Lehmann Lovegrass (*Eragrostis lehmanniana*) Treatment and Monitoring on the Appleton-Whittell Research Ranch of the National Audubon Society

2025 Annual Report

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Photo: 2025 Appleton-Whittell Research Ranch Upland Vegetation Monitoring Crew. Photo: Benjamin Beal/Audubon Southwest.

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Executive Summary:

Established in 1968, the Appleton-Whittell Research Ranch of the National Audubon Society (AWRR) is an 8,000-acre field station, wildlife sanctuary, Audubon center, and former cattle ranch located 60 miles southeast of Tucson, Arizona. The AWRR is managed for its conservation, research, and educational values by Audubon Southwest through a series of agreements between Audubon and The Research Ranch Foundation, U.S. Forest Service, Bureau of Land Management, The Nature Conservancy, Resolution Copper, and private landowners.

Although native vegetation dominates much of the AWRR, the rapid spread of non-native grasses, namely Boer and Lehmann lovegrasses (*Eragrostis curvula* and *E. lehmanianna*), threaten its ecological integrity and mission. In response to this growing threat, AWRR staff began in the late 1990’s experimenting with methods to protect and rehabilitate native grasslands. Methods explored included fire, mowing, physical removal, alteration of soil carbon-nitrogen ratios, and grazing by domestic livestock, but only chemical treatment proved effective. In 2004, AWRR staff began working to employ this treatment method in the area between AWRR’s Headquarters and Research complexes, resulting in a mostly native control patch that now spans nearly 350 acres. Alongside this effort, AWRR staff in 2003 and 2004 established 18 vegetation transects across the AWRR to monitor ongoing changes in untreated areas and to assess the effectiveness of treatment within the treated area.

Analysis of the transects highlighted in this report yielded complicated results, but the general conclusion is clear. While treatment with Glyphosate is an effective means of managing Lehmann Lovegrass, it is only so at relatively small scales. Because annual treatment is necessary, practitioners are limited to relatively small patches, and trying to expand beyond capacity can lead to unsatisfactory results. However, there is a role to be played by relatively

small, mostly native patches of grassland, and this project shows that such islands can be established and maintained by small teams of dedicated practitioners.

Management Recommendations:

This effort on the Appleton-Whittell Research Ranch shows that individual plant treatment with Glyphosate can be an effective tool with which to combat Lehman Lovegrass invasion, but with several caveats. For treatment to be successful over the long term, a commitment to consistent, annual treatment is necessary. This requires that practitioners carefully consider their capacity within the limited annual window during which Glyphosate treatment is effective and responsible before deciding upon the scope and scale of their effort. This also means that Glyphosate is likely not a useful tool at the landscape level. Despite this, and since Lehmann Lovegrass has shown itself to be capable of creating near monocultures at the expense of native species, we advise that projects like this, projects where manageably sized islands of native species are established and maintained, be replicated to serve as ecological reference sites, to provide habitat to native grassland reliant species, and to maintain living seed banks that may be used in the restoration of other impacted areas.

Table of Contents:

Introduction:

Established in 1968, the Appleton-Whittell Research Ranch of the National Audubon Society (AWRR) is an 8,000-acre field station, wildlife sanctuary, Audubon conservation action center, and former cattle ranch located 60 miles southeast of Tucson, Arizona. The AWRR is managed by Audubon Southwest, the regional office of the National Audubon Society, through a series of agreements between Audubon and The Research Ranch Foundation, U.S. Forest Service, Bureau of Land Management, The Nature Conservancy, Resolution Copper, and private landowners. True to the original intent of the Appleton family, Audubon continues to manage the AWRR for its conservation, research, and educational values - working to investigate questions key to our mission of protecting birds and the places they live, employing conservation methods that may inform best practices beyond our fences, and engaging communities, decision makers, and conservation practitioners in this work.

Although native vegetation dominates much of the AWRR, the rapid spread of non-native grasses threatens its ecological integrity and mission. In an attempt to reclaim the landscape from the devastating impacts of overgrazing brought on by the colonization of the region in the late 19^{th} and early 20^{th} centuries, Boer and Lehmann lovegrasses (*Eragrostis curvula* and *E. lehmanianna*) were introduced in the 1930s to increase grass cover and forage for livestock. The effort was successful and while there were some positive outcomes of the introductions, including a reduction in erosion, both species have become incredibly problematic invasive species. Lehmann lovegrass is the more ubiquitous of the two with near monocultures found from California to Texas, and while Boer lovegrass is slower to establish itself in new areas and has remained a more local problem, it compared to Lehmann lovegrass has an incredible ability to outcompete native species. Both species provide lower quality forage compared to native vegetation, and the areas they dominate show lower plant and wildlife richness and diversity when compared to native-dominated grasslands (Simpson, 2018).

In response to this growing threat, AWRR staff began in the late 1990's experimenting with methods to protect and rehabilitate native grasslands. Methods explored included fire, mowing, physical removal, alteration of soil carbon-nitrogen ratios, and grazing by domestic livestock, but only chemical treatment proved effective. In 2004, AWRR staff began working to employ this treatment method in the area between AWRR's Headquarters and Research complexes, resulting in a mostly native control patch that now spans nearly 350 acres. Alongside this effort, AWRR staff in 2003 and 2004 established 18 vegetation transects across the AWRR to monitor ongoing changes in untreated areas and to assess the effectiveness of treatment within the treated area (Simpson, 2018). Between 2016 and 2018, data from these transects showed treatment was successful in reducing Lehman's Lovegrass frequency along treated transects from 70% to 10%, but also that recolonization occurs quickly, making annual treatment necessary (Simpson, 2018).
This report summarizes the 2025 treatment effort on the AWRR and compares monitoring results from transects within the treatment area to comparable transects in untreated portions of the AWRR.

Methods:

Treatment: Within the 350-acre treatment area, AWRR staff employs individual plant treatment (IPT) of non-native grasses using Glyphosate at manufacturer recommended concentrations along with colorant and surfactant. Careful adherence to IPT ensures there is limited or no collateral damage to desired plants, which undergo competitive release when the frequency of non-natives is reduced. Using this method, rehabilitation of native plants does not require additional seeding in areas where native plants are present at 30-60% frequency. However, in treated areas where non-native plants have out competed native species to the point where they occur at frequencies below this threshold, seed balls packed with native grass seeds collected on the AWRR are distributed.

This work is typically conducted between July and October when summer monsoon storms create ideal treatment conditions. For treatment to be effective and for collateral damage to desirable plants to be minimized, IPT must take place…

- when grasses show enough growth to be identified to species.
- when grasses have at least 6 inches of green growth through which to absorb the herbicide.
- between rain events when soil is relatively dry and more rain is not imminent.
- during calm days with minimal wind that could carry herbicide to desirable plants.
- during the morning hours before extreme temperatures render glyphosate less effective. Glyphosate treatment is most effective at temperatures between 60- and 75-degrees Fahrenheit.

Throughout the season, AWRR staff watches conditions closely for ideal windows during which to treat. During days when conditions are poor, AWRR staff visually surveys the treatment area, identifying problematic patches to be tackled when good conditions present themselves. While the greatest effort possible is given each season, the actual amount of treatment depends upon the frequency at which ideal treatment conditions occur.

Monitoring: Each year during the peak of the monsoon green-up, typically during late August to late September, AWRR staff and volunteers monitor twelve to fifteen upland vegetation transects across the AWRR. Three of these transects are within the treatment area and the rest are outside of the treatment area. To ensure that these transects are representative of the vegetative communities found on the AWRR, they were randomly placed within key AWRR ecological sites as identified by the Soils and Ecological Sites report prepared by Breckenfeld and Robinett (Breckenfeld and Robinett, 2001).

The Pace Frequency method (University of Arizona Cooperative Extension et al., 1999) is used to gather vegetation on all surveyed transects. On each transect, four parallel lines of 25 to 50 frames each yield 100 to 200 frames. In each frame, vegetative species are recorded using the protocol below, and these data are used to calculate frequency of occurrence for each species.

Also in each frame, three points are used to establish cover. Additionally, at the time of monitoring, four photos are taken from the start of the transect, one in each of the cardinal directions. Precipitation gauges are present at the start of most transects, and these gauges are read at least three times annually. Not all transects are read each year.

<u>Pace Frequency Protocol:</u>

Equipment:

- Camera
- Frame
- Flagging
- Measuring tape
- Extra cap for rain gauge
- Clipboards
- Pencils
- Cover sheet
- Thick black marker
- Copy of cumulative record for transect being read
- Data sheets
- Sheets with previous unknown species for transect being read
- Original photo documentation template for transect being read
- Cheat sheet of nomenclature changes

Protocol:

1) Check precipitation gauge if present and record level, noting anything that may have influenced the reading (debris etc.)
2) Take landscape-oriented photos in each of the four cardinal directions in this order: North, South, East West. Use the photo documentation template to line up the shots. Include the horizon, but very little above.
3) Place the transect flag
4) Collect Pace Frequency data
    1) Fill out data sheet header
    2) Most transects are based on 200 frames (4 parallel lines of 50 frames each) and 600 cover points (3 per frame), but there is variability. Check numbers for specific transect prior to collecting data
    3) From the rain gauge, take 2 paces perpendicular to the line of the transect (in either direction), then turn in the direction of the transect line and place the frame on the ground, using your toe as a guide to reduce bias. The bearing of the transect line is found within past data for the transect being read.

4) Record cover points (Bare, Gravel, Rock, Litter, Live, or Cryptogram) at the three pre-determined points of the frame
5) Record each species that is alive and rooted in the frame, including identifiable spring annuals if produced within the year the transect is being read
6) Record woody species rooted outside of the frame but with canopy overhanging it
7) If an unknown species is encountered, compare it to previous unknowns. If identification is not possible in the field, take photos and/or specimens for identification back in the office
8) Take two paces along the transect line, place the frame at your toe, and repeat steps 4-7. Repeat until 50 frames have been read
9) After 50 frames have been read, turn away (perpendicular) from the center transect line and take 4 paces
10) Turn to be facing opposite the first line's direction of travel and repeat steps 4-8 until 50 frames are read. Upon completion of the final frame, you should be even with and about six paces away from the rain gauge at the beginning of the transect
11) Return to the rain gauge and repeat steps 3-10 to complete the third and fourth transect lines on the opposite side of the rain gauge

Analysis: While pace-frequency data is relatively easy and efficient to gather, the resulting dataset can be difficult to analyze. When attempting to use pace-frequency data to make inferences about the broader rangeland, it is important to remember that frequency does not necessarily equate to other measures of abundance and that these data are sensitive to patterns of distribution of key species, seedling establishment, and quadrat size and shape. With these concerns in mind, data was analyzed in a few different ways.

First, 2025 Lehmann Lovegrass frequency data from the transect most centrally located within the treatment area were compared to 2025 data from three transects located outside of the treatment area that share soil and ecological site characteristics with the treated transect. A Chi Square test of independence was then used to assess differences in Lehmann Lovegrass frequency between the transects. Next, Lehmann Lovegrass frequency data from these four transects collected between 2015 and 2025 were plotted to support qualitative discussion of trends. Additionally, species richness recorded between 2015 and 2025 was plotted for these transects. Separately and again to support qualitative discussion, 2015-2025 data collected on two transects located along the edge of the treatment area were plotted. Lastly, precipitation data collected from at or near each analyzed transect were plotted to look for associations with observed Lehmann Lovegrass frequency.

Results:

Figure 1: Map of the Appleton-Whittell Research Ranch of the National Audubon Society Detailing the Perimeter of the Invasive Grass Treatment Area and the Locations of Pace-Frequency Vegetation Transects

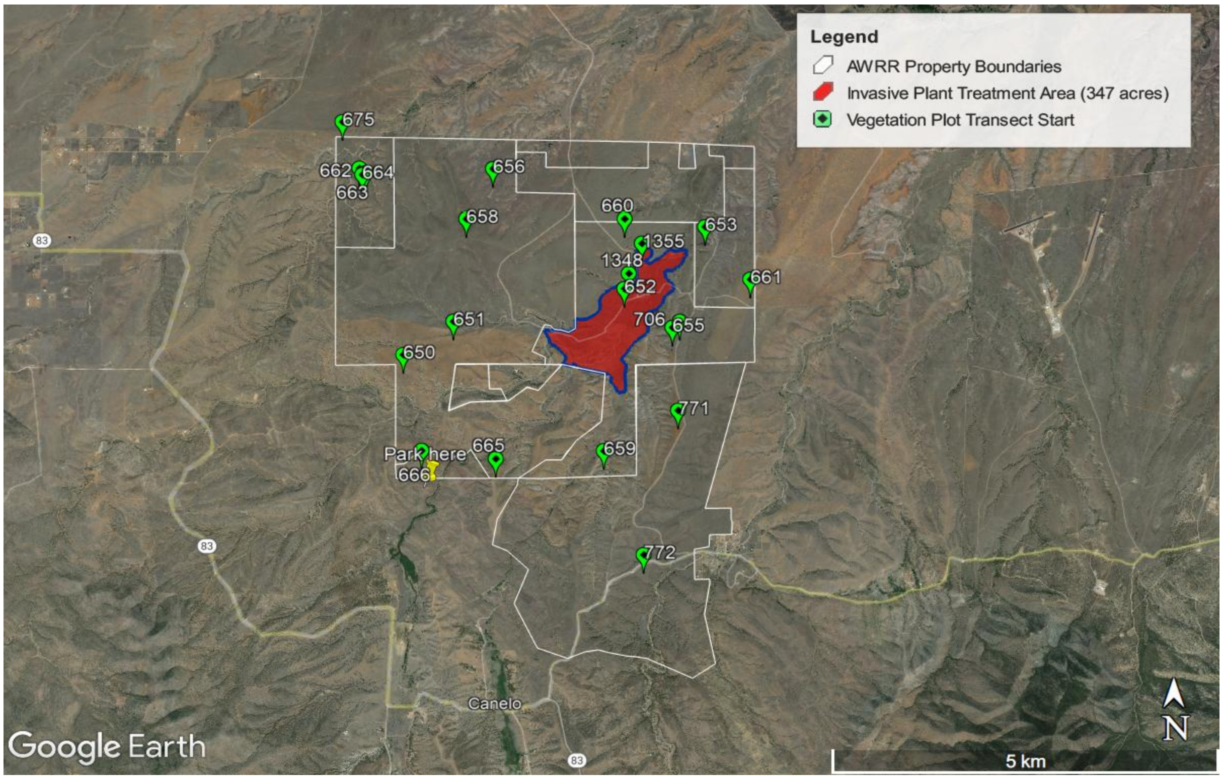


Table 1: Ecological Sites and Soils of Selected Pace-Frequency Transects on the Appleton-Whittell Research Ranch

TRANSECT	ECOLOGICAL SITE	SOIL
652	Sandy Loam Upland	Altar-like
650	Loamy Upland	Blacktail
651	Loamy Upland	Terrarosa
661	Loamy Upland	Terrarosa
1348	Sandy Loam Upland	Terrarosa Complex
1355	Loamy Upland	Terrarosa Complex

Figure 2: Number of Frames in Which Lehman Lovegrass Was and Was Not Observed In 2025 along Selected Treated and Untreated Pace-Frequency Transects on the Appleton-Whittell Research Ranch

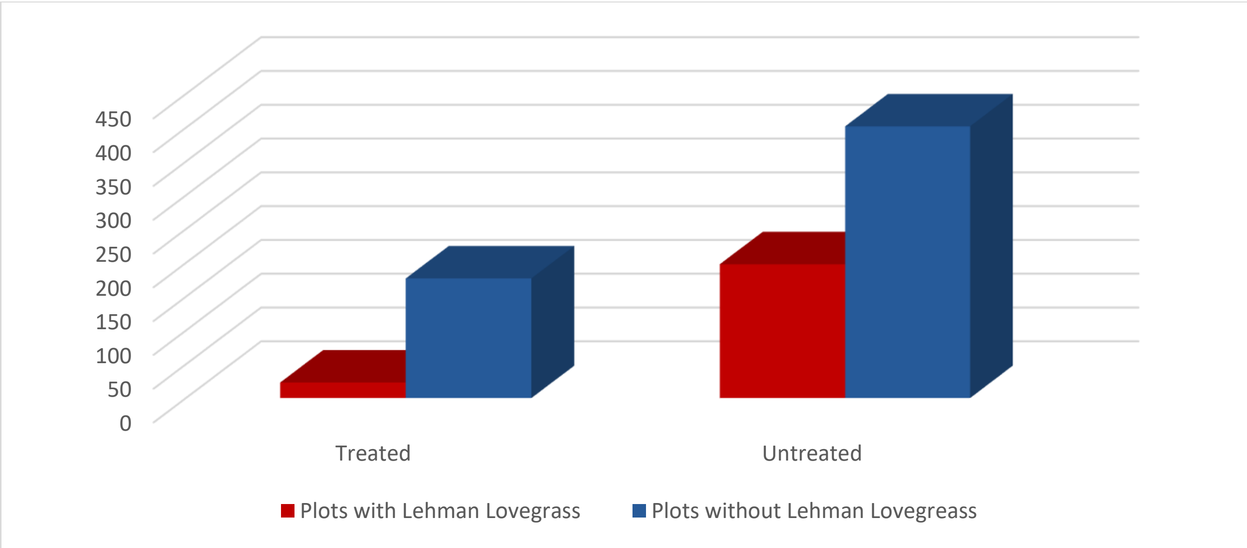


Figure 3: Frequency (%) of Lehmann Lovegrass on Selected Treated and Untreated Pace-Frequency Transects on the Appleton-Whittell Research Ranch, 2015-2025

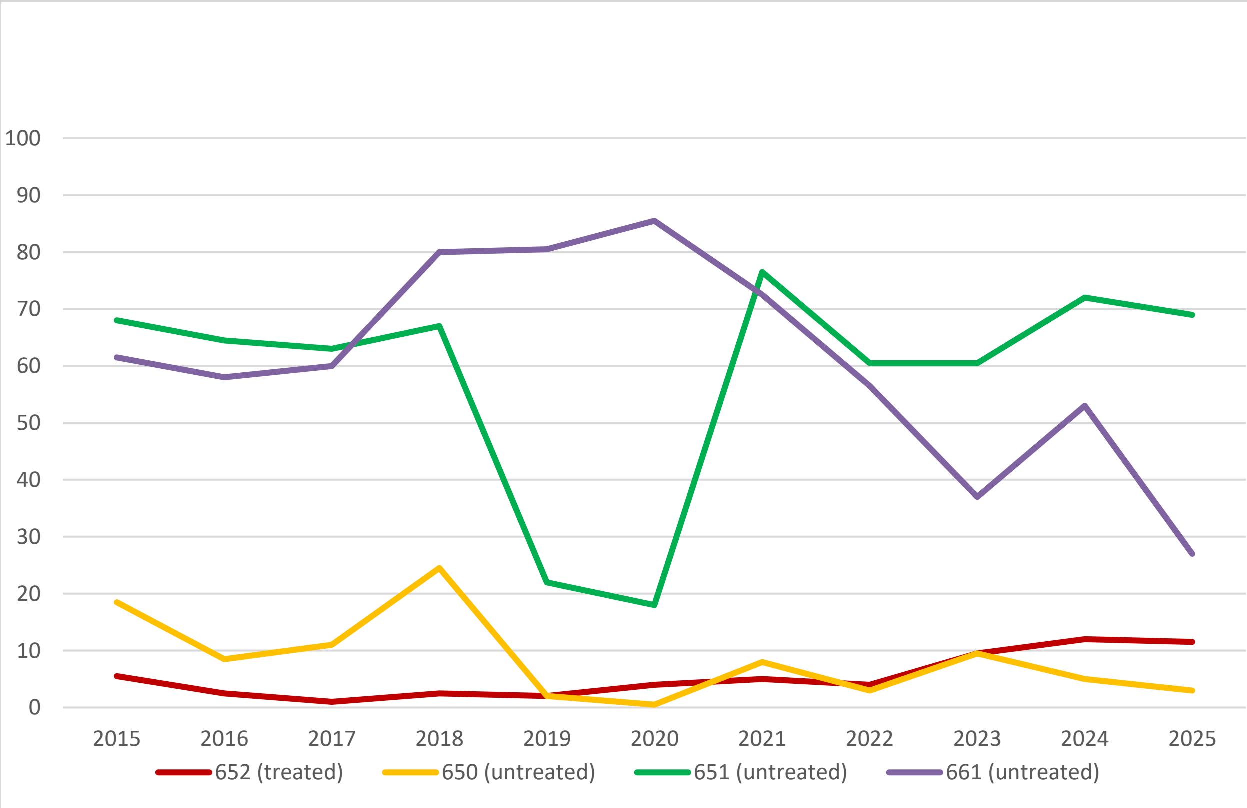


Figure 4: Species Richness on Selected Treated and Untreated Pace-Frequency Transects on the Appleton-Whittell Research Ranch, 2015-2025

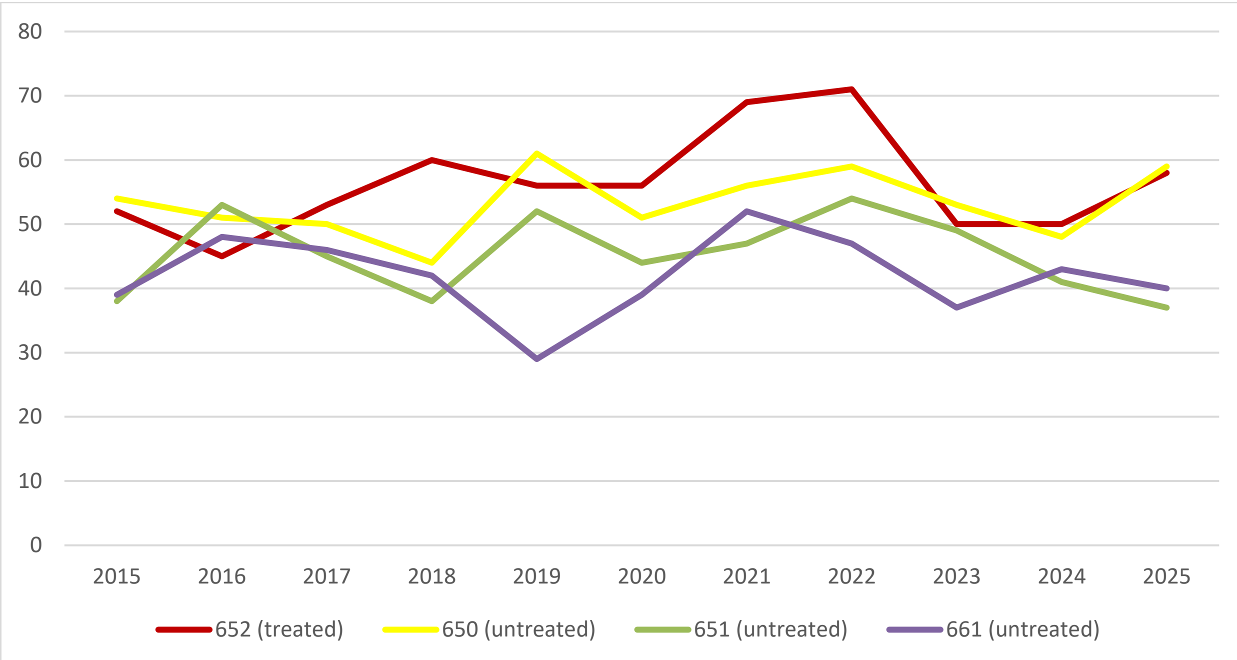


Figure 5: Annual Rainfall in Inches on Selected Treated and Untreated Pace-Frequency Transects on the Appleton-Whittell Research Ranch, 2015-2025

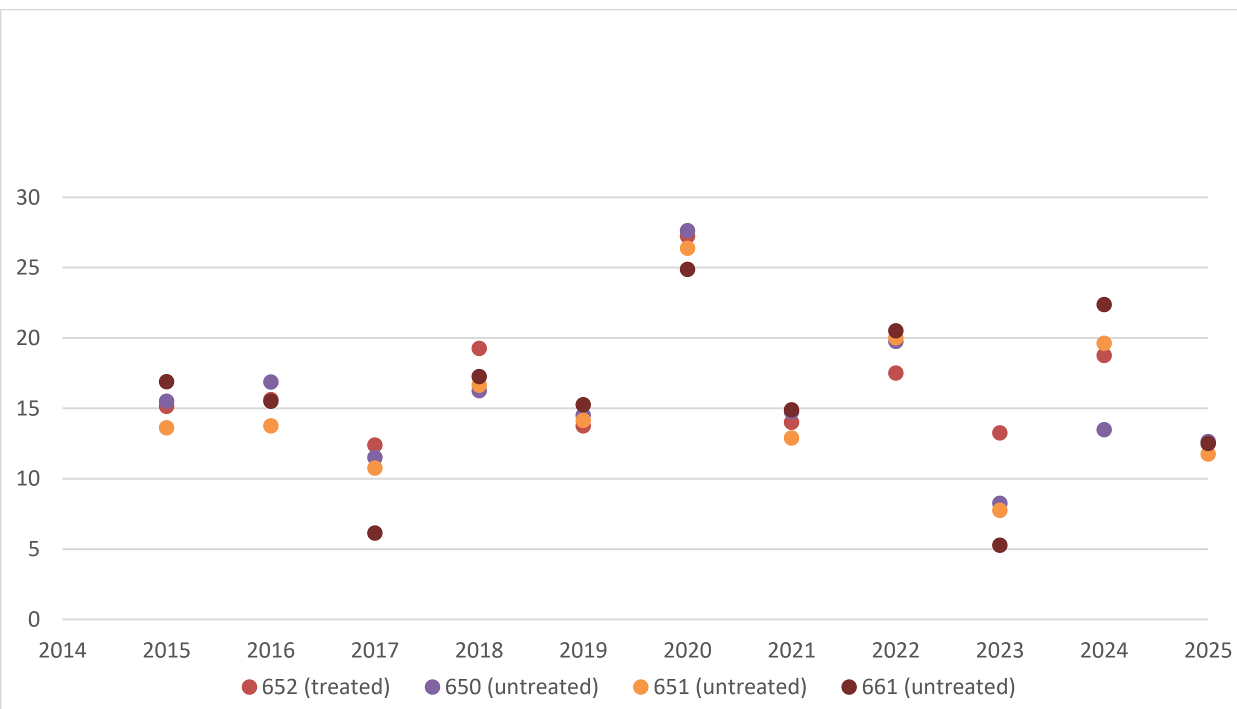
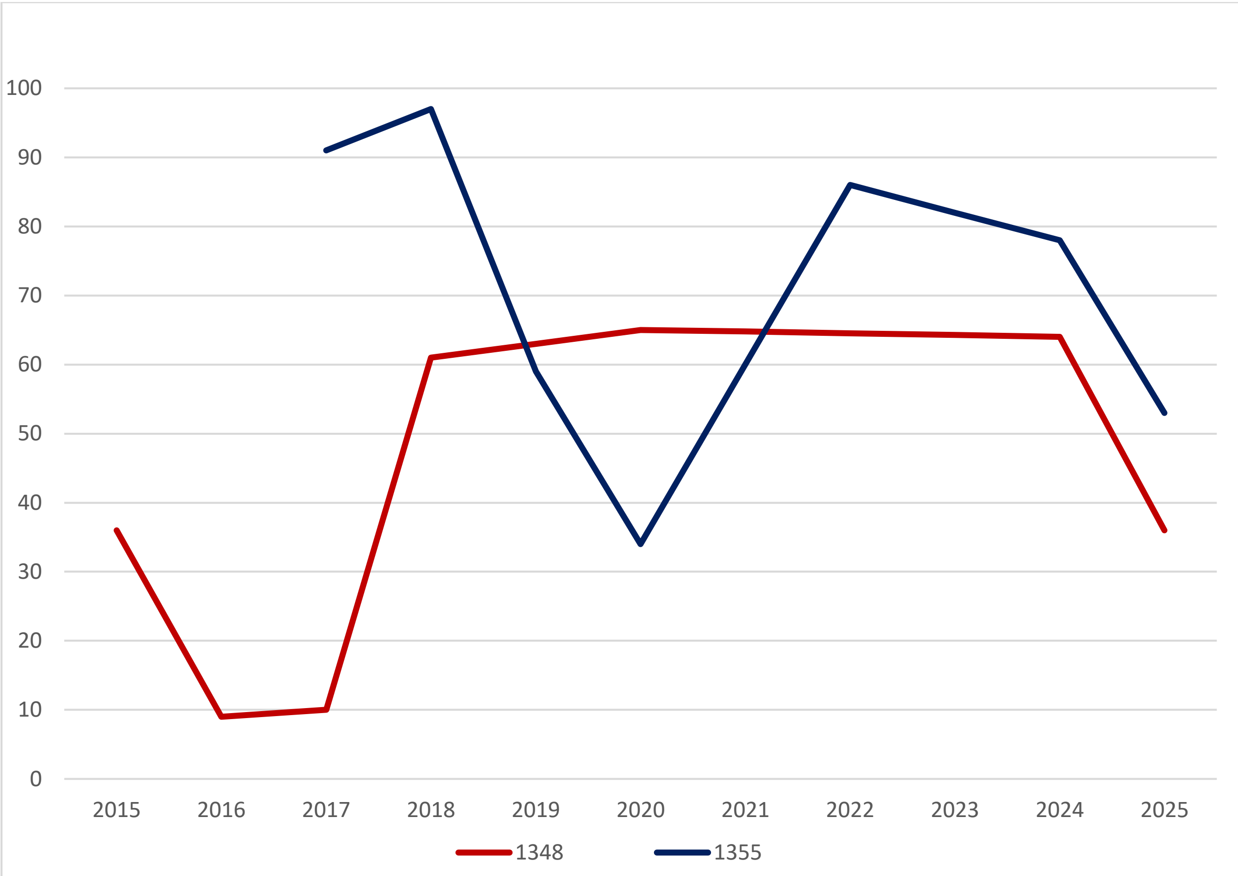


Figure 6: Frequency (%) of Lehman Lovegrass on Appleton-Whittell Research Ranch Pace-Frequency Transects 1348 and 1355, 2015-2025



Compared to untreated transects sharing soil and ecological site characteristics (Table 1), treated transect 652 showed a significantly lower frequency of Lehmann Lovegrass this year (X^2 (1, N = 800) = 34.68, p > .01) (Figure 2). While observed Lehmann Lovegrass frequency was much lower on this treated transect compared to two of the selected untreated transects (transects 651 and 661), it was slightly higher than that observed on the third untreated transect (650).

Untreated transects 651 and 661 show largest fluctuations in observed Lehmann Lovegrass frequency year-to-year. While these fluctuations mostly evened out on transect 651 with observed frequencies only changing by one percent since 2015, they have resulted in a significant decline on transect 661 with observed frequencies decreasing from 61.5 to 27 percent. Untreated transect 650 has shown less fluctuation, instead showing a steady decline in frequency since 2015 from 18.5 to 3 percent. Treated transect 652 has also remained mostly steady, showing only a slight increase in frequency from 5.5 to 11.5 percent since 2015 and a decrease of one half of one percent since last year (Figure 3).

Over the years considered in the report, species richness tends to be higher on treated transect 652 compared to the untreated transects, but this is not true in all years. Compared to the untreated transects, species richness on treated transect 652 overlaps most with untreated transect 650, which yielded a species richness one point higher than did treated transect 652 this year (Figure 4).

Annual rainfall at rain gauges on these transects read as low as six inches and as high as 27 inches between 2015 and 2025. Despite the gauges used for each transect being relatively near each other, significant variation can be seen between gauges. Annual difference between gauges reached a maximum in 2025 at nearly nine inches, but variation between two and four inches is more common. Variation is also high between years, with the biggest change between years occurring between 2020 and 2021 when there was an over 12-inch drop in the average of the gauges (Figure 5).

Transects 1348 and 1355, both of which are located near the outside edge of the treatment area (Figure 1), saw steep declines in Lehmann Lovegrass frequency shortly after their establishment, but soon after shot back up to greater than sixty percent frequency of Lehmann Lovegrass. This trend reversed this year, with both transects showing steep declines since 2024 (Figure 6).

Discussion:

For many reasons, measuring the abundance of Lehmann Lovegrass using the pace-frequency method, especially when making comparisons between transects, is difficult. While focusing on long-term trends (ten+ years) instead of on year-to-year changes can lend some clarity, complications remain. First, Lehmann Lovegrass does not distribute itself evenly across the landscape but instead tends to form dense stands that both spread from their margins and cast seed into the wind to potentially find a patch of suitable soil and create another island. Additionally, transects do not differ by treatment alone. While efforts were made to compare transects in similar ecological sites and with similar soils (Table 1), soil is not uniform across ecological sites and subtle differences, along with subtle differences in slope, aspect, and other variables, may play a role. Also, while these transects remain free from human disturbance, they do see natural disturbances – namely, fire. Of the discussed transects, the most recent burn (2018) impacted only transects 650 and 651. Despite the complexity, some conclusions can be drawn.

Transect 652 sits near the center of the treatment area (Figure 1), and as such is the best-protected of the treated transects. The significant difference between Lehmann Lovegrass frequency on this transect when compared to similar, untreated transects (Figure 2) is evidence that consistent, annual treatment with Glyphosate can be an effective means of Lehmann Lovegrass control, and the consistently low observed frequency of Lehman Lovegrass between 2015 and 2025 (Figure 3) is evidence that it can also be an effective method of ongoing maintenance. While a significant difference was observed, it is worth noting that it was mostly bolstered by the extreme difference between the treated transect and transects 651 and 661.

When compared to untreated transect 650, there was no significant difference, and in 2020, 2022, 2024, and 2025 the frequency of Lehmann Lovegrass on treated transect 652 was higher than on this untreated transect (Figure 3).This may be partially explained by a change in management at the Appleton-Whittell Research Ranch that limited treatment between 2018 and 2022, evidenced by a slow but steady rise in Lehman Lovegrass frequency on this transect beginning in 2019. Treatment recommenced in earnest in 2023, and Research Ranch staff is hopeful to see that the upward trend began to reverse, albeit slightly, this year (Figure 3).

Species richness tends to be higher on treated transect 652 compared to the untreated transects, but this is not true in all years. Compared to the untreated transects, species richness on treated transect 652 overlaps most with untreated transect 650, which yielded a species richness one point higher than did treated transect 652 this year (Figure 4). This is the expected trend given Lehmann Lovegrass' proven ability to outcompete native species and the fact that transects 652 and 650 showed consistently lower Lehmann Lovegrass frequency than did transects 651 and 661 (Figure 3), but it also shows there is more to the story. Even with a decline in Lehmann Lovegrass frequency, overall species richness depends on the availability and diversity of seed banked in the soil, the extent of reseeding efforts, precipitation, and ultimately the details of the vegetation that replaces the treated Lehmann Lovegrass. It is important to again note that frequency does not necessarily equate to abundance, and there may be species specific trends not captured through this analysis of species richness. As an example, the observed low species richness on transect 661 (Figure 4) despite declining Lehmann Lovegrass frequency (Figure 3) may be due to the increased observed frequency of Boer's Lovegrass along the transect.

The limited fluctuation of Lehmann Lovegrass frequency on treated transect 652 is easily explained by the continued pressure of treatment, the steep decline and subsequent steep rise on transect 651 can likely be explained by the 2018 fire, and the decline on transect 661 may be due to increasing frequency of Boer's Lovegrass on the transect. Less easily explained is why, following the Lehmann Lovegrass frequency decline that followed the 2018 fire, transect 650 did not see the same steep increase in Lehmann Lovegrass frequency observed on transect 651 (Figure 3). Annual rainfall readings (Figure 5) do not provide a clear explanation and it is possible that the relative frequencies of Lehmann Lovegrass and other species prior to the burn play a role, but an analysis of a temporally longer dataset and a more in-depth study of the sites would be needed to reach a firm conclusion. Also unclear is why all three untreated transects saw declines in Lehmann Lovegrass frequency this year (Figure 3), but it is possible that limited rain in 2024 (Figure 5) and late rain in 2025 play a role, as may be other climactic and/or transect-specific variables.

Treated transects 1348 and 1355, while both in the treatment area, were not used to assess the efficacy of treatment for multiple reasons. First, both transects have unique histories of confounding treatments. Transect 1348 was included in a 2014-2017 Arizona Department of Forestry and Fire Management grant intended to assess the efficacy of Glyphosate as a treatment for Lehmann Lovegrass control. This is evidenced by the relatively low and declining

Lehmann Lovegrass frequency observed from 2015 to 2017 (Figure 6). Transect 1355 was included in a 2018-2019 Arizona Department of Forestry and Fire Management grant intended to assess the efficacy of a combined mowing and Glyphosate approach to Lehman Lovegrass control. This is evidenced by the steep decline in Lehman Lovegrass frequency observed between 2018 and 2020 (Figure 6). However, both transects are at the very edge of the treatment area and are therefore most susceptible to reinvasion. Following the conclusion of these grants and owed to the limited treatment between 2018 and 2022 mentioned above, both transects saw a strong resurgence of Lehmann Lovegrass. Observed declines this year are likely due to a combination of limited rainfall (Figure 5) and the treatment effort recommencing in earnest in 2023.

Conclusions:

The complicated nature of these results underlines the complicated nature of deciding when to use Glyphosate as a treatment for Lehmann Lovegrass, and several conclusions can be drawn.

First, as evidenced by the consistently low frequency of Lehmann Lovegrass on treated transect 652, along with the transect's consistently high species richness, treatment with Glyphosate can be an effective means of managing this invasive species. However, as evidenced by the slight increase in Lehmann Lovegrass frequency on transect 652 following a lack of treatment between 2018 and 2022 and by a sharper increase on transects 1348 and 1355 over the same years, a commitment to annual treatment is necessary. This requires that before taking on a treatment project, practitioners consider their capacity within the limited annual windows during which treatment is effective and responsible. Additionally, as seen by the relatively low increase in Lehmann Lovegrass frequency on transect 652 compared to transects 1348 and 1355, both of which are at the edge of the treatment area, areas further from established Lehmann Lovegrass are more resilient to recolonization than are areas in closer proximity. This can be taken advantage of by trying to minimize the perimeter-to-acreage ratio of treatment patches (i.e. having a circular treatment area instead of a narrow, linear one) and by starting treatment at the center of the eventual patch and moving outward. Lastly, the variation in Lehmann Lovegrass frequency on untreated transects shows that while Lehmann Lovegrass can reach near monocultures in some areas, some areas are less susceptible to invasion than others.

Management Recommendations:

This effort on the Appleton-Whittell Research Ranch shows that individual plant treatment with Glyphosate can be an effective tool with which to combat Lehman Lovegrass invasion, but with several caveats. For treatment to be successful over the long term, a commitment to consistent, annual treatment is necessary. This requires that practitioners carefully consider their capacity within the limited annual window during which Glyphosate treatment is effective and responsible before deciding upon the scope and scale of their effort. This also means that Glyphosate is likely not a useful tool at the landscape level. Despite this, and since Lehmann Lovegrass has shown itself to be capable of creating near monocultures at the expense of native species, we advise that projects like this, projects where manageably sized islands of native species are established and maintained, be replicated to serve as ecological reference sites, to provide habitat to native grassland reliant species, and to maintain living seed banks that may be used in the restoration of other impacted areas.

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