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Long term monitoring of actions and outcomes: Improving and streamlining learning from Longleaf pine restorations at Morningside Nature Center

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Abstract

The restoration of natural ecosystems is ideally driven by the feedback received from monitoring programs which reflect outcomes from actions through the collection of long-term data on the health of an ecosystem. In this study, the monitoring program of a longleaf pine (*Pinus palustris*) ecosystem in north central Florida is reviewed and revised. This revision was based on contact with park managers and the analysis of existing data with the goal of improving the restoration program's effectiveness. Analysis of existing data revealed the present limited ability to draw conclusions due to the temporal limitations of the data set. To address this shortcoming, photo point data from prior years was converted into a data set that is complementary to the monitoring protocol. As part of the protocol revision, the photo point data collection was also added to the monitoring protocol. The findings illustrate the importance of maintaining and continuing monitoring programs due to the value of long-term data for assessing changes in an ecosystem over time. In addition, future data collections will yield more useful feedback as a result of improvements made to the protocol. The design of a monitoring program must be closely linked to the specifics of the restoration program intended to be studied. This study provides an account of this process to be referenced during the revision of similar monitoring programs.

Keywords: longleaf pine, ecological monitoring, ecological restoration

Introduction

In cases where ecosystems have been damaged to the point where conservation and protection alone are not sufficient to allow for recovery, ecological restoration must be undertaken (Gann et al., 2019). Restoration aims to repair a degraded landscape through the implementation of restorative and management actions, such as prescribed fire, removal of invasive species, or plantings (Gann et al., 2019). Adaptive management is a learning-based approach to restoration that uses the knowledge learned from outcomes of actions to continually adjust management techniques in an iterative cycle (Gann et al., 2019; Williams, 2011), allowing for more efficient use of management resources and improved restoration outcomes (Sutter & Rutledge, 2017). Ecological monitoring, the collection of data on an ecosystem's structure and composition, is crucial to the decision-making process of adaptive management due to the feedback it provides on the outcomes of management actions (Gann et al., 2019; Ruiz-Jaen & Aide, 2005; Sutter & Rutledge, 2017; Williams, 2011). In addition, long-term monitoring data is useful for detecting changes in ecosystem structure or function, evaluating ecological responses to disturbance, guiding environmental legislation, and contributing to the overall understanding of ecological theory and dynamics (Lindenmayer & Likens, 2010). Despite their value, monitoring programs are commonly not implemented and often fail or are ineffective due to problems such as poor design or lack of funding(Caughlan & Oakley, 2001; Lindenmayer & Likens, 2010; Sutter & Rutledge, 2017). With limited resources, volunteers or students may be recruited to collect data for monitoring as a cost-effective approach. However, using largely untrained personnel means that data may be inconsistent or contain errors. To ensure results are management and policy-relevant, well-developed partnerships must be established between scientists, managers, and policy-makers, which presents an additional challenge to maintaining a successful monitoring program (Lindenmayer & Likens, 2018; Sutter & Rutledge, 2017). Collected data should be frequently used and examined to evaluate ecosystem change, especially resulting from the implementation of management actions or policies. Conclusions drawn from this process must be effectively communicated to managers and policymakers (Lindenmayer & Likens, 2010; Sutter & Rutledge, 2017). The sharing of results through publications or other outreach also provides information that can help other landowners or managers (Sutter & Rutledge, 2017). In this way, monitoring can play a crucial role in informing the decisions which shape the way ecosystems are managed.

To examine monitoring program design and implementation, Morningside Nature Center was selected, where the restoration of degraded longleaf pine ecosystems is ongoing in three separate restoration projects. Longleaf pine forests are ecosystems with an open canopy of longleaf pine, low-density midstory, and herbaceous groundcover layer, maintained by frequent, low-intensity fires (Kirkman et al., 2017; Oswalt et al., 2012). The longleaf pine ecosystem is one of the most species-diverse in North America. Acting as a habitat for many threatened or endangered species of plants and animals, some of which can be found only or primarily in longleaf pine forests (Brockway et al., 2006). Once spanning over 37 million hectares of the southeast United States, longleaf forests have been reduced to only around 2.2% of their original range post-European settlement to over-harvesting, conversion of sites for other uses, and fire exclusion (Jose et al., 2006; Kirkman et al., 2017; Oswalt et al., 2012). The threatened status of this economically and ecologically valuable ecosystem has resulted in the growing interest in the conservation, management, and restoration of longleaf pine forests among land-owners, scientists, and the public (Alavalapati et al., 2006; McIntyre et al., 2017). The majority of remaining fragments have been altered past the point of resiliency, making human intervention necessary for recovery to the pre-disturbance state (Jose et al., 2006; Oswalt et al., 2012), but restoration is especially difficult due to the high complexity and geographic variation of longleaf pine ecosystems (Kirkman et al., 2017; Peet, 2006), as well as the long time frame needed for recovery (Jack & McIntyre, 2017; Sutter & Rutledge, 2017). Longleaf pine forests situated on public lands present an important target and ideal opportunity for restoration due to the ability to implement long-term programs, availability of resources, and low risk of land conversion to other uses as compared to private lands (McIntyre et al., 2017). Morningside Nature Center is an optimally positioned site for study as restoration goals are likely not out of reach in the near-term; despite degradation associated with previous land use, soil and remnant species composition are relatively intact, giving the park a high potential for full restoration. The specific purpose of this study is to evaluate and improve the monitoring program at Morningside Nature Center, through 1) the revision of protocol/design, 2) the assessment of management outcomes, and 3) the communication to managers and policymakers.

Methods

Morningside Nature Center is a 416-acre nature park located in Gainesville, Florida (29.659115° N, -82.276665° E) consisting primarily of fire-dependent mesic flatwoods and sandhill natural communities. Before its purchase in 1964 by the city of Gainesville, the land was used for logging and turpentine production, and a lack of regular fire led to degradation of these natural communities. The City of Gainesville's Nature Operations Division (NOD) is currently restoring 27 acres of the park, employing regular prescribed fire, selective removal of undesirable vegetation such as fire intolerant oaks, targeted herbicide use, and occasional scattering of seeds or planting of containerized plants. Restoration occurs within three units (4AB, 5A, 3B) which were all shown by aerial photos to contain open pine savanna in 1937. Monitoring at Morningside began in 2014 as a University of Florida student-driven project, establishing 15 plots distributed over the three restoration units to be revisited twice annually in the spring and fall. Within each plot, the number or percent cover category of 12 categories of plant species are recorded, with the aim to track changes in ecosystem structure or health.

Monitoring Protocol Revision

In order to better align the results of monitoring with the goals of management, the Gainesville NOD staff were met on site at Morningside Nature Center in December 2021. Key insights into management perspectives on monitoring data and its potential applications were recorded and incorporated into a revision of the monitoring design, resulting in the addition of steps to the protocol and species categories to the data sheet. In addition, the plant identification guide used during the monitoring procedure was updated based on a document created by managers identifying commonly found vegetation in the park (Appendix A).

Refinement of Restoration Goals and Outcomes Assessment

To optimize the utility of monitoring data for measuring restoration progress, restoration goals were refined based on maps of natural community and soil composition. To assess management outcomes, a list of restoration actions was compiled, including type of action, date, and unit (Appendix A) to create a timeline of each unit's management history. Next, the existing monitoring data, collected based on the initial protocol (Appendix B), was gathered and analyzed. The data set included ten instances of monitoring over seven years (2014-2021) and measured either the number of plants or estimated percent cover (recorded as a cover class with values 1-5) of 12 vegetation categories in each 4m by 4m plot. Changes in the coverage of key categories (longleaf pine, deciduous oaks, and fire-intolerant oaks, measured by number of trees; groundcover and wiregrass, measured by cover class) over time were graphed in order to identify trends and compare restoration units in the context of their management history.

Most recorded management actions occurred before the start of the monitoring program, meaning that monitoring data did not reflect outcomes of actions at key initial stages of restoration. To provide complementary data during these early stages of restoration, photo point data maintained by the Gainesville NOD were converted to cover and tree count estimates within a 4m by 4m plot.

Results

Monitoring Protocol Revision

Review of the existing protocol (Appendix B) and data set by practitioners revealed shortcomings in the data collection method which were addressed in the creation of the revised protocol (Appendix C). Changes made primarily focused on the addition of steps either to provide relevant information to management or to reduce errors and improve the reliability of the data (Table 1). Practitioners confirmed that the approach of the revised program was sound and would produce information useful to their decision making.

Table 1. Changes Made to Monitoring Protocol

Component	Change	Explanation
Protocol	Added step of taking photo points with a tripod.	Photo points provide visualization of changes over time and can be referenced to confirm trends detected by numerical data.
	Added step of measuring canopy with Li-Cor canopy analyzer.	Canopy composition is associated with the health of sandhill/longleaf pine forests.
Data collection sheet	Added "Palmettos" category to percent cover measurements.	Palmettos are a commonly found species at Morningside and are targeted for removal by management.
	Added "Hardwoods over 3 ft. tall" category to percent cover measurements.	Added in order to specifically represent trees targeted for removal by management.
Plant species identification guide	Added commonly found species as identified by park managers.	Improve data integrity by assisting identification of species.
	Added photos of all species included in categories monitored.	Improve data integrity by assisting identification of species.

Refinement of Restoration Goals and Outcomes Assessment

Management actions provided by park staff were recorded between the years 1983-2020 and differed in timing and frequency between units, but each type of action was linked to a restoration goal. Regular prescribed fire (every 1-3 years) maintains ecosystem structure and species composition by reducing ground litter and hardwoods, allowing for the growth of pines and grasses (Florida Natural Areas Inventory (FNAI), 2010). Desirable species are also introduced through the planting of containerized longleaf pines and wiregrass (*Aristida stricta*) tubelings. The scattering of wildflower and grass seeds is implemented to increase and diversify groundcover. The use of herbicide, hand-cutting, and logging is done to remove undesirable vegetation such as fire-intolerant oaks and loblolly pines. In a unique approach to raising funds to support restoration, at the initial stages of the project, trees harvested as a restoration action were sold as biomass for energy production.

In unit 4AB, after clearing prior to 1949 (as shown by aerial photos) the area was recolonized with weedy fast growing undesirable trees, until an outbreak of southern pine beetles killed most loblolly pines, after which other undesirable hardwoods were logged and chipped in 2001. After herbiciding undesirable vegetation and a prescribed fire (Figure 1a), wiregrass and longleaf pine increased (from an average cover category of 0 to 4 and from an average of 0 trees per plot to 2, respectively, within 4 years) following planting in 2002 (Figure 1b). Non-pine trees decreased from an average of 5 trees per plot to 0 after logging (2001) and the use of herbicide (2002).Wiregrass and groundcover both increased by 1 average cover category after seeds were scattered (2009, 2010, 2012, 2014) within 10 years of the first instance. Currently (in 2022), according to management, the site has achieved a sufficient amount of pine needles and grasses to provide fuel for burns, but canopy density is higher than desired. Future management plans involve selective oak removal and thinning of pines.

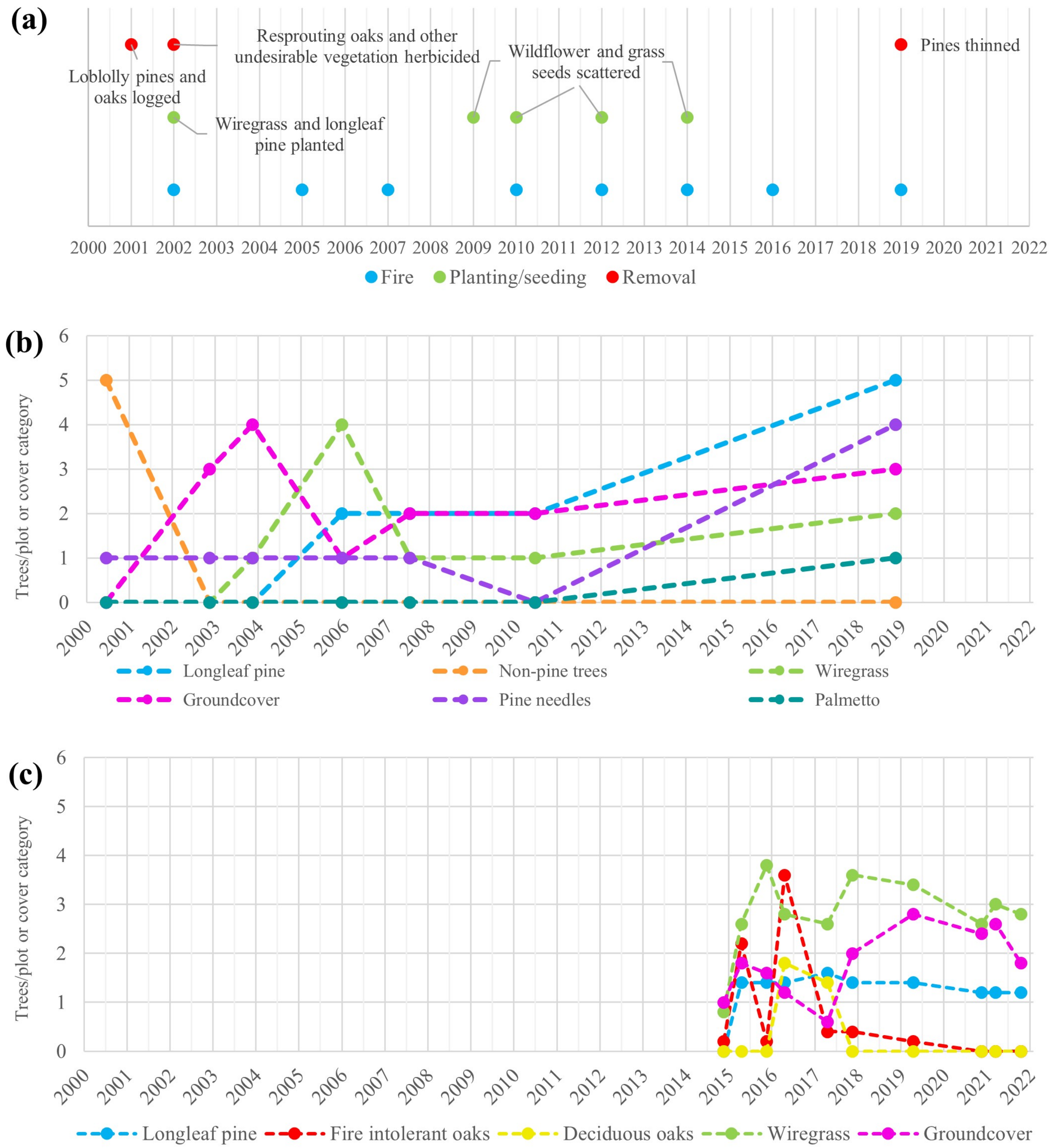
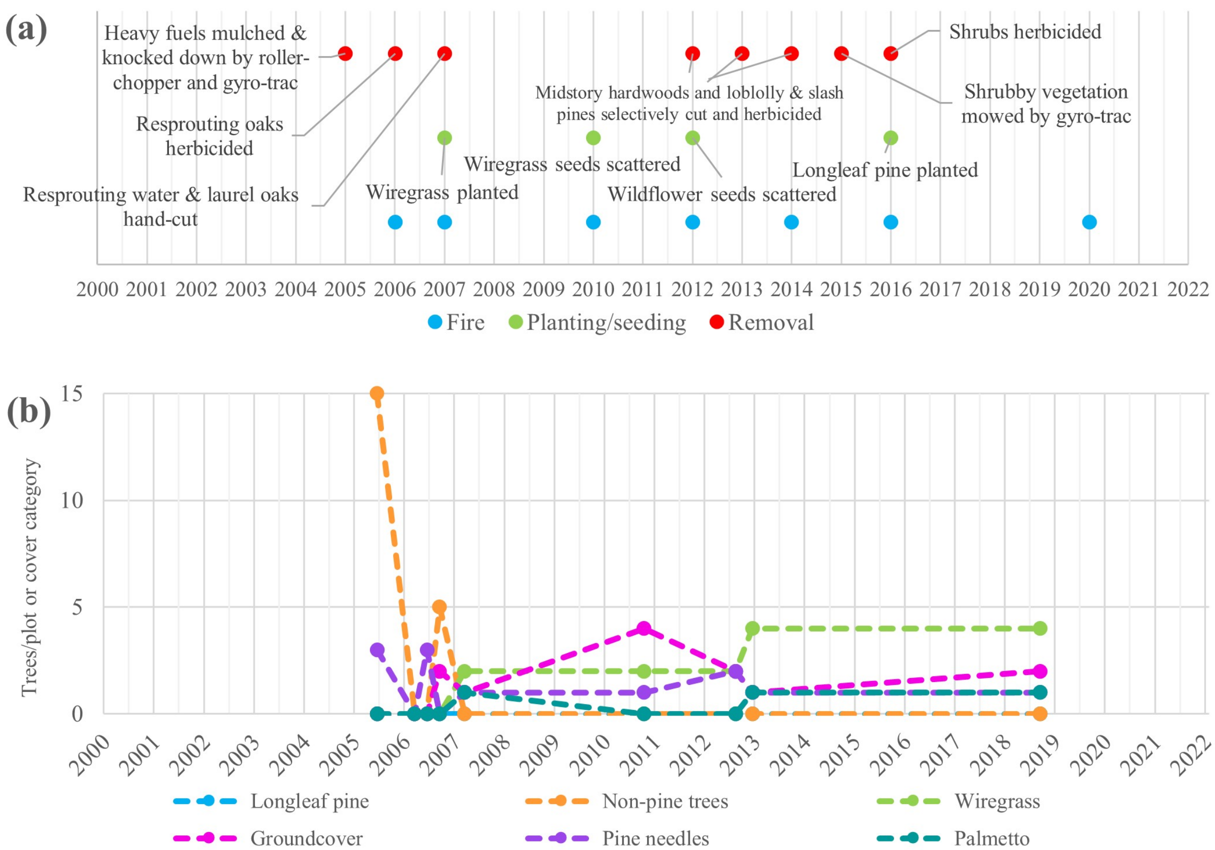


Figure 1. Restoration progress in unit 4AB, with timelines of (a) restoration and management actions (b) species compositions obtained from photopoint data, and (c) species compositions obtained from monitoring data.

In unit 5A, a lack of fire from the 1930s to 1990s allowed for the encroachment of oaks. An early attempt at prescribed fire in 1993 resulted in a smoldering duff fire, killing most canopy trees, eliminating groundcover, and eventually leading to further oak encroachment over the next two decades. The site was cleared in 2005 by gyro-trac mowing and roller chopping (Figure 2a).

Planting of wiregrass in 2007 increased wiregrass cover category from 0 (no plants) to 2 (21-40% cover) the following year; groundcover continues to persist (Figure 2b). Planting of longleaf pine (2016) did not result in a dramatic increase in this unit. Currently, unit 5A lacks adequate longleaf pine densities and contains undesirable vegetation such as loblolly pine; future management plans involve continued growing season fire, targeted herbicide, and loblolly pine removal.



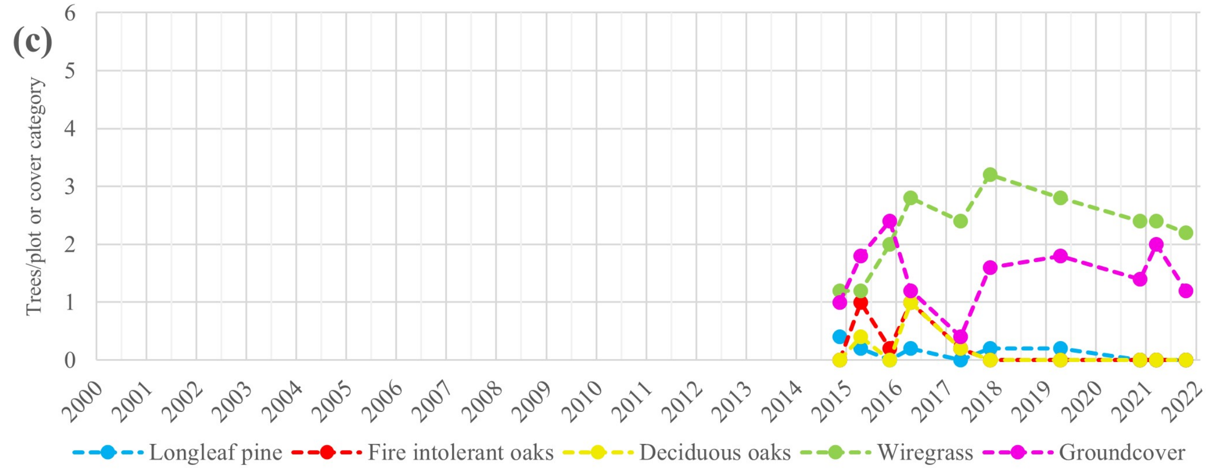


Figure 2. Restoration progress in unit 5A, with timelines of (a) restoration and management actions (b) species compositions obtained from photopoint data, and (c) species compositions obtained from monitoring data.

In unit 3B, according to management, an abnormally high amount of longleaf pines regenerated after 1949 following clearing, and groundcover had become highly reduced by the 1980s. From 1983 to 2001, six prescribed burns were completed in the area. Few restoration actions were subsequently undertaken due to the nearly intact pine savanna (Figure 3a). Thinning of longleaf pines (2001) was successful in decreasing amounts of longleaf pine, and planting of wiregrass (2002) lead to an increase in its cover (Figure 3b). The nearly completely restored state of this unit led to a relatively stable species composition over time. Currently, unit 3B is similar to goal conditions; future management plans involve continued growing season fire.

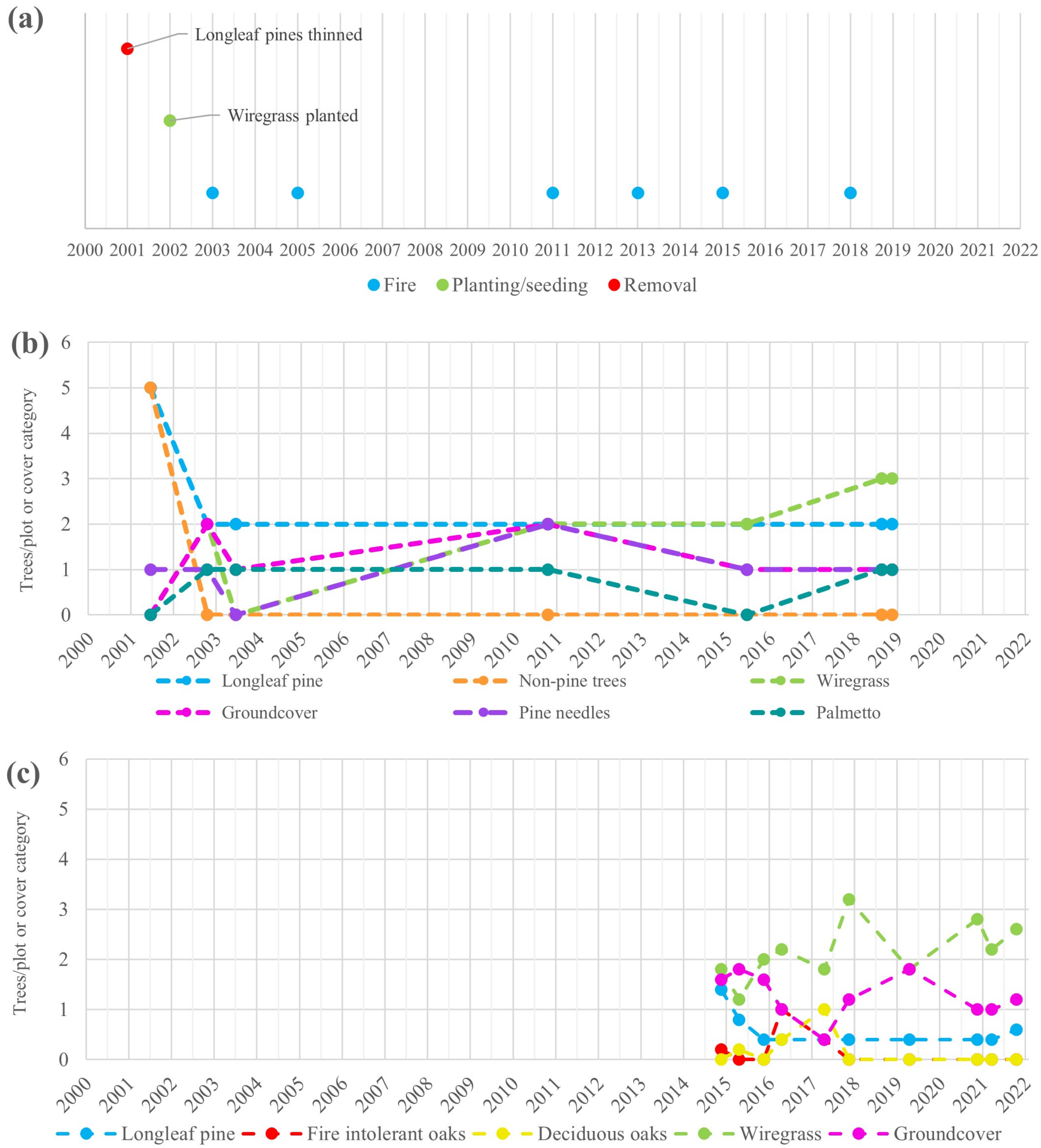


Figure 3. Restoration progress in unit 3B, with timelines of (a) restoration and management actions (b) species compositions obtained from photopoint data, and (c) species compositions obtained from monitoring data.

The visualization of existing monitoring data obtained between the years 2014-2020 showed minor changes in species composition over time within units and some differences between units (Figures 1c, 2c, 3c), while the photo point data from initial restoration marked more considerable changes in composition. The average number of longleaf pines within each unit remained relatively stable over time. All units experienced an increase in wiregrass coverage over the monitoring period (by 2 in unit 4AB, 1 in unit 5A, and 0.8 in unit 3B), but ultimately did not have major differences between them at the last data point recorded (ranged from 2.2 to 2.8).

Discussion

During the revision process, communication with managers was key to identifying areas of the monitoring program needing improvement. Managers anticipated that data would be more useful if it was more consistent in quality, and more tightly coupled to management objectives and restoration goals. Morningside Nature Center monitoring is not unique in these challenges; poor focus and a lack of collaboration between scientists and resource managers are a common cause of the ineffectiveness of monitoring programs (Lindenmayer & Likens, 2010).

In response to concerns, improvement in protocol focused on consistency and the achievement of restoration goals. One potential source of errors within monitoring data can come from differences between observers. Data at MNC is often taken by students who may be inexperienced at plant identification; the addition of a plant identification guide addresses this issue. Other changes included the addition of several measured attributes that inform decision-making. The new categories of “palmettos” and “hardwoods over 3 ft. tall” represent vegetation groups that are targeted for removal, and their inclusion in the data set allows managers to plan and assess the effectiveness of removal efforts. These results show that obtaining management input is crucial to the process of designing a monitoring program for which usable data is the goal. Because revisions resulted in additional protocol steps, future evaluations should assess whether the improved protocol makes the data-collection process too lengthy or complicated.

Units improved in species composition over time as a result of restoration actions as supported by photopoint and monitoring data which shows increases in desirable vegetation (longleaf pine and wiregrass) and decreases in undesirable vegetation (hardwoods). The use of herbicide and other removal methods is successful in reducing hardwoods as indicated by the decrease in number of trees following these actions. Planting of plugs and dispersal of seeds is an effective method of increasing wiregrass cover as supported by the subsequent increases seen in each unit. Planting of longleaf pines was considered by managers to be effective in unit 4AB as it resulted in an increase in the average number of trees per plot (from 0 to 2) 4 years after planting. However, planting of longleaf pines in unit 5A did not result in an increase. This disparity may be due to differences in timing/frequency of management actions leading to less-optimal conditions for longleaf pine growth at the time of planting in unit 5A. It is also likely that the reintroduction of fire played a significant role in the improvements seen in each unit.

Changes in species composition reflected by the monitoring data are minor, which is expected as actions taken at this later stage of the restoration are mainly to maintain current composition. Although photopoint data was useful for tracking large, dramatic changes during the initial stages of restoration, monitoring data will be more suited to detecting the more nuanced changes that are expected to occur in the future as frequency and intensity of restoration actions slow. In addition, the monitoring data is still limited in the amount of time it covers, making it difficult to detect long-term changes and differentiate them from short-term fluctuations; many ecological processes occur over long time spans and may take decades to become detectable (Lindenmayer & Likens, 2018; Sutter & Rutledge, 2017). However even from existing data, it can be seen that in general, planting resulted in increased longleaf pine, scattering of seeds resulted in increased cover of wiregrass, and herbicide application resulted in reduction of undesirable vegetation. This suggests that practitioners have effectively learned from previous actions and continue to refine their approach to meet restoration goals at Morningside Nature Center.

The results of the analysis of long-term data on ecosystem structure at Morningside Nature Center will be used to inform the management program on the effects of actions on species compositions, guiding future decisions and improving the effectiveness of the park's restoration program. The revisions made to the monitoring program design will improve the quality of future monitoring data by producing information that is more relevant to managers. The partnerships formed between scientists and managers during the process are a clear example of use-inspired science or knowledge co-production (Nel et al., 2016) and will continue to be beneficial to both restoration and monitoring efforts as they progress. In addition, the results of this study will add to the collection of scientific knowledge on longleaf pine ecosystems and the role that monitoring plays in their restoration, contributing to the overall effort to restore longleaf pine ecosystems. Because of the demonstrated value of this long-term data, future work should focus on ensuring the successful continuation of the monitoring program, which will yield more conclusions and new findings as the reliability of the data improves.

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Appendix A

Common flatwoods species in each cover type at Morningside

Non-native graminoids
- Bahiagrass--*Paspalum notatum*
- Centipededgrass--*Eremochloa ophiuroides*

Wiregrass

Other native grasses
- Bluestems--*Andropogon* spp.
- Creeping bluestem--*Schizachyriumscoparium*
- Lopsided indiangrass--*Sorghastrumsecundum*
- *Cyperus* spp.
- Witchgrasses--*Dichanthelium* spp.
- Foxtail grasses--*Setaria* spp.
- Thin paspalum--*Paspalum setaceum*
- Hairsedges--*Bulbostylis* spp.

Native forb/legume/subshrub
- Florida paintbrush--*Carphephoruscorymbosus*
- Partridge pea, sensitive pea--*Chamaecrista*spp
- Elephant's foot—*Elephantopus* spp.
- *Eupatorium* spp.
- Huckleberry spp.--*Gaylussacia* spp.
- St. John's wort spp.--*Hypericum* spp.
- Silk grass; grass-leafed goldenaster--*Pityopsis graminifolia*
- Milkpea spp.--*Galactia* spp.
- Hoarypea spp.--*Tephrosia* spp.
- Blazing star spp.--*Liatris* spp.
- Shiny blueberry--*Vaccinium myrsinites*
- Palafoxia--*Palafoxia integrifolia*
- Coastalplain honeycombhead--*Balduinaangustifolia*
- Snoutbean spp.--*Rhynchosia* spp.
- Goldenrod spp.—*Solidago* spp.
- Summer farewell—*Dalea pinnata*

Rubus

Vines
- Muscadine--*Vitis rotundifolia*
- Greenbriar spp. --*Smilax* spp.
- Confederate jasmine--*Gelsemiumsempervirens*

Palmettos
- Cabbage palm--*Sabal palmetto*
- Saw palmetto--*Serenoa repens*

Non-natives
- Threeflower ticktrefoil--*Desmodiumtriflorum*
- Mexican clover spp.--*Richardia* spp.

Mesophytic woody
- Laurel oak—*Quercus laurifolia*
- Water oak—*Quercus nigra*
- Sweetgum—*Liquidambar styraciflua*
- Loblolly pine—*Pinus taeda*
- Devil's walkingstick—*Aralia spinosa*

Deciduous oaks
- Turkey oak-*Quercus laevis*
- Bluejack oak—*Quercus incana*
- Southern red oak—*Quercus falcata*

Sand live oak – *Quercus geminata*

Other hardwoods
- Winged sumac--*Rhus copallina*
- Wax myrtle—*Morella (Myrica) cerifera*
- Persimmon—*Diospyros virginiana*

History of Management and Restoration Actions in Units 4A/4B, 5A, and 3B

Units 4A/4B

History

- 1937: Aerial photo shows open pine savanna.
- 1949: Aerial photo shows that this area was completely cleared.
- 1950s to 1990s: Recolonized by weedy, fast growing trees—laurel oak, water oak, loblolly pine. Wiregrass and other groundcover eliminated either by initial disturbance or by shade from the canopy oaks.
- By 1990s: This area of shady, closed-canopy loblolly pine/oak forest separated the park's remaining healthy sandhill into two isolated areas.
- Early 1990s: NOD staff tried to improve health of system with fire; fire did not carry wellthrough unit.
- 2001: Southern Pine Beetles infested and killed loblolly pines.

Initial State

- Closed canopy hammock with dying loblolly pines (see photo). No groundcover.

Restoration Actions

- 2001: Loblolly pines logged; oaks logged and chipped.
- 2002 (Fall): NOD staff sprayed resprouting oaks and other undesirable vegetation with glyphosate.
- 2002 (October): prescribed fire used to prepare for planting.
- 2002 (November): planted container-grown wiregrass and longleaf pine
- One wiregrass tubeling per square meter
- 350 pines per acre
- 2003: 1-year survival of wiregrass: ~80%; pines ~90%.
- 2005 (Summer): Prescribed fire burned approximately 1/3 of unit.
- 2007 (Summer): Successful prescribed fire burned the entire unit.
- 2010 (Summer): Prescribed burn under borderline high humidity conditions was moderately successful.
- 2009, 2010, 2012,2014: wildflower and grass seeds collected from onsite sandhills were scattered to augment groundcover diversity.
- 2012, 2014, 2016, 2019—successful growing season burns.
- 2005-present: occasional cutting/girdling of offsite pines (loblolly) and oaks.
- 2019- Thinned some pines to open canopy, plan to continue thinning over time.
- Future: pine needles and grasses should continue to provide sufficient fuel for Rx fires.
- Selective oak removal and thinning of pines ongoing.

Unit 5A

History

- 1937: Aerial photo shows open pine savanna.
- 1930s-1990s: Historical Aerial photos show increasing tree canopy, indicating oak encroachment due to a lack of fire.
- 1992 (Winter): First attempt to use prescribed fire in this unit. 1st burn did not carry through

unit, due to lack of proper fuels.

- 1993 (Spring): A second burn attempted under drier conditions, and fire burned down into heavy duff and smoldered for 3 weeks. This ground fire killed most canopy trees in about 1/3 of the unit, including most remaining longleaf pines.
- 1993-2005: No further fire attempted.

Initial State (2005; see photo)

- Dense midstory of loblolly pines, water and laurel oaks, and wax myrtle with few canopy trees and no groundcover. Very high stem density, and very little sunlight reaching the forest floor. Heavy vegetation a severe fire hazard, difficult to burn safely, and poor habitat for sandhill and flatwoods species.

Restoration Actions

- 2005: Florida Division of Forestry Wildfire Mitigation Team used Gyro-Trac mower and roller-chopper to mulch & knock down heavy fuels (see photos for comparison of these two methods).
- 2006 (March): Prescribed fire used to remove woody materials and prepare the site for planting.
- 2006 (Summer): Resprouting undesirable woody plants in 2/3 of the unit were treated with foliar herbicide.
- 2007 (February): Prescribed fire conducted to prepare for planting.
- 2007 (Feb-Mar): Wiregrass plugs planted (1 plant/m^2) using volunteers and staff. 1-year survival estimated at about 70%.
- Winter 2007-Summer 2008—contractor hired to hand-cut resprouting water oaks and laurel oaks and treat stumps with herbicide.
- 2010 (March): prescribed burn. Fire carried through most of unit, but did not burn thickest shrub areas.
- 2010 (Fall/winter): scattered wiregrass seeds collected from 4a/4b to augment grass cover.
- 2012 (summer): Prescribed burn; successful except in shrubbiest areas.
- 2012 (fall/winter): wildflower seeds collected from onsite sandhills & flatwoods were scattered to augment groundcover diversity.
- 2012-2014: some selective cutting and herbiciding of midstory hardwoods and loblolly & slash pines.
- 2014 (Summer): Prescribed burn; grassy areas burned well but shrubby areas mostly did not.
- 2015 (November): Gyro-Trac mowing of shrubby vegetation in overgrown parts of the unit.
- 2016 (June) Prescribed burn
- 2016 (October) herbicide treatment of shrubs
- 2016 (December) planted containerized longleaf pines (250 trees/acre).
- 2020 (June) Prescribed burn; fire carried through most of unit, except for thick shrubby areas.
- Future: Continue regular growing season fire; targeted herbicide as needed, selective loblolly pine removal.

Unit 3B

History

- 1937: Aerial photo shows open pine savanna.
- 1949: Aerial photo shows unit mostly cleared.
- Post-1949: abnormally high density of young longleaf pines regenerated.
- 1940s to 1980s: Groundcover diversity and cover greatly reduced, either due to soildisturbance or to shade from overstocked pines.

- 1980s-2001: Regular prescribed fire (6 burns from 1983-2001; average interburn interval=4.7years).

Initial state (2001):

- An even-aged longleaf pine stand with unnaturally high tree density. Wiregrass virtually absentand diversity of groundcover low. Little if any cone production or regeneration of longleaf pine
.

Restoration Actions:

- 2001: Longleaf pines thinned.
- 2002: Wiregrass tubelings planted at 1 plant per 2 square meters.
- 2003, 2005, 2011, 2013, 2015,2018: Growing season prescribed fire
- 2012-present—occasional cutting of offsite oaks along south edge
- Future: Continued growing season fire.

Appendix B

Initial Monitoring Protocol

1. Write names of group members and the date at the top of the data sheet.

2. Locate plot (marked by a piece of rebar at each corner with an orange safety cap).

3. Place “PVC corner guides” at opposite corners to help visualize the square plot.

4. Count the number of trees within each plot and record the number of trees for each species under the respective categories on the data sheet.

5. Determine the percent cover of wiregrass (refer to cover scale at top of data sheet) and record the cover class.

6. Determine the percent cover of all other grass species grouped together (refer to cover scale at top of data sheet) and record the cover class.

7. Determine the percent cover of all other groundcover species (excluding vines) grouped together (refer to cover scale at top of data sheet) and record the cover class.

8. Determine the percent cover of blackberry (refer to cover scale at top of data sheet) and record the cover class.

9. Determine the percent cover of all other vine species grouped together (refer to cover scale at top of data sheet) and record the cover class.

10. Determine the percent cover of all invasive species grouped together (refer to cover scale at top of data sheet) and record the cover class.

Appendix C

Revised Monitoring Protocol

1. Write names of group members and the date at the top of the data sheet.

2. Locate plot (marked by a piece of rebar at each corner with an orange safety cap).

3. Take a photo of the plot from the southeastern rebar, facing northwest, using the tripod.

4. Using the Li-Cor plant canopy analyzer, determine the LAI (leaf area index) from the middle of the plot and record the value on the data sheet.

5. Count the number of trees with a DBH (trunk diameter at breast height, ~4.5 feet) over 1 inch within each plot and record the number of trees for each species under the respective categories on the data sheet.

    a. Long leaf pine

    b. Loblolly

    c. Undesirable fire intolerant species (water oak, laurel oak)

    d. Deciduous oaks (turkey oak, bluejack, southern red oak)

    e. Sand live oak

    f. Other hardwoods

6. Determine the percent cover for each category as indicated on the data sheet (refer to cover scale at top of data sheet and/or examples of percent cover classes on page 3) and record the cover class on the data sheet.

    a. Hardwoods over 3 feet tall (remove for restoration purposes)

    b. Palmettos

    c. Wiregrass

    d. Other understory grasses (excluding wiregrass)

    e. Other groundcover species (excluding grasses and vines)

    f. Rubus/blackberry

    g. Other vine species (excluding rubus)

    h. Invasive species