983) but eventually described as *D. destructiva* (Redlin, 1991) were first recognized in New York in the spring of 1979 (Daughtrey et al., 1996). Therefore, many stems could have succumbed to *D. destructiva* and not have been sampled in the northern FIA inventories during the late 1980s. However, the southern FIA inventories may not have been impacted due to the lag time that would result from the movement of *D. destructiva* migration southward.

This analysis does not discriminate among causal agents of *C. florida* mortality. However, with declines correlating geographically with the known *D. destructiva* distribution coupled with numerous localized investigations implicating *D. destructiva* in significant *C. florida* losses, it can be assumed that *D. destructiva* has had a significant impact on populations in the region. While the assumption of the authors is that a significant amount of the *C. florida* declines revealed by this investigation can be attributed to the impacts of the fungus *D. destructiva*, other factors are likely to have played some role, particularly in states where *D. destructiva* has not been identified as problematic (e.g., Mississippi). For example, Pierce (2001), in Indiana, attributed *C. florida* mortality to competition with *Acer saccharum* and mediated by fire suppression activities. In Kentucky, McEwan et al. (2000) reported a 36% decline in *C. florida* density in an old-growth stand prior to the documentation of *D. destructiva* in the area. While it is possible *D. destructiva* was present without having been documented, McEwan et al. (2000) suggested that factors such as canopy closure, drought, and natural canopy-gap dynamics may have been an important factor. That theory is supported by a study by Oswalt and Oswalt (2010), which found that changes in *C. florida* populations were significantly related to changes in all live volumes of forest density. The well documented deleterious impacts of *D. destructiva*, however, cannot be ignored. According to reports from Anderson (1991) and Knighten and Anderson (1992, 1993), *D. destructive*-mediated *C. florida* mortality increased from 0% to 23% in the Appalachians between 1988 and 1993. Concomitantly, the area estimated to be infected with *D. destructiva* increased from 0.2 to 7.0 million ha over the same period (Daughtrey et al., 1996). Moreover, Windham et al. (1993) reported widespread infection and rapid die-off of *C. florida* throughout the Great Smoky Mountains National Park in the early 1990s.

While the declines in *C. florida* populations were significant for this study, loss estimates were generally lower than many of the documented studies at much smaller scales. For example, while the results of this study suggested losses of approximately 60% of the *C. florida* population in east Tennessee and 74% on the Cumberland Plateau, Hiers and Evans (1997) reported *C. florida* declines of approximately 98% from *C. florida* population estimates first reported by McGee (1986) in Tennessee. Myers et al. (2004) observed significant declines of *C. florida*, also on the Cumberland Plateau, and documented the species' complete disappearance from the subcanopy on their study site. The current study suggests that while the loss amounted to approximately 74% of the *C. florida* population, declines averaged >10 million stems per county on the Cumberland Plateau between times 1 and time 2 (**Table 1**). The loss of *C. florida* on the Cumberland Plateau in Tennessee during the period of this study was approximately 170 million trees.

In Maryland, *C. florida* declines averaged between 56 and 79% among four regions between times 1 and 2. Sherald et al.

(1996) documented *C. florida* mortality at approximately 77% between 1976 and 1992. Regional relative declines of *C. florida* populations in Pennsylvania ranged from 63% to 82% with no change in mean county-level populations estimates in the North Central Allegheny region. Williams and Moriarty (1999) reported *C. florida* mortality in the northern Allegheny Plateau of between 58% and 68%. The lack of significant change in some parts of the Allegheny region could be a result of the lower densities of *C. florida* documented in the area (Williams & Moriarty, 1999). In some areas, the lack of significant change was possibly due to a limited number of counties in some regional FIA units (e.g., Western unit in Maryland has two counties).

It is important to note that the estimates reported here for the period 1983 to 1995 (time 1) were generated during a time when FIA implemented periodic inventories. The estimates generated for the period 2005-07 (time 2) were generated from the FIA program's annual inventory design (Bechtold & Patterson, 2005). As a result, additional uncertainty is introduced when comparing estimates across time. However, analyses at broad scales, such as the one here, reduce the probability of the additional uncertainty significantly influencing the results. Fei and Steiner (2007) used similar methods (time 1 data was from periodic inventories and ranged from 1980-1995 while time 2 data was from annual inventories with a much smaller range) to identify large-scale increases in *Acer rubrum* populations in eastern forests. Regional differences as a result of FIA organizational structure between the North and South are recognized during implementation of both the periodic and annual inventories. However, focus on tree level variables minimizes the impact of such differences.

Given the documented range of dogwood prior to 1971 (Little, 1971) and its substantial decline from the 1980s to the present, we hypothesize that future dogwood populations will continue to wane. The deleterious effects of *D. destructiva*, combined with inter- and intra-specific competition, defoliators, and little emphasis on restoration and management engenders little hope for slowing the decline of *C. florida* populations on the landscape. Additionally, climate change effects might be expected to negatively affect *C. florida* populations. The relatively widespread *C. florida* range could ensure its stability in limited southern locations, while the majority of its extent in the middle and high latitudes may face increased competition due to climate-change induced species migration (Woodall et al., 2009). Some evidence from this study suggests that range shifts may already be occurring in *C. florida* populations given that the greatest losses in biomass occurred in the species' northern range and greatest gains occurred in its southern range. However, range shifts were not the focus of this study and further investigation and monitoring over time will be necessary to corroborate those initial observations. Although the future range and magnitude of *C. florida* populations is uncertain, the need for continued monitoring and proactive approaches to restoration and management is evident.

Conclusion

While declines were widespread in the substate units surrounding the Appalachians, the largest declines appeared to be centered within the Appalachian ecoregion. These results indicate that an important component of the eastern deciduous forest may be suffering serious declines. Our results support many smaller, localized investigations of *C. florida* mortality as well as large quantities of anecdotal evidence that has been accumulated over time. *Cornus florida* has been an important tree species in the Appalachian ecoregion. Faced with large-scale declines in populations of *C. florida*, particularly in the midstory of eastern deciduous forests, further expansion of generalist species such as *A. rubrum* may be expected to occur. The need for continued monitoring and proactive restoration and management goals for *C. florida* is evident.

Acknowledgements

The authors thank the USDA Forest Service Southern Research Station (SRS) and Northern Research Station (NRS) for funding and support for this project. We also acknowledge the hard work and dedication of SRS and NRS field crews.

REFERENCES

Anderson, R. L. (1991). *Results of the 1990 dogwood anthracnose impact assessment and pilot test in the southeastern United States*. Protection Report R8-PR 20. Atlanta, GA: US Department of Agriculture Forest Service, Southern Region.

Bechtold, W. A., & Patterson, P. L. (2005). *The enhanced forest inventory and analysis program—National sampling design and estimation procedures*. General Technical Report SRS-80. Asheville, NC: US Department of Agriculture Forest Service, Southern Research Station.

Britton, K. O. (1994). Dogwood anthracnose. In C. Ferguson, & P. Bowman (Eds.), *Threats to forest health in the southern Appalachians* (pp. 17-20). Gatlinburg, TN: Southern Appalachian Man and the Biosphere Co-operative.

Carr, D. E., & Banas, L. E. (2000). Dogwood anthracnose (*discula destructiva*): Effects of and consequences for host (*Cornus florida*) demography. *American Midland Naturalist, 143,* 169-177. doi:10.1674/0003-0031(2000)143[0169:DADDEO]2.0.CO;2

Chellemi, D. O., Britton, K. O., & Swank, W. T. (1992). Influence of site factors in dogwood anthracnose in the Nantahala Mountain range of western North Carolina. *Plant Disease, 76,* 915-918. doi:10.1094/PD-76-0915

Daughtrey, M. L., & Hibben, C. R. (1983). Lower branch dieback, a new disease of northern dogwoods. *Phytopathology, 73,* 365.

Daughtrey, M. L., Hibben, C. R., Britten, K. O., Windham, M. T., & Redlin, S. C. (1996). Dogwood anthracnose, understanding a disease new to North America. *Plant Disease, 80,* 349-358. doi:10.1094/PD-80-0349

Fei, S., & Steiner, K. C. (2007). Evidence for increasing red maple abundance in the eastern United States. *Forest Science, 53,* 473-477.

Goebel, P. C., & Hix, D. M. (1996). Development of mixed-oak forests in southeastern Ohio: A comparison of second-growth and old-growth forests. *Forest Ecology and Management, 84,* 1-21. doi:10.1016/0378-1127(96)03772-3

Hannah, P. R. (1993). Composition and development of two Appalachian hardwood stands in North Carolina. *Journal of the Elisha Mitchell Scientific Society, 109,* 87-98.

Hepting, G. H. (1971). *Diseases of forest and shade trees of the United States*. Agriculture Handbook, US Department of Agriculture, Washington DC.

Hiers, J. K., & Evans, J. P. (1997). Effects of anthracnose on dogwood mortality and forest composition of the Cumberland Plateau (USA). *Conservation Biology, 11,* 1430-1435. doi:10.1046/j.1523-1739.1997.97009.x

Holzmueller, E., Jose, S., Jenkins, M., Camp, A., & Long, A. (2006). Dogwood anthracnose in eastern hardwood forests: What is known and what can be done? *Journal of Forest, 104,* 21-26.

Jenkins, M. A., & Parker, G. R. (1998). Composition and diversity of woody vegetation in silvicultural openings of southern Indiana forests. *Forest Ecology and Management, 109,* 57-74.

doi:10.1016/S0378-1127(98)00256-4
Jenkins, M. A., & White, P. S. (2002). *Cornus florida* L. mortality and understory composition changes in western Great Smoky Mountains National Park. *Journal of the Torrey Botanical Society, 129,* 194-206. doi:10.2307/3088770
Knighten, J. L., & Anderson, R. L. (1992). *Results of the 1991 dogwood anthracnose impact assessment and pilot test in the southeastern United States.* Protection Report R8-PR 23, US Department of Agriculture Forest Service, Southern Region.
Knighten, J. L., & Anderson, R. L. (1993). *Results of the 1992 dogwood anthracnose impact assessment and pilot test in the southeastern United States*. Protection Report R8-PR 24, US Department of Agriculture Forest Service, Southern Region.
Little, E. L. Jr. (1971). *Atlas of United States trees, volume 1, conifers and important hardwoods*. US Department of Agriculture Miscellaneous Publication 1146.
McCune, B., Cloonan, C. L., & Armentano, T. V. (1988). Tree mortality and vegetation dynamics in Hemmer Woods, Indiana. *American Midland Naturalist, 120,* 416-431. doi:10.2307/2426014
McEwan, R. W., Muller, R. N., Arthur, M. A., & Housman, H. H. (2000). Temporal and ecological patterns of flowering dogwood mortality in the mixed mesophytic forests of eastern Kentucky. *Journal of the Torrey Botanical Society, 127,* 221-229. doi:10.2307/3088759
McGee, C. E. (1986). Loss of Quercus spp. dominance in an undisturbed old-growth forest. *Journal of the Elisha Mitchell Scientific Society, 102,* 10-15.
Mielke, M. and Langdon, K. (1986). Dogwood anthracnose fungus threatens Catoctin Mountain Park. *Park Science, 6,* 6-8.
Muller, R. N. (1982). Vegetation patterns in the mixed mesophytic forest of eastern Kentucky. *Ecology, 63,* 1901-1917. doi:10.2307/1940129
Myers, B. R., Walck, J. L., & Blum, K. E. (2004). Vegetation change in a former chestnut stand on the Cumberland Plateau of Tennessee during and 80-year period (1921-2000). *Castanea, 69,* 81-91. doi:10.2179/0008-7475(2004)069<0081:VCIAFC>2.0.CO;2
Omernik, J. M. (1987). Ecoregions of the conterminous United States. Map (scale 1:7,500,000). *Annals of the Association of American Geographers, 77,* 118-125.
Orwig, D. A., & Abrams, M. D. (1994). Land-use history (1720-1992), composition, and dynamics of oak-pine forests within the Piedmont and Coastal Plain of northern Virginia. *Canadian Journal of Forest Research, 24,* 1216-1225. doi:10.1139/x94-160
Oswalt, C. M., & Oswalt, S. N. (2010). Documentation of significant losses in *Cornus florida* L. populations throughout the Appalachian ecoregion. *International Journal of Forestry Research,* 2010. doi:10.1155/2010/401951.
Pierce, A. A. (2001). *Population dynamics of flowering dogwood (Cornus florida L.) and community structure at the Ross biological reserve*. M.S. Thesis, West Lafayette, IN: Purdue University.
Quarterman, E., Turner, B. H., & Hemmerly, T. E. (1972). Analysis of virgin mixed mesophytic forests in Savage Gulf, Tennessee. *Bulletin of the Torrey Botanical Club, 99,* 228-232. doi:10.2307/2484607
R Development Core Team (2009). *R: A language and environment for statistical computing*. R Foundation for Statistical Computing, Vienna. http://www.R-project.org
Reams, G. A., Smith, W. D., Hansen, M. H., Bechtold, W. A., Roesch, F. A., & Moisen, G. G. (2005). *The forest inventory and analysis sampling frame*. General Technical Report SRS-80, Asheville, NC: US Department of Agriculture Forest Service, Southern Research Station.
Redlin, S. C. (1991). *Discula destructiva* sp. nov., cause of dogwood anthracnose. *Mycologia, 83,* 633-642. doi:10.2307/3760218
Schwegman, J. E., McClain, W. E., Esker, T. L., & Ebinger, J. E. (1998). Antracnose-caused mortality of flowering dogwood (*Cornus florida* L.) at Dean Hills Nature Preserve, Fayette County, Illinois, USA. *Natural Areas Journal, 18,* 204-207.
Sherald, J. L., Stidham, T. M., Hadidian, J. M., & Hoeldtke, J. E. (1996). Progression of the dogwood anthracnose epidemic and the status of flowering dogwood in Catoctin Mountain Park. *Plant Disease, 80,* 310-312. doi:10.1094/PD-80-0310
Smith, W. B. (2002). Forest inventory and analysis: A national inventory and monitoring program. *Environmental Pollution, 116,* 233-242. doi:10.1016/S0269-7491(01)00255-X
Smith, W. B. (2006). An overview of inventory and monitoring and the role of FIA in national assessments. *Proceedings RMRS-P=42CD.* Fort Collins, CO: US Department of Agriculture Forest Service, Rocky Mountain Research Station.
Thomas, W. A. (1969). Accumulation and cycling of calcium by dogwood trees. *Ecological Monographs, 39,* 101-120. doi:10.2307/1950739
US Department of Agriculture (2004). *Field instructions for southern forest inventory*. Unpublished report. Knoxville, TN: Southern Research Station, Forest Inventory and Analysis.
US Department of Agriculture (2006). *FIA field methods for phase 3 measurements. Version 3.0*. Arlington, VA: US Department of Agriculture Forest Service, Forest Inventory and Analysis Program. http://fia.fs.fed.us/library/field-guides-methods-proc
Williams, C. E., & Moriarity, W. J. (1999). Occurrence of flowering dogwood (*Cornus florida* L.) mortality by dogwood anthracnose (*Discula destructiva* Redlin), on the northern Allegheny Plateau. *Journal of the Torrey Botanical Society, 126,* 313-319. doi:10.2307/2997315
Windham, M. T., Montgomery-Dee, M. E., & Parham, J. (1993). Site parameters that affect dogwood anthracnose incidence and severity. In B. L. James (Ed.), *Proceedings of the 38th Southern Nursery Research Conference* (pp. 184-187). Marietta, GA: Southern Nurserymen's Association.
Woodall, C. W., Oswalt, C. M., Westfall, J. A., Perry, C. H., & Nelson, M. D. (2009). Tree migration detection through comparisons of historic and current forest inventories. *Proceedings RMRS-P-56CD*. Fort Collins, CO: US Department of Agriculture Forest Service, Rocky Mountain Research Station.
Woodall, C. W., Oswalt, C. M., Westfall, J. A., Perry, C. H., Nelson, M. D., & Finley, A. O. (2010). Selecting tree species for testing climate change migration hypotheses using forest inventory data. *Forest Ecology and Management, 259,* 778-785. doi:10.1016/j.foreco.2009.07.022

Appendix

Table A1.
Estimates of the number of trees (a) and aboveground biomass (b) of dogwood for times 1 and 2 along with sampling error, annualized and relative change for each state.

(a)

State	Time 1			Time 2			Annualized change	Relative change (%)
	Trees	Sampling error	n plots	Trees	Sampling error	n plots		
Alabama	1,092,781,586	50,158,675	4515	551,279,079	26,847,291	5375	–31,853,089	–49.6
Arkansas	695,217,351	32,258,085	5878	412,492,486	21,490,859	5571	–23,560,405	–40.7
Connecticut	2,666,645	1,998,917	344	6,018,066	2,708,130	352	159,591	125.7
Delaware	9,936,015	6,829,023	200	3,399,814	1,726,086	244	–326,810	–65.8
Florida	54,537,078	7,182,533	12,441	42,081,521	8,832,911	6781	–622,778	–22.8
Georgia	810,863,469	27,812,617	12,015	469,478,198	25,680,457	6252	–18,965,848	–42.1
Illinois	65,072,594	6,299,027	10,956	72,839,330	10,467,012	6028	353,033	11.9
Indiana	194,670,206	9,188,434	11,439	95,374,628	8,936,603	4644	–4,728,361	–51
Iowa	421,023	271,728	12,767	347,740	400,944	6018	–4311	–17.4
Kansas	239,876	299,221	14,875	-	-	-	–18,452	–
Kentucky	622,999,161	43,859,141	3239	343,061,256	19,828,941	4280	–15,552,106	–44.9
Louisiana	192,997,713	18,508,481	2893	125,069,753	12,982,240	5449	–4,851,997	–35.2
Maine	372,484	385,484	3001	-	-	-	–33,862	–
Maryland	71,647,439	15,110,445	1224	24,698,245	6,362,268	548	–2,347,460	–65.5
Massachusetts	-	-	-	1,224,278	1,256,109	566	58,299	–
Michigan	33,119,687	5,203,103	18,483	25,303,000	4,511,525	13,196	–558,335	–23.6
Minnesota	-	-	-	282,382	255,895	17,855	16,611	–
Mississippi	600,732,681	30,276,927	5300	283,426,132	18,280,986	5176	–26,442,212	–52.8
Missouri	529,244,953	15,930,273	17,259	576,198,500	23,393,659	7924	2,608,530	8.9
Nebraska	2,288,061	1,513,095	14,449	-	-	-	–95,336	–
New Jersey	19,876,558	8,946,439	644	10,667,028	6,266,879	417	–484,712	–46.3
New York	31,115,655	6,388,044	5367	11,535,384	4,238,100	3832	–1,506,175	–62.9
North Carolina	931,343,766	28,871,657	9373	359,643,076	22,981,193	4565	–25,986,395	–61.4
Ohio	416,455,023	24,904,010	5056	120,156,133	12,400,113	4356	–19,753,259	–71.1
Pennsylvania	199,013,009	17,891,270	5447	71,699,850	13,056,543	4676	–7,489,009	–64
Rhode Island	3,233,847	3,027,204	100	1,289,850	736,246	140	–92,571	–60.1
South Carolina	340,599,514	16,519,076	7020	218,043,116	16,505,864	3416	–5,836,019	–36
Tennessee	764,366,052	37,836,120	2950	315,639,335	17,675,803	4449	–24,929,262	–58.7
Texas	158,475,178	13,644,713	3705	85,545,756	8,734,222	3741	–4,861,961	–46
Virginia	912,976,646	28,393,574	7314	332,856,088	18,273,799	4585	–25,222,633	–63.5
West Virginia	522,150,905	32,112,281	3341	140,680,993	15,488,977	1376	–22,439,407	–73.1

(b)

State	Time 1			Time 2			Annualized change	Relative change (%)
	Mg	Sampling error	n plots	Mg	Sampling error	n plots		
Alabama	14,681,920	45,285	4515	5,690,852	259,079	5375	–528,886	–61.2
Arkansas	7,175,656	70,683	5878	3,092,813	160,235	5571	–340,237	–56.9
Connecticut	113,247	813	344	93,488	42,608	352	–941	–17.4
Delaware	33,165	687	200	86,072	30,550	244	2645	159.5
Florida	676,545	35,599	12,441	365,771	61,211	6781	–15,539	–45.9
Georgia	9,585,290	128,559	12,015	4,785,739	231,602	6252	–266,642	–50.1
Illinois	509,127	5466	10,956	300,419	34,315	6028	–9487	–41
Indiana	1,589,255	17,684	11,439	551,966	52,741	4644	–49,395	–65.3
Iowa	1260	839	12,767	309	357	6018	–56	–75.4
Kansas	525	27,130	14,875	-	-	-	–40	-
Kentucky	6,296,147	93,049	3239	3,615,705	217,727	4280	–148,913	–42.6
Louisiana	2,742,943	91,882	2893	1,534,816	149,570	5449	–86,295	–44
Maine	811	259,955	3001	-	-	-	–74	-
Maryland	69,528	133,572	1224	293,671	65,502	548	11,207	322.4
Massachusetts	-	-	-	12,416	9022	566	591	-
Michigan	252,253	7145	18,483	91,411	16,089	13,196	–11,489	–63.8
Minnesota	-	-	-	616	558	17,855	36	-
Mississippi	9,293,321	263,639	5300	2,851,748	174,260	5176	–536,798	–69.3
Missouri	4,151,419	50,126	17,259	2,499,988	110,693	7924	–91,746	–39.8
Nebraska	8027	106,323	14,449	-	-	-	–334	-
New Jersey	322,914	0	644	227,303	127,288	417	–5032	–29.6
New York	442,769	623,789	5367	130,228	44,569	3832	–24,042	–70.6
North Carolina	10,298,401	489,489	9373	3,446,261	202,293	4565	–311,461	–66.5
Ohio	4,003,046	252,498	5056	1,188,839	115,158	4356	–187,614	–70.3
Pennsylvania	1,481,278	437,786	5447	719,055	99,045	4676	–44,837	–51.5
Rhode Island	12,960	318,677	100	18,859	9338	140	281	45.5
South Carolina	3,920,441	173,465	7020	2,098,895	140,715	3416	–86,740	–46.5
Tennessee	9,592,100	485,761	2950	3,429,733	196,362	4449	–342,354	–64.2
Texas	1,904,753	182,551	3705	704,505	73,524	3741	–80,017	–63
Virginia	7,147,407	261,572	7314	2,288,775	143,201	4585	–211,245	–68
West Virginia	3,687,075	352,415	3341	1,655,703	186,155	1376	–119,492	–55.1

Table A2.
Mean difference between times 1 and 2, sample size, t statistic and associated p-value for number of trees and biomass by diameter class for dogwood in the Eastern United States.

Diameter class	n	Trees (no.)			Biomass (Mg)		
		Mean of difference	t[2]	P[3]	Mean of difference	t[2]	P[3]
2	1390	–2,720,635	–21.92	**<.0001**	–17,018	–23.04	**<.0001**
4	1390	–503,314	–15.34	**<.0001**	–19,137	–17.78	**<.0001**
6	1390	–64,865	–11.76	**<.0001**	–4759	–13.94	**<.0001**
8	1390	–4932	–4.23	**<.0001**	–865	–6.34	**<.0001**
10	1390	–600	–1.83	.0682	–171	–2.68	**.0075**
12	1390	–85	–.86	.3914	–46	–1.46	.1452
14	1390	68	1.44	.1507	30	1.15	.2489
All stems	1390	–3,294,313	–22.76	**<.0001**	–41,884	–23.08	**<.0001**

[1]County-level mean difference of the number of dogwood stems > 2.5 cm (1-inch) diameter between times 1 and 2; [2]Paired T-test pairing time 1 county-level estimates to time 2 county-level estimates; [3]p-value of paired t-test. Bold numerals denotes significance at the .05 level.

Table A3.
Estimates of the number of trees and aboveground biomass of dogwood for times 1 and 2 along with associated sampling error, t statistic, p-value and percent change by diameter class.

Diameter class	Time 1	Sampling error	Time 2	Sampling error	t[1]	P[2]	Percent change
	Trees (millions)						
2	7548.80	103.12	3767.08	67.15	–21.92	**<.0001**	–50
4	1486.86	34.8	787.31	22.93	–15.34	**<.0001**	–47
6	216.54	6.61	126.38	2.97	–11.76	**<.0001**	–42
8	23.92	1.49	17.06	.91	–4.23	**<.0001**	–29
10	2.91	.39	2.07	.28	–1.83	.0682	–29
12	.37	.11	.25	.1	–.86	.3914	–32
14+	.02	.02	.11	.06	1.44	.1507	592
	Biomass (Mg)						
2	39,594,515	607,329	15,939,283	324,914	–23.05	**<.0001**	–60
4	44,387,753	1,105,408	17,788,644	573,147	–17.78	**<.0001**	–60
6	12,512,048	396,567	5,897,061	149,144	–13.94	**<.0001**	–53
8	2,788,154	180,239	1,585,685	89,260	–6.34	**<.0001**	–43
10	576,669	81,240	338,093	48,256	–2.68	**.0075**	–41
12	123,230	38,511	58,671	22,941	–1.46	.1452	–52
14+	11,213	11,370	168,520	89,332	1.15	.2489	1403

[1]Paired T-test pairing time 1 county-level estimates to time 2 county-level estimates; [2]p-value of paired t-test. Bold numerals denotes significance at the .05 level.

Table A4.
Mean difference between times 1 and 2, sample size, t statistic and associated p-value for number of trees and biomass by state for dogwood in the Eastern United States.

State	n	Trees (no.)			Biomass (Mg)		
		Mean of difference[1]	t[2]	P[3]	Mean of difference[1]	t[2]	P[3]
Alabama	67	–8,081,781	–7.69	**<.0001**	–134,192	–8.31	**<.0001**
Arkansas	72	–3,927,404	–5.39	**<.0001**	–56,716	–6.19	**<.0001**
Connecticut	8	418,917	.84	.4313	–2471	–.36	.7328
Delaware	3	–2,181,978	–2.36	.1422	17,634	1.47	.2795
Florida	30	–414,954	–0.87	.3917	–10,359	–1.72	.0958
Georgia	133	–2,567,326	–8.06	**<.0001**	–36,091	–8.87	**<.0001**
Illinois	53	146,623	.72	.4747	–3937	–2.99	**.0043**
Indiana	68	–1,460,115	–4.42	**<.0001**	–15,253	–5.18	**<.0001**
Iowa	2	–36,359	–.09	.94	–474	–.61	.6534
Kansas	3	–79,972	–2.77	.1091	–175	–2.35	.143
Kentucky	105	–2,665,048	–6.05	**<.0001**	–25,513	–4.7	**<.0001**
Louisiana	44	–1,543,978	–2.46	**.018**	–27,461	–3.44	**.0013**
Maine	1	–372,484			–811		
Maryland	22	–2,134,850	–3.2	**.0043**	10,188	3.25	**.0038**
Massachusetts	1	1,224,278			9022		
Michigan	35	–223,088	–.89	.378	–4594	–2.12	**.0417**
Minnesota	1	282,382			558		
Mississippi	75	–4,231,111	–7.65	**<.0001**	–85,890	–8.52	**<.0001**
Missouri	77	610,406	1.63	.107	–21,442	–5.16	**<.0001**
Nebraska	3	–762,571	–3.35	.0787	–2675	–2.42	.137
New Jersey	11	–837,688	–.76	.4626	–8699	–.45	.6629
New York	30	–652,807	–2.13	.0416	–10,421	–2.48	**.0194**
North Carolina	99	–5,774,619	–8.99	**<.0001**	–69,219	–9.06	**<.0001**
Ohio	62	–4,778,786	–5.38	**<.0001**	–45,395	–5.1	**<.0001**
Pennsylvania	59	–2,157,888	–5.09	**<.0001**	–12,918	–4.1	**.0001**
Rhode Island	3	–648,043	–.49	.673	1966	.23	.8402
South Carolina	45	–2,722,960	–3.67	**<.0001**	–40,473	–4.28	**<.0001**
Tennessee	90	–4,985,419	–7.66	**<.0001**	–68,462	–9.16	**<.0001**
Texas	40	–1,823,369	–4.05	**.0002**	–30,009	–4.96	**<.0001**
Virginia	96	–6,043,939	–12.51	**<.0001**	–50,616	–11.64	**<.0001**
West Virginia	51	–7,480,127	–8.51	**<.0001**	–39,839	–6.01	**<.0001**

[1]County-level mean difference of the number of dogwood stems > 2.5 cm (1-inch) diameter between times 1 and 2; [2]Paired T-test pairing time 1 county-level estimates to time 2 county-level estimates; [3]p-value of paired *t*-test. Bold numerals denotes significance at the .05 level.

Table A5.
Mean difference between times 1 and 2, sample size, *t* statistic and associated p-value for number of trees and biomass by state and FIA unit for dogwood in the Eastern United States.

State	FIA unit code	Unit name	n	Trees (no.)			Biomass (Mg)		
				Mean of difference[1]	t[2]	P[3]	Mean of difference[1]	t[2]	P[3]
Alabama	1	Southwest-South	5	–7,605,138	–2.59	.0608	–148,496	–2.5	.0669
	2	Southwest-North	7	–16,365,688	–4.66	**.0035**	–244,723	–3.67	**.0105**
	3	Southeast	21	–4,852,196	–2.69	**.0142**	–88,654	–2.92	**.0084**
	4	West Central	9	–11,016,959	–3.64	**.0066**	–188,035	–4.39	**.0023**
	5	North Central	15	–8,454,062	–3.47	**.0038**	–129,189	–4.5	**.0005**
	6	North	10	–6,103,411	–5.75	**.0003**	–104,343	–4.97	**.0008**
Arkansas	1	South Delta	9	–942,188	–1.52	.1672	–18,786	–2.01	.0787
	2	North Delta	9	–289,672	.75	.4721	59	.02	.9872
	3	Southwest	20	–3,676,100	–5.72	**<.0001**	–36,793	–6.03	**<.0001**
	4	Ouachita	10	–3,613,440	–4.49	**.0015**	–61,999	–5.5	**.0004**
	5	Ozark	24	–6,968,503	–3.66	**.0013**	–106,631	–4.68	**.0001**
Connecticut	1	Connecticut	8	418,917	.84	.4313	–2471	–0.36	.7328
Delaware	1	Delaware	3	–2,181,978	–2.36	.1422	17,634	1.47	.2795
Florida	1	Northeastern	12	86,250	.34	.743	–850	–.37	.722
	2	Northwestern	14	–965,504	–.98	.3448	–21,616	–1.76	.1012
	3	Central	4	8360	.01	.9905	515	.16	.8826
Georgia	1	Southeastern	16	–441,100	–1.6	.1308	–7177	–3.57	**.0028**
	2	Southwestern	16	–907,228	–2.58	**.0208**	–9543	–2.01	.0629
	3	Central	48	–1,525,543	–3.61	**.0007**	–33,094	–4.95	**<.0001**
	4	North Central	32	–3,609,528	–6.36	**<.0001**	–48,309	–6.77	**<.0001**
	5	Northern	21	–6,245,248	–5.59	**<.0001**	–66,582	–4.73	**.0001**
Illinois	1	Southern	15	779,910	1.65	.1203	–4159	–1.4	.178
	2	Claypan	17	–81,072	–.21	.8352	–5404	–1.9	.0754
	3	Prairie	21	–121,400	–.57	.5769	–2593	–2	.0588
Indiana	1	Lower Wabash	14	–2,606,899	–2.48	**.0277**	–21,917	–2.78	**.0156**
	2	Knobs	17	–3,612,894	–5.66	**<.0001**	–39,490	–6.54	**<.0001**
	3	Upland Flats	8	–184,226	–.57	.5886	–4392	–1.49	.1806
	4	Northern	29	3510	.04	.9708	–826	–1.41	.1681
Iowa	1	Northeastern	1	–420,460			–1259		
	3	Southwestern	1	347,740			309		
Kansas	1	Northeastern	1	–199,955			–284		
	2	Southeastern	2	–59,980	–1.67	.344	–121	–1.37	.4013

Continued

Kentucky	1	Eastern	8	–4,316,515	–2.68	**.0317**	–32,230	–1.12	.2995
	2	Northern Cumberland	13	–5,884,127	–4	**.0018**	–46,023	–3.04	**.0102**
	3	Southern Cumberland	12	–7,240,478	–3.72	**.0034**	–47,961	–1.95	.0777
	4	Bluegrass	23	–77,139	–.24	.811	1974	.86	.4004
	5	Pennyroyal	20	–1,466,521	–2.03	.0565	–32,250	–2.47	**.0231**
	6	Western Coalfield	19	–1,759,430	–2.43	**.0256**	–27,156	–2.53	**.0209**
	7	Western	10	–1,738,479	–1.75	.1133	–13,200	–.87	.4067
Louisiana	1	North Delta	6	–95,374	–.11	.9166	–8623	–.98	.3738
	2	South Delta	8	1,584,953	2.76	**.028**	11,115	2.73	**.0294**
	3	Southwest	10	–3,923,268	–2.89	**.0178**	–47,262	–3.4	**.0079**
	4	Southeast	7	–3,355,577	–1.47	.1928	–32,609	–2.66	**.0375**
	5	Northwest	13	–1,332,362	–1.37	.1967	–41,892	–1.94	.0763
Maine	3	Penobscot	1	–372,562			–811		
Maryland	2	Central	14	–2,090,903	–2.21	**.0453**	6702	2.36	**.0346**
	3	Southern	3	–2,278,547	–1.86	.2041	23,345	1.39	.2991
	4	Lower Eastern Shore	3	–635,148	–0.79	.5137	10,380	1.74	.2247
	5	Western	2	–4,476,482	–1.78	.3257	14,559	1	.5
Massachusetts	1	Massachusetts	1	1,224,278			12,416		
Michigan	3	Northern Lower Peninsula	8	527,934	1.62	.1486	1172	1.14	.2925
	4	Southern Lower Peninsula	27	–445,613	–1.49	.1472	–6303	–2.32	**.0288**
Minnesota	3	Central Hardwood	1	282,382			616		
Mississippi	1	Delta	7	–2,290,818	–1.19	.2785	–72,744	–2.39	.0543
	2	North	26	–3,415,566	–4.01	**.0005**	–79,410	–4.28	**.0002**
	3	Central	14	–3,126,130	–3.42	**<.0001**	–78,748	–6.77	**<.0001**
	4	South	17	–5,155,069	–4.04	**.0009**	–78,304	–3.42	**.0035**
	5	Southwest	11	–7,371,896	–4.49	**.0012**	–130,391	–4.15	**.002**
Missouri	1	Eastern Ozarks	14	–1,095,115	–.98	.3457	–71,175	–6.84	**<.0001**
	2	Southwestern Ozarks	12	3,803,624	2.74	**.0193**	–19,465	–1.55	.1493
	3	Northwestern Ozarks	11	1,718,808	1.72	.1157	–13,792	–1.35	.2073
	4	Prairie	21	–150,491	–1.11	.2789	–1,468	–2.28	**.0336**
	5	Riverborder	19	49,619	.18	.8554	–12,553	–3.94	**.001**
Nebraska	1	Eastern	3	–762,571	–3.35	.0787	–2675	–2.42	.137
New Jersey	1	New Jersey	11	–837,688	–.76	.4626	–8699	–.45	.66
New York	1	Adirondack	2	–315,089	–15.18	**.0419**	–658	–2.56	.2371
	2	Lake Plain	4	–603,804	–.77	.4951	–11,570	–1.38	.262
	3	Western Adirondack	1	583,387			867		
	5	Southwest Highlands	3	–970,217	–2.42	.1369	–8747	–1.54	.2638
	6	South-Central Highlands	6	–845,510	–3.23	**.0233**	–9733	–2.8	**.0378**
	7	Capitol District	6	597,749	1.51	.1911	–987	–.5	.6385
	8	Catskill-Lower Hudson	8	–1,590,625	–1.72	.129	–21,916	–1.5	.1774

Continued

North Carolina	1	Coastal Plain	21	–3,117,924	–3.61	**.0017**	–38,811	–3.62	**.0017**
	2	Northern Coastal Plain	22	–1,645,716	–4.4	**.0003**	–21,958	–5.34	**<.0001**
	3	Piedmont	35	–6,349,888	–7.06	**<.0001**	–83,812	–6.6	**<.0001**
	4	Mountains	21	–11,798,050	–6.53	**<.0001**	–124,818	–6.07	**<.0001**
Ohio	1	South-Central	10	–10,020,912	–3.27	**.0097**	–92,995	–2.88	**.018**
	2	Southeastern	7	–11,123,902	–2.88	**.028**	–93,624	–2.25	.0653
	3	East-Central	11	–5,534,590	–3.17	**.01**	–58,209	–3.99	**.0026**
	4	Northeastern	15	–1,689,125	–2.83	**.0134**	–16,695	–2.75	**.0156**
	5	Southwestern	10	–2,226,981	–1.58	.1482	–29,127	–1.57	.1515
	6	Northwestern	9	–1,080,125	–1.71	.1248	–5241	–1.15	.2831
Pennsylvania	0	South Central	9	–2,926,970	–3.4	**.0094**	–3350	–.7	.5044
	5	Western	11	–3,828,340	–2.86	**.0171**	–33,283	–3.64	**.0045**
	6	North Central/Allegheny	11	1466	0	.9987	661	.1	.921
	7	Southwestern	5	–4,456,441	–2.26	.0872	–29,428	–2.64	.0576
	8	Northeastern/Pocono	12	–975,408	–2.38	**.0366**	105	.04	.9678
	9	Southeastern	11	–2,262,721	–3.66	**.0044**	–20,667	–3.55	**.0053**
Rhode Island	1	Rhode Island	3	–648,043	–.49	.673	1966	.23	.8402
South Carolina	1	Southern Coastal Plain	11	–685,049	–.65	.5326	–20,495	–1.54	.1549
	2	Northern Coastal Plain	16	–1,056,274	–2.16	**.047**	–8949	–1.25	.2292
	3	Piedmont	18	–5,449,847	–3.63	**.0021**	–80,703	–4.56	**.0003**
Tennessee	1	West	15	–2,868,802	–3.2	**.0064**	–53,766	–3.89	**.0016**
	2	West Central	11	–3,545,042	–2.77	**.0197**	–63,742	–2.8	**.019**
	3	Central	21	–2,261,837	–3.28	**.0038**	–40,496	–4.33	**.0003**
	4	Plateau	16	–10,654,752	–4.7	**.0003**	–132,547	–5.21	**.0001**
	5	East	27	–5,506,879	–5	**<.0001**	–62,323	–6.17	**<.0001**
Texas	1	Southeast	19	–1,751,245	–2.46	**.0244**	–29,628	–3.48	**.0027**
	2	Northeast	21	–1,888,624	–3.25	**.004**	–30,353	–3.45	**.0025**
Virginia	1	Coastal Plain	31	–3,140,022	–6.26	**<.0001**	–25,794	–7.28	**<.0001**
	2	Southern Piedmont	17	–6,315,451	–5.67	**<.0001**	–54,187	–6.62	**<.0001**
	3	Northern Piedmont	17	–7,343,111	–6.53	**<.0001**	–52,239	–5.59	**<.0001**
	4	Northern Mountains	14	–9,872,185	–5.61	**<.0001**	–84,658	–4.84	**.0003**
	5	Southern mountains	17	–6,615,961	–8.98	**<.0001**	–62,655	–6.55	**<.0001**
West Virginia	2	Northeastern	18	–5,052,487	–5.59	**<.001**	–31,133	–3.2	**.0052**
	3	Southern	14	–13,888,298	–8.37	**<.0001**	–85,217	–7.01	**<.0001**
	4	Northwestern	19	–5,058,187	–4.53	**.0003**	–14,650	–2.3	**.0333**

[1]County-level mean difference of the number of dogwood stems > 2.5 cm (1-inch) diameter between times 1 and 2; [2]Paired T-test pairing time 1 county-level estimates to time 2 county-level estimates; [3]p-value of paired *t*-test. Bold numerals denotes significance at the .05 level.

