CHAPTER 2

Evaluating the Extent and Severity of Black Cherry Regeneration Declines in Eastern Forests and Exploring Potential Causes

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How to cite this chapter:

Vickers, Lance A.; Royo, Alejandro A.; Stout, Susan L.; Ristau, Todd; Oldland, William K.; Knapp, Benjamin O.; Knapp, Lauren S.P.; Hille, Andrea. 2025. Evaluating the extent and severity of black cherry regeneration declines in eastern forests and exploring potential causes. In: Conkling, B.L.; Pandit, K., eds. Forest Health Monitoring: Evaluation Monitoring project summaries 2023. Gen. Tech. Rep. WO-105a. Washington, DC: U.S. Department of Agriculture, Forest Service. 9–16. Chapter 2. https://doi.org/10.2737/WO-GTR-105a-Chap2.

INTRODUCTION

This project resulted from conversations between researchers and managers in Pennsylvania, both noting persistent deterioration in tree canopy vigor and seedling numbers for black cherry (*Prunus serotina*) in the Allegheny region, the epicenter of the species' commercial range. The Forest Health Collaborative subsequently identified black cherry decline as a top threat to Allegheny hardwood ecosystems (USDA Forest Service 2018a). Preliminary analyses of Forest Inventory and Analysis (FIA) data showed a ≈50-percent decline in seedling abundance from 2000 to 2017 in Pennsylvania (USDA Forest Service 2018b).

Royo and others (2021) examined the relative strength of available evidence of five factors known or assumed to influence forest health broadly and black cherry dynamics in the Allegheny region: climate variability, deer browsing, senescence, negative plant-soil microbial feedback loops (i.e., pathogens), and reduced nitrogen availability. The authors concluded that declines in black cherry health and regeneration were not temporary anomalies. Their review suggested that altered nitrogen deposition dynamics since the Clean Air Act Amendments of 1990 and strengthened negative soil-microbial feedback loops, particularly given a warmer and wetter climate, represented promising avenues for future research. In contrast, succession, senescence, and deer browsing may have an influence in localized instances but were not suspected to underlie the regional decline. Prior research has shown black cherry to be a nitrogen-demanding species during germination and growth (Auchmoody 1979, 1982) and that it may accrue critical densities of pathogenic fungi that eventually limit regeneration (Johnson and others 2012, Reinhart and others 2005, Stanosz 1992) in dense stands. This study therefore posited that three mutually nonexclusive mechanisms may limit regeneration of black cherry: (1) advancing forest successional status, (2) changes in soil nutrition, and (3) intensified negative density dependence.

As an Evaluation Monitoring project funded under the U.S. Department of Agriculture, Forest Service, Forest Health Monitoring Program, this study had an overarching goal to provide insight into which locales may be at greatest risk of losing their future black cherry component. It proposed an examination of seedling dynamics, including the extent and severity of declining abundance, over 5–20 years at multiple spatial scales. The hypothesis was that seedling abundance declines would be pronounced in the Allegheny region, where black cherry has historically been most dominant, but less severe across the range of black cherry. Specifically, it was an investigation into whether the occurrence or magnitude of declining black cherry seedling abundance was localized or varied with latitude, varied with historic mature black cherry stocking, or varied geospatially with changing atmospheric deposition.

METHODS

Data From Forest Inventory and Analysis

This project relied on data collected as part of the FIA Program (https://www.fia.fs.usda.gov/). This national inventory has a long history of data collection and is administered at the State level; however, the methodology has undergone numerous changes and refinements throughout that history, generally trending towards more uniformity across States with time. Disparities in methodologies across States limited the inferential potential of early data (ca. pre-1980) at broad scales and those data are not readily accessible by the public. Therefore, this project only used publicly accessible data, which generally spans ca. 1980 to present, covering a period when inventory methodologies became similar enough to allow broad spatiotemporal-scale investigations (though note that inventories prior to ca. 2000 still suffer from temporal incongruency, i.e., an entire State was inventoried in a single effort, but not all States were inventoried the same year). Around 2000, FIA adopted a nationalized and annualized inventory protocol in which the inventory was continuous in every State, i.e., a fixed percentage of inventory plots is measured every year in every State such that plots are remeasured every 5–7 years and, after the initial cycle, statewide inventories are updated yearly as the oldest data are replaced by the remeasured data.

The FIA Program collects data on permanent sample plots at known locations that are systematically distributed across all forested lands around the country such that each sample plot generally represents about 6,000 acres, though certain areas such as national forests are sampled with higher intensity. At each FIA sample location, one or more conditions, which include information on land/water, forest/nonforest, reserved/not reserved, stand type, ownership, and accessibility, are recorded. The tree data collected include species, diameter at breast height (d.b.h.), status as live or dead, whether a dead stem is to be counted as a harvest removal or other mortality, and several other attributes, for all trees with d.b.h. ≥5.0 inches, on a cluster of nested subplots at each sample location (Bechtold and Patterson 2005). For saplings (d.b.h. = 1.0–4.9 inches), species, d.b.h., and location are consistently collected for live stems only (the fates of dead or harvested stems of this size are not tracked), and seedlings (d.b.h. <1.0 inch and height ≥6.0 inches for softwoods or ≥12.0 inches for hardwoods) are simply tallied by species.

Data From the National Atmospheric Deposition Program

This study also relied on publicly available data from the National Trends Network of the National Atmospheric Deposition Program (NADP; https://nadp.slh.wisc.edu/). The National Trends Network is the largest long-term network for precipitation chemistry across the United States and originated in 1977. Basic data elements include measures of free acidity (H^+ as pH), conductance, calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^+), potassium (K^+), sulfate (SO_4^{2-}), nitrate (NO_3^-), chloride (Cl^-), bromide (Br^-), and ammonium (NH_4^+) and are made available on the NADP website. These basic data undergo further modeling and interpolation analyses to develop publicly available annualized continuous cover raster (grid) layers, or maps, for the various elements. Analyses used the raster layers for total rainfall, free acidity (H^+ as pH), calcium (Ca^{2+}), magnesium (Mg^{2+}), sulfate (SO_4^{2-}), nitrate (NO_3^-), and ammonium (NH_4^+), which spanned the years 1985–2018.

Analyses

Data from both FIA and NADP were summarized at various spatial scales including ecological subsections and sections (Cleland and others 2007), and across the entire Eastern U.S. range of black cherry (east of 100° W longitude). The range of black cherry was defined as any ecological subsection in the Eastern United States where the summarized black cherry density for stems with d.b.h. ≥1.0 inch was ≥1 stem per acre in the most recent FIA inventories from each State (since the earliest forest inventories were less consistent across States). This study did not uncover any conspicuous, reliable differences in range extent across the time periods used (ca. 1990–2020). The ecological sections included in this range are depicted in figure 2.1.

Because of some temporal inconsistencies in methodology, this study could only examine population metrics such as density, frequency, basal area, size distribution, species composition, and importance value as far back as about 1990 and only for stems with a d.b.h. ≥1.0 inch (hereafter trees). Importance values for trees were calculated as the sum of relative stem density, relative basal area, and proportion of occupied plots in a given area (e.g., ecological section) for a given species divided by 300. Since stems with a d.b.h. <1.0 inch (hereafter seedlings) were not consistently inventoried prior to the adoption of the nationalized and annualized inventory, only seedling data at the species range scale from around 2005 onward (varying by State) were analyzed.

RESULTS

As defined herein, the Eastern U.S. range of black cherry spanned 34 States and 80 ecological sections (fig. 2.1). At this scale, only modest change was observed in black cherry tree populations from ca. 1990 to 2020, and changes that were noted at this scale tended slightly positive for density, dominance, frequency, and importance metrics. However, at the same spatial scale, seedling populations decreased in all metrics from 2005 to 2020, including a 43-percent

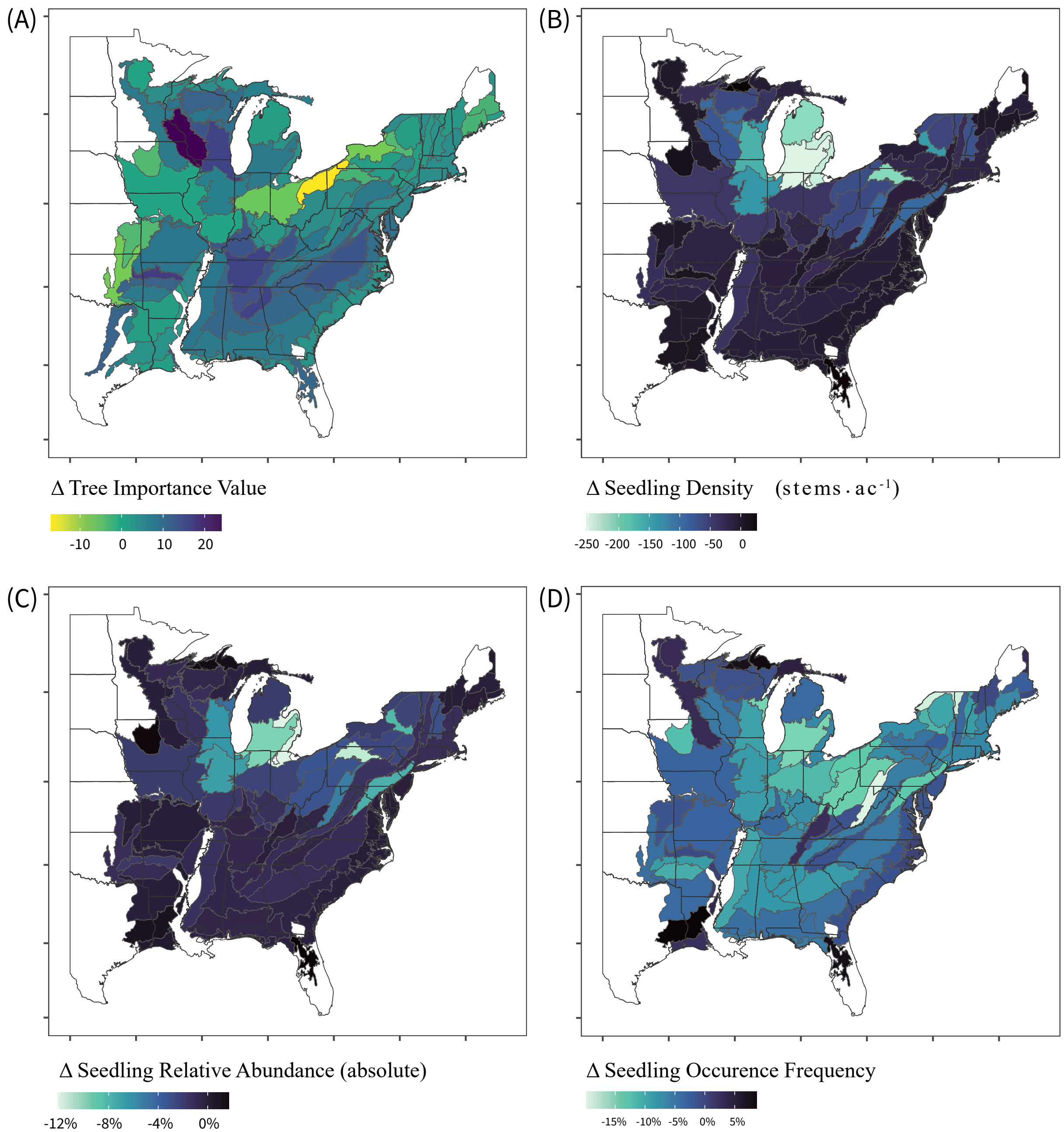

Figure 2.1 —(A) Net change in rangewide importance value from ca. 1990 to 2020 for black cherry trees (defined as stems with diameter at breast height (d.b.h.) ≥1 inch) summarized at the ecological section scale. (B) Net change in seedling density from ca. 2005 to 2020. (Seedlings are defined as stems with a total height ≥12 inches but d.b.h. <1 inch.) (C) Net absolute change in seedling relative abundance from ca. 2005 to 2020. (D) Net absolute change in seedling occurrence frequency from ca. 2005 to 2020. Range includes ecological subsections where the species was present beyond a trace amount (tree density per acre ≥1) ca. 2020. Approximate year summarizes State-level Forest Inventory and Analysis data that were the closest temporal match to nominal year. Δ = total change from the latest time period to the earliest for each metric.

decline in overall abundance, 38-percent decline in relative abundance, and 28-percent decline in occurrence frequency (table 2.1). In the same study period, seedling abundances for all other species combined also decreased, but only about 8 percent, which further highlights the magnitude of the 43-percent change that was observed for black cherry.

In 1990, black cherry importance was highest in ecological sections within the Allegheny region bordering Lake Erie but not limited to a particular State or ecological section. Instead, the importance of black cherry to forests was evident across a broader region sometimes referred to as the "Rust Belt," "Industrial Midwest," or the "Great Lakes megalopolis," which can include parts of Illinois, Indiana, Michigan, Minnesota, New York, Ohio, Pennsylvania, West Virginia, Wisconsin, Ontario, and Quebec in various combination. By 2020, the relative magnitude of importance between the Allegheny region and the rest of the Rust Belt region was more subdued, indicating that the Allegheny region had experienced a more severe decline in black cherry importance from 1990 to 2020 (fig. 2.1A). The seedling population declined consistently in total density and relative abundance from ca. 2005 to 2020. A consistent decline trend of change was not detected along a latitudinal gradient, but the greatest declines again occurred in the Rust Belt region and, most prominently, in southern Michigan and northwestern Pennsylvania (fig. 2.1B). Reductions in seedling relative abundance largely mirrored those ecological sections where the density declined the most (fig. 2.1C). Decreasing occurrence of black cherry seedlings overall was widespread (fig. 2.1D).

Declines in black cherry tree and seedling populations were highly correlated with the prior importance value (ca. 1990) or seedling abundance (ca. 2005) of black cherry at the scale of ecological sections, i.e., losses were more extreme in the regions where it was once most prominent. The observed decreases in the absolute density of black cherry seedlings ($r = -0.64$), their relative abundance ($r = -0.71$), and their occurrence frequency ($r = -0.63$) were all magnified in regions with higher black cherry tree importance values.

Table 2.1—Rangewide[a] population across 15 years[b] for black cherry seedlings (height ≥12 inches)

Year	Abundance	Relative abundance	Frequency
	(stems/acre)	(% stems/acre)	(% plots)
2005	94.8	4.5	25.9
2020	53.9	2.8	18.6
Δ	-43%	-38%	-28%

Δ = percent change in metrics from 2005 to 2020.

[a] Range includes ecological subsections where the species was present beyond a trace amount (tree density per acre ≥1) ca. 2020.

[b] Approximate year summarizes State-level Forest Inventory and Analysis data that were the closest temporal match to nominal year.

The magnitude of recent declines in seedling relative abundance at the scale of the ecological section tended to increase in severity with higher levels of seedling relative abundance at the beginning of the monitoring period (r = -0.87).

Black cherry tree importance in 1990 was positively correlated with total nitrogen deposition (r = 0.78) and sulfate deposition (r = 0.65) as measured in the late 1980s (which approximates the era of peak atmospheric deposition) at the scale of an ecological section. At that time, evidence suggested that both nitrate and ammonium were positively correlated with black cherry importance, though nitrate- had a stronger correlation (r = 0.72 vs. r = 0.56) and broader range of inputs. By 2020, nitrate deposition rates decreased substantially and the correlation between black cherry importance and total nitrogen deposition was nearly halved. Similarly, the rates of sulfate deposition by 2020 were about one-third of 1990 levels and sulfate deposition was no longer correlated with black cherry importance in 2020. For black cherry seedlings, the ecological sections with the greatest reductions in relative abundance and frequency from 2005 to 2020 also tended to be the regions with the greatest flux in deposition rates since 1990 (fig. 2.2). Changing deposition rates for nitrogen and sulfate were correlated with reductions in relative abundance and frequency and, since no relationship with ammonium was found, nitrate is the more likely driver of any nitrogen-seedling effects.

CONCLUSIONS

The aim of this project was to evaluate the extent and severity of declines in black cherry seedling populations and to explore potential causes of this decline that threaten the sustainable management of this species. This study used statistical analyses of long-term datasets to examine trends and potential effects on seedling populations across multiple ecologically and statistically meaningful spatiotemporal scales. The results of this analysis showed evidence of changes in black cherry tree and seedling populations, but the occurrence and magnitude of those changes varied across the Eastern U.S. range of the species. Regions that experienced the highest magnitude of change tended to be those with historically high black cherry importance which, in turn, also tended to be regions that had high nitrate and sulfate deposition rates prior to 1990. In these regions, deposition rates of nitrate and sulfate have since declined as has the strength of their correlations with black cherry. The observational nature of this study could not determine that the changes observed in black cherry were caused by changes in atmospheric deposition quantity or composition, but the strength of correlations reported here suggest that controlled experiments to test that hypothesis are warranted. In the meantime, managers interested in promoting black cherry may face the most challenges in the very areas where black cherry has historically thrived.

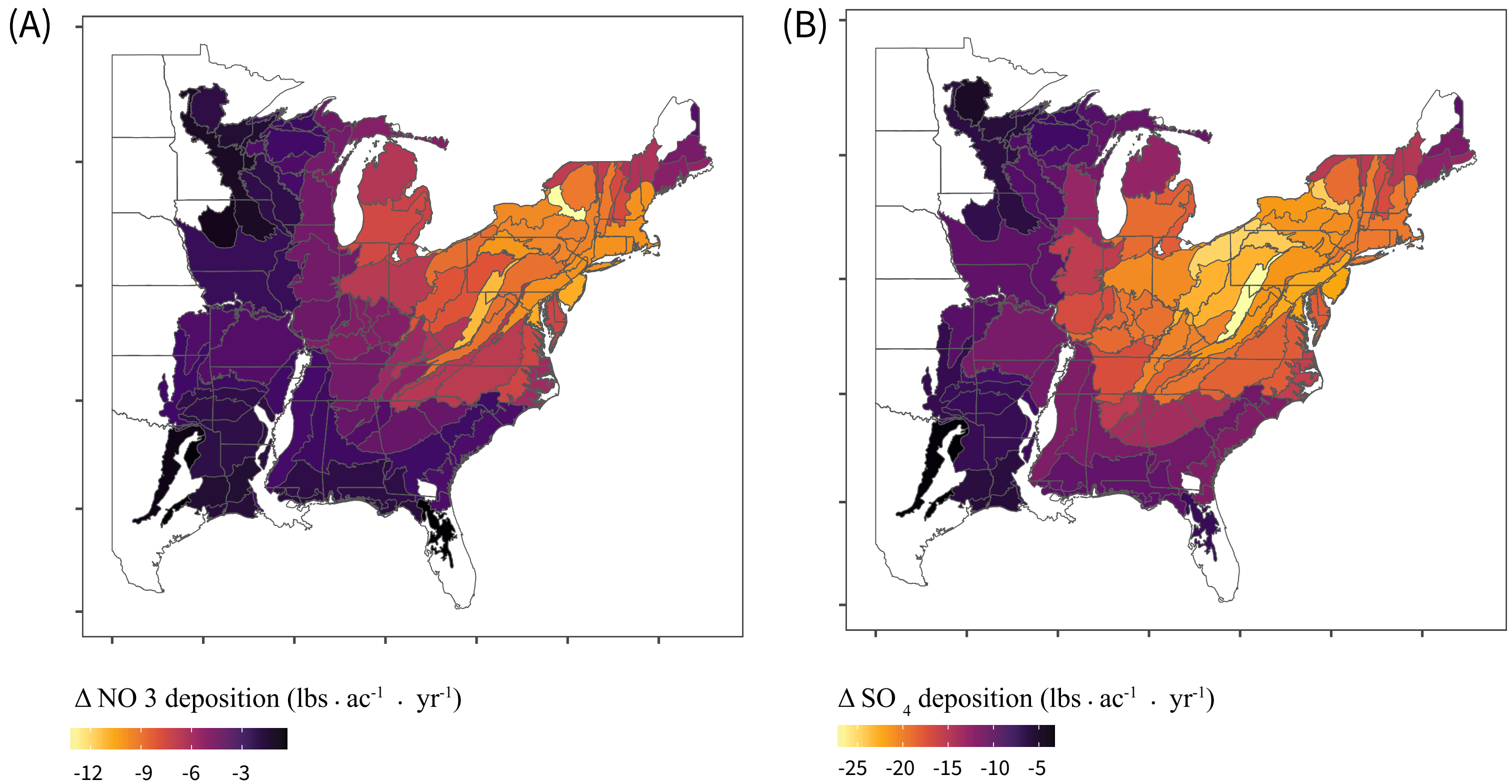

Figure 2.2 —Net change in rangewide atmospheric deposition of nitrate (A) and sulfate (B) from ca. 1990 to 2020 for black cherry summarized at the ecological section scale. Range includes ecological subsections where the species was present beyond a trace amount (tree density per acre ≥1) ca. 2020. Approximate year summarizes National Atmospheric Deposition Program data that were the closest temporal match to nominal year. Δ = total change from the latest time period to the earliest for each metric. Data retrieved from National Atmospheric Deposition Program (https://nadp.slh.wisc.edu/).

ACKNOWLEDGMENTS

This work was funded as Evaluation Monitoring project 19-CA-299 by the U.S. Department of Agriculture, Forest Service, Forest Health Monitoring Program. The authors appreciate the assistance of Rick Turcotte, Stephen Burr, Barbara Conkling, and the many other representatives from the Forest Service that corresponded and assisted with the administration of this grant. The authors also appreciate the nonfinancial support from the Forest Service (Allegheny National Forest, Forest Inventory and Analysis Program, and Northern Research Station), Allegheny Forest Heath Collaborative, Allegheny Hardwood Utilization Group, Pennsylvania Department of Natural Resources Bureau of Forestry, University of Kentucky, and University of Missouri.

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