CHAPTER 6

Application of Forest Inventory and Analysis Data and Site-Specific Factors in Understanding Flowering Dogwood Decline in the Southeastern United States

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INTRODUCTION

Flowering dogwood (*Cornus florida* L.) is a common forest understory tree that is widely distributed in the Eastern United States, where it ranges from eastern Oklahoma and eastern Texas through the southern Gulf Coast to northern Florida, extending north as far as southern Michigan and New England (Little 1971). Flowering dogwood is an important understory component of old-growth forests (Goebel and Hix 1996, McCune and others 1988) that has seen varying degrees of localized and regional health problems across its natural habitat in recent years (Oswalt and others 2012). Although disease in the northeastern population of dogwoods in the United States has been mainly attributed to dogwood anthracnose caused by a fungal pathogen (*Discula destructiva* Redlin; Britton 1994), in the Western Gulf region where the pathogen has yet to be detected, the apparent prevalence of unhealthy dogwoods may indicate a decline complex according to the general description, i.e., predisposing, inciting, and contributing factors that result in disease (Manion 1981). The objectives of this study were (1) to understand the increasing flowering dogwood mortality and population decline in the Southeastern United States over the past few decades; (2) to identify the predisposing, inciting, and contributing factors that could be leading to a decline complex; and (3) to investigate interactions between the identified factors based on Forest Inventory and Analysis (FIA) data and site-specific field survey observations. Findings from the study could facilitate future development of flowering dogwood decline risk assessment tools to assist land managers with management decisions.

MATERIALS AND METHODS

Analysis of Flowering Dogwood Mortality From Forest Inventory and Analysis Data

The flowering dogwood mortality in the FIA plots in the Southeastern United States was obtained from the FIA online data repository for 1958 to 2018, using multiple specific FIA subset databases and the FIA Database User Guide P2_8-0 (https://usfs-public.box.com/v/FIA-FIADB-UserGuides). Data from 12 States including Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, South Carolina, Tennessee, Texas, and Virginia were analyzed to identify biotic and abiotic variables and determine the relationships between the flowering dogwood year of mortality (MORTYR) and the causal agents (AGENTCD) (i.e., animal, diseases, fire, insects, silviculture, competition by vegetation, weather related factors, and others) in the FIA plots surveyed. A total of 186,871 flowering dogwood trees from the FIA plots were evaluated. Data analyses were performed using JMP-SAS statistical software.

Evaluations of Site-Specific Field Plots for Evidence of Flowering Dogwood Decline

A limited-scope, multiyear field survey was conducted from 2020 to 2022 at the Catahoula, Evangeline, Kisatchie, and Winn Ranger Districts of the Kisatchie National Forest, LA, as well as a privately owned site in Pollock, Grant Parish, LA (adjacent to the Catahoula Ranger District). The survey primarily focused on the health of flowering dogwood in Louisiana, where dogwood anthracnose is currently absent, and was aimed at investigating the role site-specific factors may have on a population decline in Louisiana and the Western Gulf region. A total of 103 flowering dogwood trees were identified, tagged, and repeatedly evaluated during the study period. Healthy and unhealthy flowering dogwood trees within diverse forest canopy structures across survey sites were evaluated using selected variables associated with the potentially declining flowering dogwood trees (table 6.1). Visual evaluation of crown conditions and the assessment of crown dieback incidence and severity on individual trees were recorded. The overall crown health condition based on severity of dieback was scored on a scale ranging from 0 to 4, where 0 = no dead branches, 1 = <1/3 dead crown, 2 = 1/3–2/3 dead crown, 3 = >2/3 dead crown, and 4 = entirely dead. Symptomatic tissue samples for laboratory analysis and site-specific data were collected at survey sites. Data analyses were performed using JMP-SAS statistical software.

Tissue samples were collected from symptomatic (i.e., discolored foliage) flowering dogwood trees to determine the presence of *D. destructiva*, the causal pathogen of dogwood anthracnose. Other fungi isolated from tissue samples were cultured on potato dextrose agar at ambient temperature in the laboratory and subsequently identified using morphological characteristics and DNA analysis of the nuclear ribosomal internal transcribed spacer (ITS) region. Insect specimens associated with declining trees were collected and identified based on morphological characteristics.

Field assessments and other planned study activities, including movements within and across States, were limited to sites solely in Louisiana due to the COVID-19 (coronavirus) pandemic, which substantially hindered travel/research activities and negatively impacted the installation and evaluation of field plots and survey components of the study.

Table 6.1—Field survey data variables evaluated for flowering dogwood decline

Variable	Definitions/categories
Site type	Residential/park = RES; privately owned forest = PVTF; publicly owned forest = PUBF
Forest type	Pine dominated = PINE; mixed pine/hardwood = MPH; hardwood = HDWD
Burn history	Not known = NK; last 5 years (based on knowledge or bole scorch) = 5; 5 or more years = 5+
Canopy exposure	Open canopy condition = O; partially open canopy = P; closed canopy condition = C
Dieback	Score (0–4): 0 = no dead branches; 1 = <1/3 dead branches, 2 = 1/3–2/3 dead crown; 3 = >2/3 dead crown; 4 = entirely dead
Position of dieback mortality	Upper = U; midcrown = M; lower = L
Epicormics	Yes/no. If yes, 1 = 1–10; 2 = 11–20; 3 = >20.
Woody stem galls	None = N; light = L; moderate = M; heavy = H. If limbs are too high to accurately assess, note "TH"; if only a few limbs are low enough to observe, note such.
Club galls on fine twigs	None = N; light = L; moderate = M; heavy = H. If limbs are too high to accurately assess, note "TH"; if only a few limbs are low enough to observe, note such.
Leaf spots/lesions	None = N; light = L; moderate = M; heavy = H. If limbs are too high to accurately assess, note "TH"; if only a few limbs are low enough to observe, note such.
Flower spots/lesions	None = N; light = L; moderate = M; heavy = H. If limbs are too high to accurately assess, note "TH"; take representative picture if possible.
Trunk scarring	Presence of burn damage (meaning cambium, callus tissue formed around exposed xylem) = BD; mechanical damage = MD; wildlife damage = WD
Fungal/bacterial canker	If damage is present, classify intensity by 1 = <25% of bole circumference affected; 2 = 25–50%; 3 = >50%
Woodborer exit holes	Presence = yes/no. If yes, denote number observed and any other notes on such.
Fungal fruiting bodies	Presence = yes/no. If yes, note at tree base/soil line "S" or on tree as "T." Take representative picture if possible.
Seedlings	Presence/absence of seedlings (defined here as trees <3 feet tall) within 25 feet of tree = yes/no. If yes, note approximate number.
Other notes	Note any other leaf/branch/trunk abnormalities and attempt to quantify.

RESULTS

Analysis of Flowering Dogwood Mortality From Forest Inventory and Analysis Data

Results showed that 17.9 percent (33,382) of flowering dogwood trees were lost between 1958 and 2018 due to various factors, including silviculture/land clearing activities, vegetation impacts (such as suppression of growth, competition with other plant species, and vines/kudzu (*Pueraria montana*)), diseases, weather, fire, and insect damage, among others. Flowering dogwood mortality increased significantly during periods from 1979 to 1981, 1986 to 1989, 1999 to 2000, and 2008 to 2009, while the highest tree mortality across the region occurred between 1986 and 1989 (fig. 6.1). Approximately 36 percent of tree mortality or losses was related to silviculture/land clearing activities, 31 percent was from vegetation impacts, and 17 percent was associated with diseases, while the remaining individual causal agents—i.e., weather, insects, animal, fire, and "unknown"—accounted for tree mortality ranging from 0.1 to 7 percent.

Silviculture and land clearing activities increased flowering dogwood mortality steadily from 1958 for more than a decade, then accelerated in mid-1970s, and peaked in 1986/1987 before decreasing gradually. A similar trend was observed for the vegetation impacts (i.e., suppression, competition, vines/kudzu etc.) on flowering dogwood mortality during the same period. Further analyses showed that unknown or unidentified factor(s) may have contributed to mortality as well; however, the overall impacts of the "unknown," along with other agents (including animal, fire, insects, and weather), were minimal. Variability in flowering dogwood mortality was noticeable across FIA plots in the 12 States. In Kentucky, flowering dogwood mortality was significantly higher from 1980 to 1982 and from 1986 to 1988 than at any other periods. The highest mortality in Kentucky was recorded in 1987, when 722 trees died across the FIA plots, attributed to "no agents recorded." Although no causal agent was recorded as responsible for tree death during these two periods, the periods corresponded with years of extended and extreme drought events according to the statewide Standardized Precipitation Index (SPI), which measures the deviation from the climatological average for a given period.

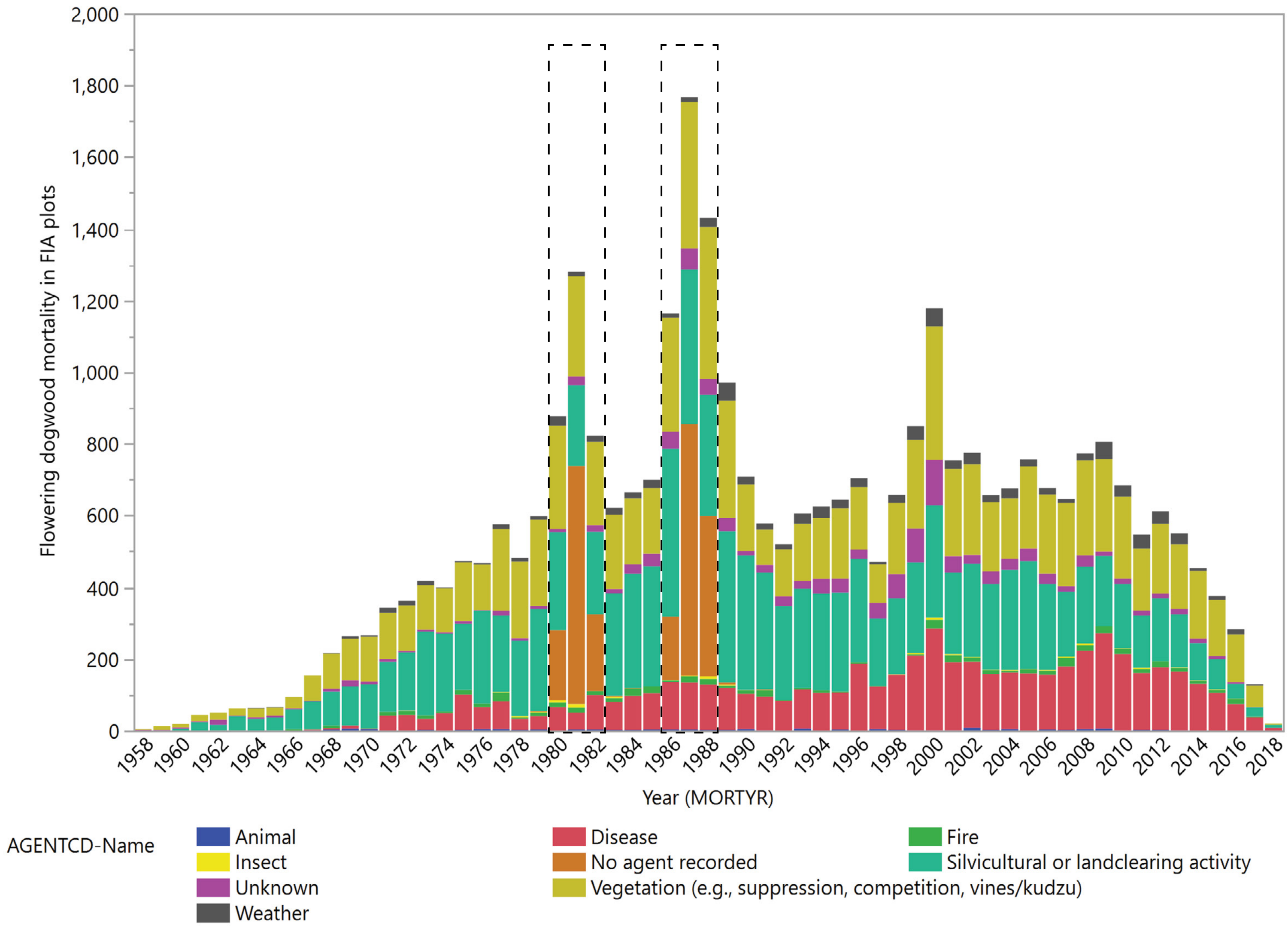

Figure 6.1 —Abiotic and biotic agents associated with flowering dogwood mortality across Forest Inventory and Analysis (FIA) plots in the Southeastern United States for 1958–2018, based on observations and the causal agents from the FIA Database (FIADB) according to the FIADB user guide. Although FIA data do not indicate what could have caused flowering dogwood mortality during periods shown inside dashed rectangles, climate data suggest that periods of extreme drought events corresponded with the two periods of significant tree mortality in Kentucky.

Evaluations of Site-Specific Field Plots for Evidence of Flowering Dogwood Decline

Results from data collected from field plots showed that over 70 percent of tagged flowering dogwood trees evaluated had some level of observed dieback during initial assessments, with 75 percent at the Catahoula Ranger District and 59.2 percent at the Pollock site in 2020, and 84 percent at the Evangeline Ranger District, 50 percent at the Kisatchie Ranger District, and 100 percent at the Winn Ranger District in 2021. The affected trees were at various stages of dieback with most showing >1/3 dead crown, while approximately 7 percent were dead across locations by the time the final assessments were conducted (fig. 6.2). Further analysis identified an interaction between canopy exposure and the incidence of dieback on flowering dogwood at the Evangeline Ranger District in 2021 and 2022. Results indicate a higher incidence of dieback in partially open canopies compared to closed or open canopy stands (fig. 6.3).

Visual assessments of flowering dogwood conducted during spring 2020 showed most trees had healthy foliage and minor blemishes on flowers across sites. Swollen twig terminals caused by the dogwood club gall midge (Diptera: Cecidomyiidae: *Resseliella clavula* (Beutermüller)) were commonly observed. Other symptoms including callused cankers were found in the secondary and/or tertiary branches of flowering dogwoods, while insect exit holes were noticed on symptomatic twigs examined at the Pollock site. Also, at the Kisatchie National Forest in late summer of 2020, the black twig borer (*Xylosandrus compactus* (Eichhoff)) was found in twigs on a few declining trees (fig. 6.4).

Diverse species of pathogenic and opportunistic fungi isolated from declining flowering dogwood tissue samples collected from the Kisatchie Ranger District include *Botrytis cinerea* (botrytis blight), *Cytospora brevispora* (canker), *C. pruinosa* (canker), *Clonostachys rosea*, *Epicoccum nigrum*, *Fusarium lateritium* (stem canker), *Lasiodiplodia theobromae* (canker), *Nigrospora sphaerica*, and *Pestalotiopsis microspora*. Other fungal species isolated from samples collected at the Winn Ranger District in 2021 include *Colletotrichum acutatum*, *C. fioriniae*, *C. fructicola*, *C. siamense*, *Diaporthe phaseolorum*, *Fusarium verticillioides*, and *Myrothecium* spp. However, *D. destructiva*, the causal pathogen of dogwood anthracnose, was not detected, nor were disease-related symptoms observed on the evaluated dogwood trees.

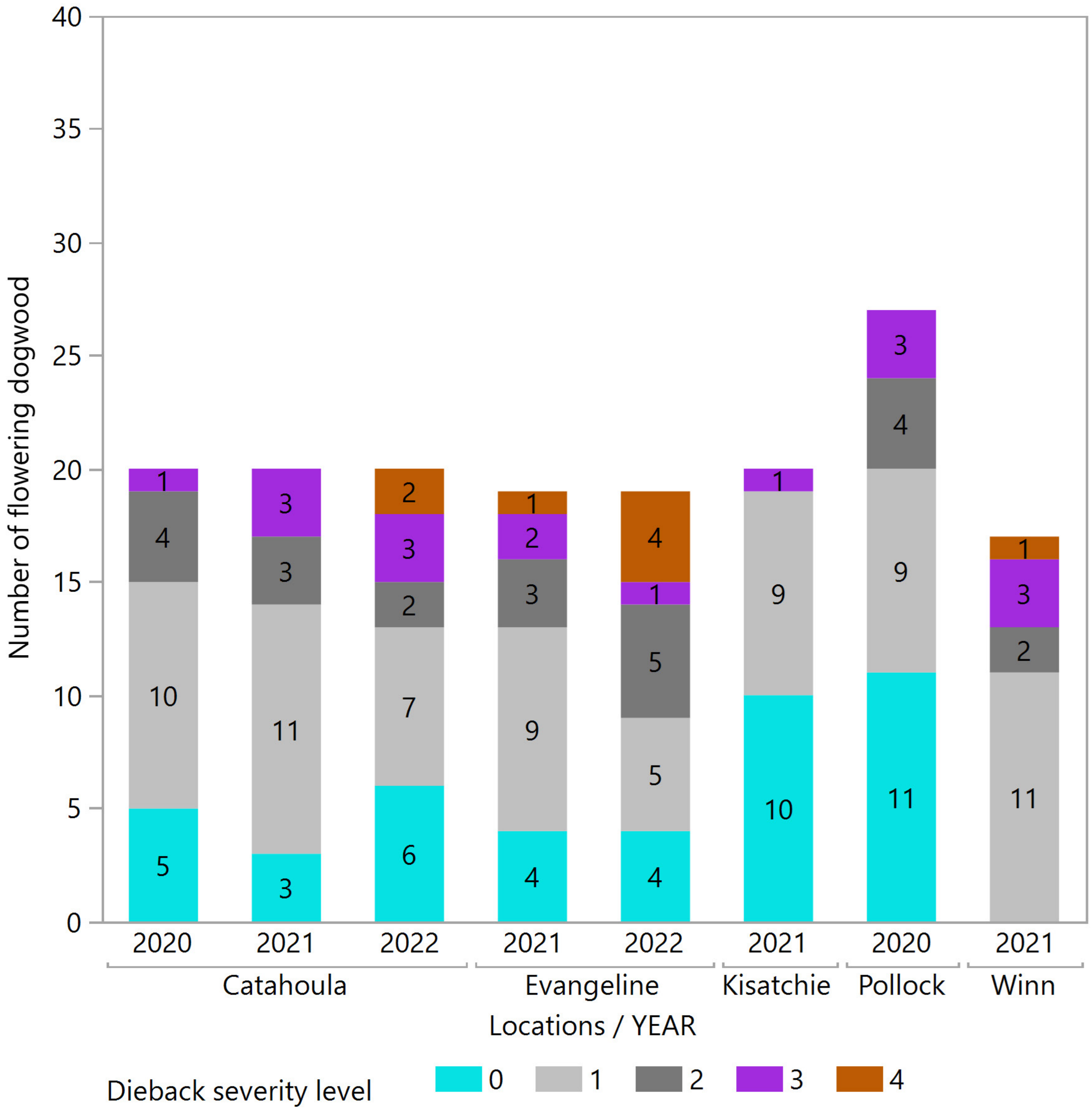

Figure 6.2—Incidence and severity of dieback on flowering dogwood at multiple field survey locations from 2020 to 2022 in Louisiana. The severity was scored on a scale of 0 to 4, where 0 = no incidence or dead branches, 1 = <1/3 dead crown, 2 = 1/3–2/3 dead crown, 3 = >2/3 dead crown, and 4 = entirely dead.

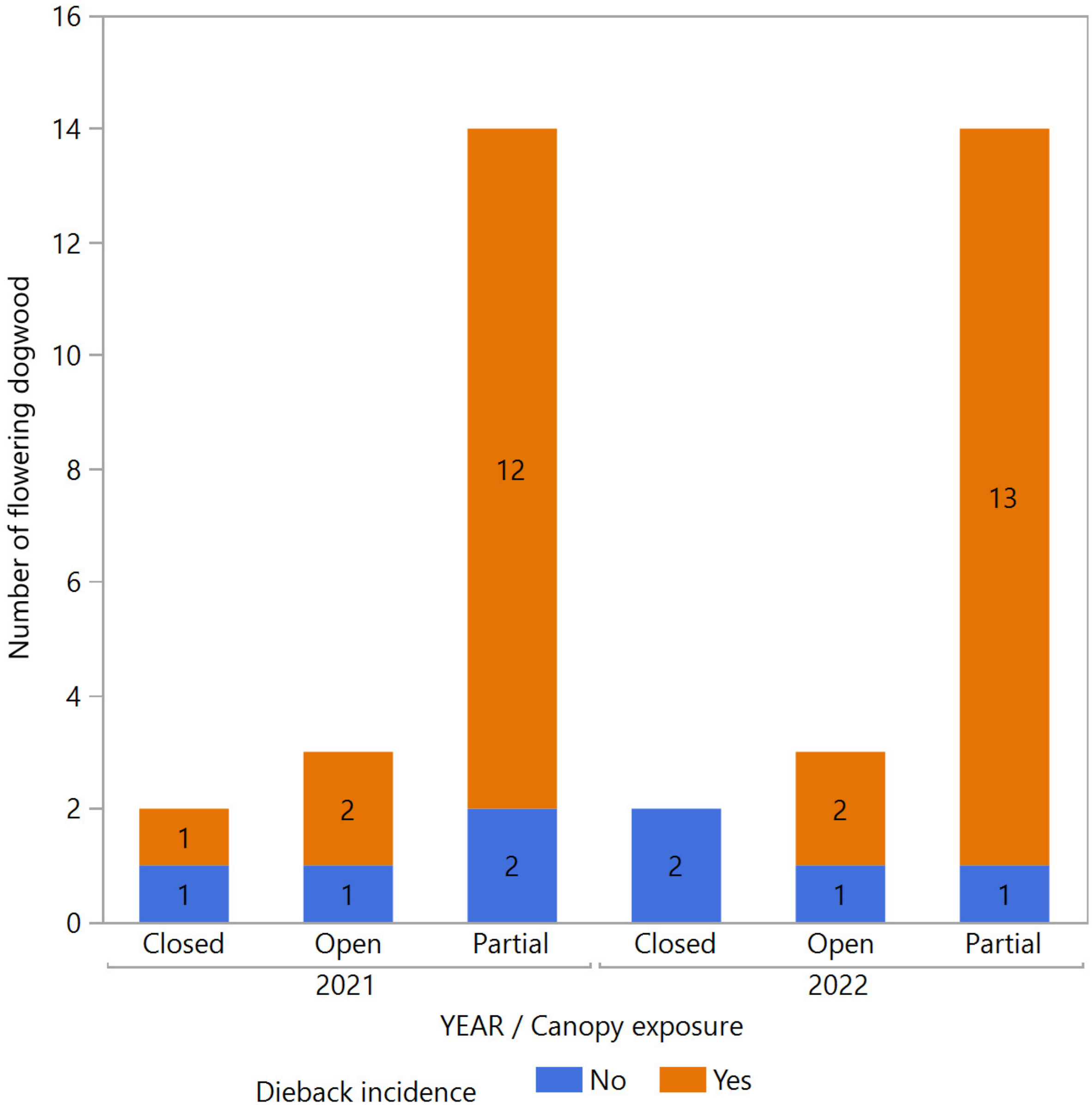

Figure 6.3—Canopy exposure and the incidence of dieback on flowering dogwood trees evaluated in 2021 and 2022 at the Evangeline Ranger District, Kisatchie National Forest, LA.

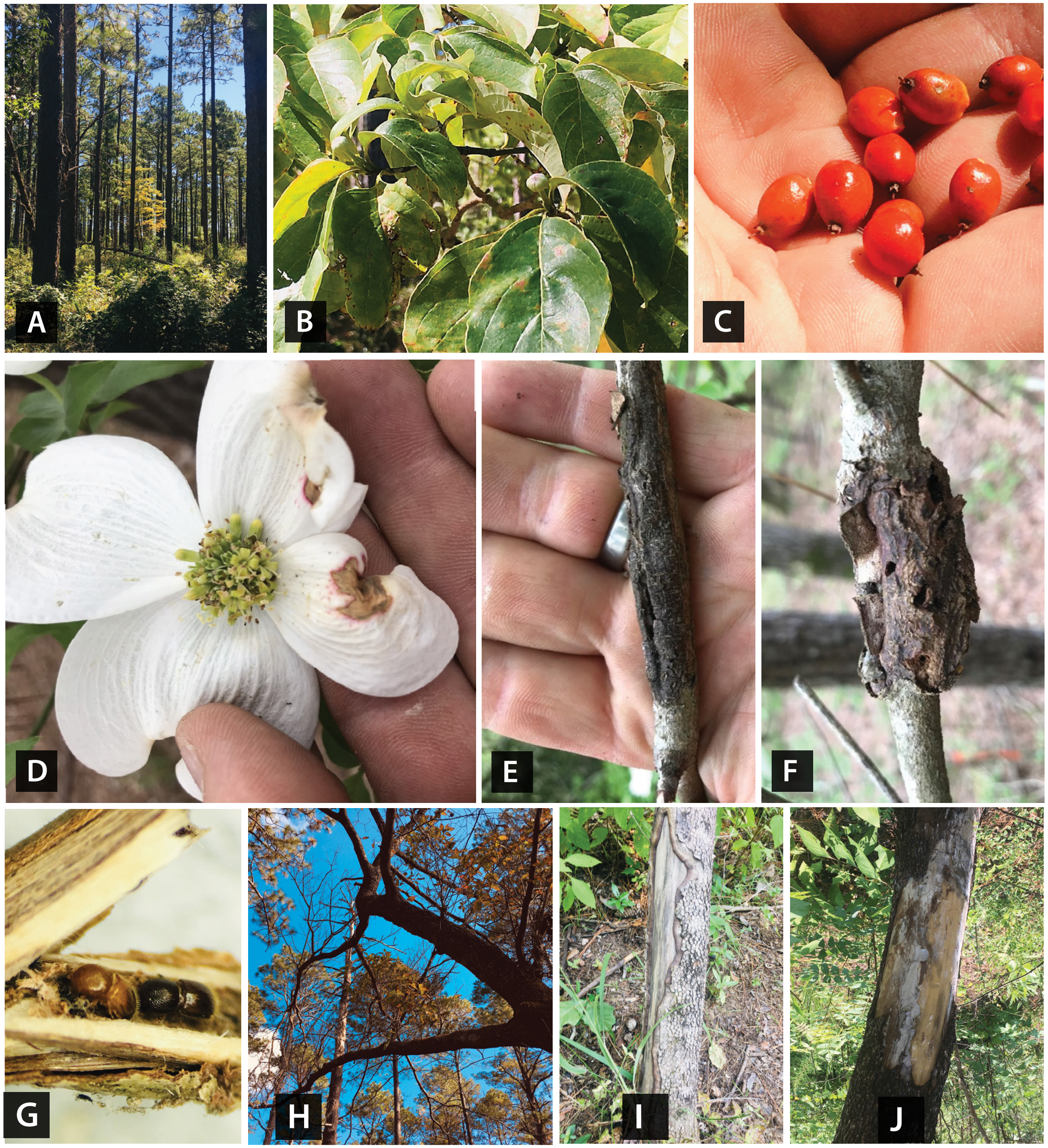

Figure 6.4 —(A) Healthy flowering dogwood trees observed within a pine stand; (B) leaves; (C) ripe berries, at the Kisatchie National Forest, LA, in late summer in 2020; (D) blighted flower caused by Botrytis cinerea*; (E and F) callused-over cankers in twigs observed in the secondary/tertiary branches; (G) black twig borers on symptomatic twigs; (H) flowering dogwood tree decline observed in an open forest canopy structure; and (I and J) abiotic factors including old wound and fire injury observed on declining trees at the Kisatchie National Forest, LA. A–C and G–J: USDA Forest Service photos by Rabiu Olatinwo; D–F: USDA Forest Service photos by Wood Johnson.*

DISCUSSION

Flowering dogwood is a very shallow-rooted forest understory tree that prefers indirect afternoon sunlight or direct morning light, hence requiring overstory protection particularly in late summer when critical water needs must be met to prevent stress or death from the hot afternoon sun (Smith and others 2023). Flowering dogwood is not drought tolerant and therefore is vulnerable to water stress that may also predispose it to diseases and insect pest attacks (e.g., borers). These characteristics as well as site-specific predisposing factors relating to forest canopy structure could be important in determining the sensitivity of flowering dogwood to decline causal agents, the decline progression, and subsequent tree mortality.

Whatever the causal agents or interactions among multiple agents that might be involved, documented geographic distribution (Little 1971) and the FIA flowering dogwood mortality data collected since the 1980s across the Southeastern United States clearly indicate that a substantial decline has occurred in flowering dogwood populations. In the absence of any long-term management and restoration plans, the damaging effects of the dogwood anthracnose pathogen (in some regions), combined with various abiotic and biotic factors including competition by other species and defoliators, diminish the hope of decelerating the decline of flowering dogwood populations on the landscape (Oswalt and others 2012). Although dogwood anthracnose was not detected nor any related symptoms observed on the evaluated flowering dogwood trees in Louisiana from this study, other opportunistic and pathogenic fungi such as *B. cinerea* and various types of cankers were recovered from vulnerable declining dogwoods in the Kisatchie National Forest and nearby forests in Louisiana.

Results from field surveys in this study suggest a higher incidence of dogwood dieback in partially open canopies than in closed or open canopies. Ward and Stephens (1993) noted that shade-intolerant woody species declined slowly in some plots as the forest matured and the canopy closed. In a study on the influence of site factors on dogwood anthracnose in the Nantahala Mountain range of western North Carolina, Chellemi and others (1992) observed higher disease incidence and greater severity in interior forest areas where the lowest evaporative potential was found. These observations highlight the complexity of the forest canopy structure that protects vulnerable flowering dogwood from exposure to direct sun on one hand, and the conducive environment within the interior forest area that may support the proliferation of pathogens and subsequent disease development on the other hand.

Silviculture and land clearing activities, vegetation impacts due to suppression of growth, competition from other plant species, diseases caused by pathogens, climate/weather, fire, and insect pests were each implicated to varying degrees as causal agents in flowering dogwood mortality according to the FIA survey data examined in this study. The extreme and extended period of drought events associated with a changing climate in part of the Southeastern United States may continue to affect flowering dogwood populations negatively, perhaps shifting habitat suitability in parts of the region that could expose the flowering dogwood population to further competition from climate change-induced species migration (Oswalt and others 2012, Woodall and others 2009).

CONCLUSIONS

Monitoring the complex interactions among predisposing, inciting, and contributing factors and their roles in tree decline would be helpful in assessing the impacts of a changing climate on flowering dogwood populations as well as mitigating tree decline or mortality in forest stands across the region. Continuous exposure of flowering dogwood to stressors such as drought, pathogens/pests, and direct sunlight because of overstory tree harvesting/canopy opening may increase and expand the distribution of flowering dogwood decline in southeastern forests over time.

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