Ten-years of Experimental Restoration Trials on Leeward East Maui

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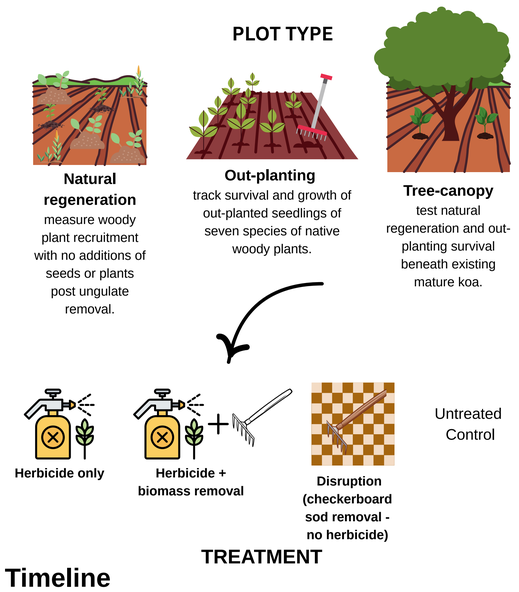
Introduction

The native forests on the leeward side of Haleakalā, East Maui were denuded by feral cattle, goats, and pigs for nearly 200 years, leaving only fragments in the Kahikinui–Nakula regions. Multiple organizations are working towards restoring this region to protect the watershed and reintroduce and recover native species. To this end, in 2012, a section of the Nakula Natural Area Reserve (NAR) was fenced and ungulates were removed (Fig.1).

From 2013–2015 we set up experimental plots to compare grass suppression and out-planting techniques. Decade-long surveys reveal how different treatments influenced native seedling recruitment, survival, and vegetation recovery. We present these 10-year results to identify the most effective long-term strategies for rebuilding Hawai'i's montane mesic forests in this region.

Methods

Sixty-seven experimental plots were assigned to one of the below plot types, with each plot receiving one of four treatment options. See Warren et al. (2019) for methods on plot design and monitoring procedures.



Timeline

Treatment	Date Applied	10-year monitoring
natural regeneration	Jul 2013	Jul 2023
outplanting	Dec 2013	Dec 2023
tree canopy	Dec 2013	Dec 2023

Statistical Approach (R 3.4.4)

- Linear mixed-effects models with ANOVA to test:
- Native seedling density across natural-regeneration treatments.
- Species-specific survivorship across out-planting & tree-canopy treatments.
- Survivorship and height differences between plot types and treatments.

Scan here for list of plants

References

- Warren, C., H. Mounce, L. Berthold, C. Farmer, D. Leonard, and F. Duvall. 2019. Experimental restoration trials in Nakula Natural Area Reserve in preparation for reintroduction of Kiwikiu (Pseudonestor xanthophrys). Pacific Cooperative Studies Unit Technical Report #199. University of Hawai'i at Mānoa, Department of Botany. Honolulu, HI. 102 pages.
- Baker, P. J., P. G. Scowcroft, J. J. Ewel. 2009. Koa (Acacia koa) ecology and silviculture. Gen. Tech. Rep. PSW-GTR-211. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station. 129 p.
- Scowcroft, P. G., and R. E. Nelson. 1976. Disturbance during logging stimulates regeneration of koa. USDA Forest Service Research Note PSW-306, Berkeley, CA.
- R Core Team (2024). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.

Acknowledgments

Dr. Fern Duvall passed away in 2022 prior to the ten-year results presented here. His contributions to the restoration of Nakula Natural Area Reserve and conservation in Hawai'i in general are impossible to overstate and he is greatly missed. Mahalo nui to the many volunteers and staff that have contributed to this restoration work since 2013. We would not have been able to do this without their hard work and dedication. American Bird Conservancy, U.S. Fish & Wildlife Service, Hawai'i Department of Land & Natural Resources- Division of Forestry & Wildlife and Native Ecosystems and Management, Disney Conservation Fun, Nā Koa Manu Conservation, Windward Aviation, and Native Nursery also supported this work.

Key Results

Natural Regeneration:

- Grass reduction resulted in a significant increase in naturally germinated trees (F =5.22, p = 0.009) with herbicide + biomass removal having the most positive effect.
- 'A'ali'i experienced significant positive effect in herbicide + biomass removal plots, averaging about 113 seedlings per plot, roughly 10x any other treatment(F = 5.42, p = 0.007).
- Koa showed little reaction to herbicide + biomass removal but responded well to herbicide alone, averaging ≈ 45 seedlings per plot versus fewer than 13 in controls (F = 2.45, p = 0.095).
- Three new species recorded at 10 yrs poha berry, 'ōlapa, and 'ākala.
- Grass-reduction plots retained a larger pool of new, smaller recruits, indicating sustained regeneration.

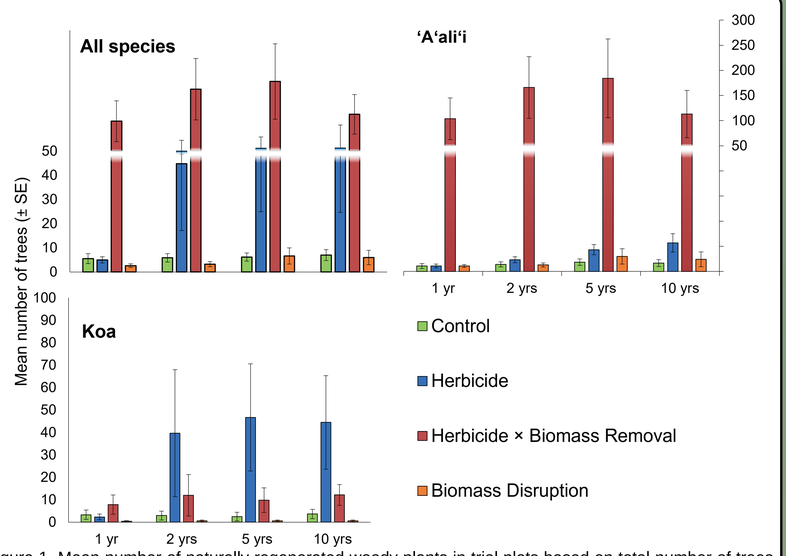


Figure 1. Mean number of naturally regenerated woody plants in trial plots based on total number of trees in a plot at time of survey.

Out-planting:

Survivorship

- Overall survival: 54% (2,168 of 4,045 seedlings)
- Top performers: 'a'ali'i 85%, 'ōhi'a 87%, koa 59% (together making up 82% of survivors)
- Low: 'ākala 21 %, māmaki 1 %
- survival differences among treatments were negligible for every species.

Plant Height

- No effect of treatment on overall plant height, except māmane (F = 2.90, p = 0.021). The herbicide-only treatment resulted in more large māmane (56% were >3m in height).

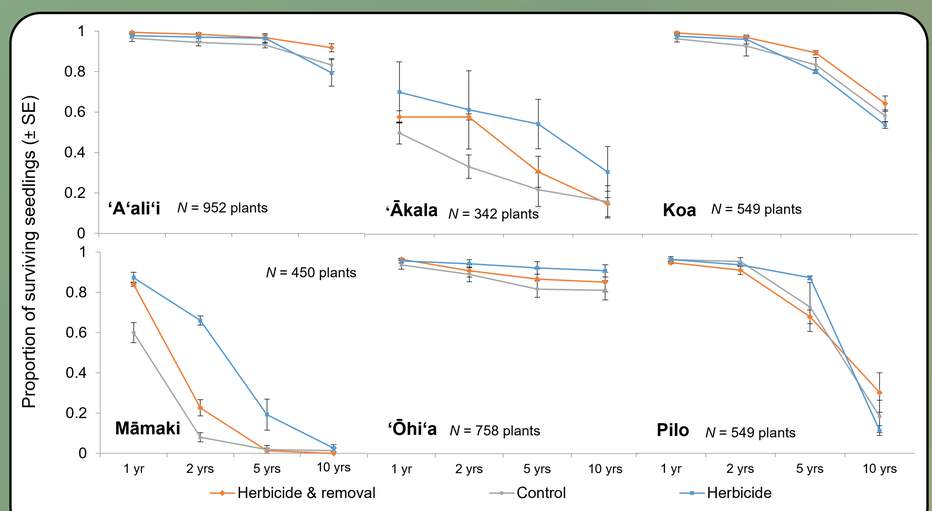


Figure 2. The proportion of surviving seedlings from one to ten years among experimental treatments in outplanting plots.

Tree Canopy:

Survivorship

- No effect of treatment on long-term survivorship, with overall survivorship dropping to 37.1% by 10 yrs.
- Contrasting with outplanting plots, māmaki survivorship was higher in tree canopy plots by 2 yrs but declined > 65% to an overall of just 3% by 10 yrs.

Plant Height

- Grass reduction resulted in larger 'a'ali'i (F = 80.89, p = < 0.001, df = 12), 'ōhi'a (F = 128.39, p < 0.001, df = 8), and pilo (F = 23.08, p = 0.027, df = 12).

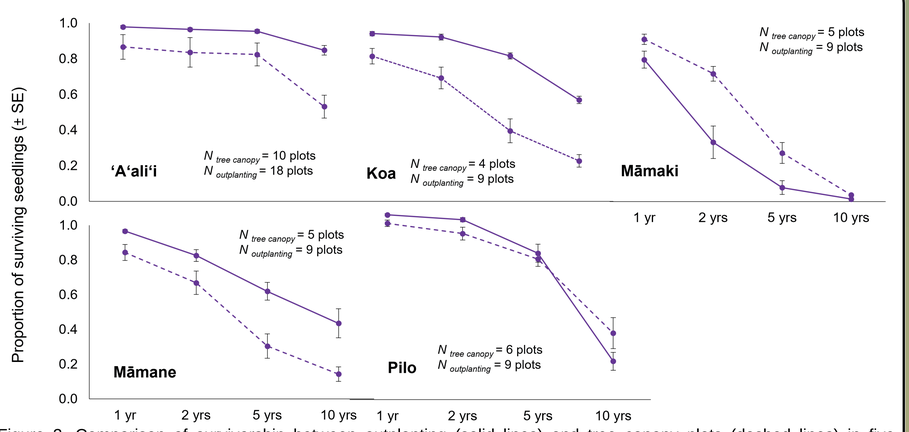


Figure 3. Comparison of survivorship between outplanting (solid lines) and tree canopy plots (dashed lines) in five species across time.

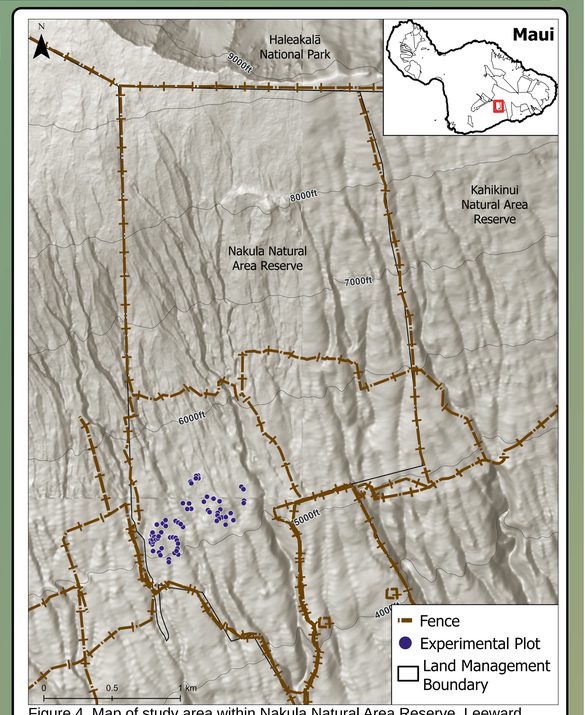


Figure 4. Map of study area within Nakula Natural Area Reserve, Leeward, East Maui.

Figure 5. Satellite imagery of the study area in Nakula NAR showing location of the experimental plots at the beginning of the trials (2013) and after ten years (2023). Imagery courtesy of Google LLC.

Figure 6. An example of experimental plots over the course of the trials, after one (2014), three (2016), and five years (2018). Plots are denoted by red borders for illustrative purposes only.

Summary of Findings and Recommendations:

Key Findings:

- Natural Regeneration: 'a'ali'i and koa naturally regenerated best, especially where non-native grasses were removed.
- Out-planting Success: Most native species had >80% survivorship at 2 years. Herbicide treatments led to larger seedlings, but long-term benefits were strongest with herbicide + removal.
- Canopy vs. Open Planting: Open areas yielded better growth and survival than planting under koa canopy.
- Long-Term Effects: Some plots matured into dense forest patches. Continued germination was seen in herbicide + removal plots, including new species. Shrubs had lower survivorship, and high planting density increased competition and mortality.

Recommendations:

- Prioritize koa, 'ōhi'a, and 'a'ali'i for canopy formation and natural grass suppression. Plant shrubs (māmaki, māmane, pilo) later, after canopy species are established.
- Use herbicide + manual removal where feasible for lasting grass control. Maintain wider plant spacing to reduce competition.
- Continue long-term monitoring to inform adaptive management.

Impact:

- Over 300,000 native seedlings planted and removal of ungulates since 2013 have significantly restored Nakula NAR, supporting forest recovery and native bird return (Fig. 5, Fig. 6). In 2019 and 2022, 'i'iwi (*Drepanis coccinea*) were documented in Nakula NAR, the first records of the species in the region in modern history.

Questions, comments - please reach out to Hillary at hillary@mauiforestbirds.org