An invasive grass has significant impacts on tropical dry forest ecosystems in Hawaii: The role of science in landscape level resource management and native forest restoration in West Hawaii

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Hawaii's dry forests are among the most endangered of all ecosystems in the archipelago. These forests harbor a rich flora with unique species assemblages. Unfortunately, these once extensive communities have been severely fragmented and degraded by deforestation, development, fire, nonnative ungulate grazing, and invasions by alien plant species such as fountain grass (*Pennisetum setaceum*). Fountain grass was introduced as an ornamental in the early 1900's and has since consumed over 200,000 acres from the coast to over 3000 m elevation on the leeward side of the Big Island of Hawaii (Degener 1940, Wagner and others 1990). While fountain grass biomass is greatest in degraded open areas, it also invades and represents up to 90% cover in the understory of remnant native dry forests (Cabin and others 2000).

A dry forest preserve at Kaupulehu, North Kona has been the site of various research and restoration projects (Fig. 1).

Figure 1. Kaupulehu Mauka dry forest exclosure. This 6-acre parcel is owned by Kamehameha Schools and leased to the National Tropical Botanical Garden. All fountain grass (*Pennisetum setaceum*) was removed from the exclosure in 1995.

We have outlined the current barriers that prevent the natural regeneration of dry forests and have sequentially targeted our research efforts to overcome these barriers and begin the process of dry forest restoration. Our restoration research efforts over the past 5 years have led us to successful ungulate exclusion and removal, cost-effective grass removal techniques and successionally appropriate native plant restoration regimes (Cabin and others 1999, 2000, 2002, Cordell and others 2002). This process follows a pattern that begins with fast-growing weedy, more generalist native species that ultimately create a suitable micro-environment for slower growing native species (Figs. 2-4).

Figure 2. Fast growing native vines such as *Canavalia hawaiiensis* are successfully used in Hawaiian dry forest restoration projects. These vines quickly produce a dense cover and deter re-emergence of fountain grass and other invasive plants

Figure 3. Weedy native shrubs (*Sida fallax* shown here) grow quickly and provide a suitable micro-environment for slower growing native trees and shrubs that require specific environmental conditions for survival.

Figure 4. *Pleomele hawaiiensis*, a federally listed endangered species requires relatively shaded and cool conditions for survival. This species would be planted near to last in a successionally appropriate dry forest restoration plan.

Our invasive species control program has evolved in scale from square meter plots to landscapes. For example, we have successfully controlled invasive grasses using the glyphosate-based herbicide (Roundup® at a rate of 1.5-2 percent) on a small scale with backpack sprayers and on a larger scale using a boom sprayer attached to a helicopter (Cordell and others 2002, Castillo and others, unpublished data) (Fig. 5).

Figure 5. The fountain grass in the foreground has been sprayed with herbicide from a helicopter, and the grass in the background has been subjected to a controlled burn. This project is part of a Joint Fire Science Project (photo by Project leader – Michael Castillo) to evaluate cost-effective management strategies.

Other methods, such as the use of bulldozers, controlled burning, and cattle grazing have been successfully used to varying degrees, or are currently being evaluated. Once controlled, fountain grass poses a relatively minor threat in the short term and if followed up with a sound restoration plan, can eventually be kept at bay. It is our hope that by using these techniques landowners and land managers can successfully reverse the current trend of dry forest decline in Hawaii.

Additionally, our invasive species research approach has focused on understanding ecosystem level impacts of invasive grasses on native forest ecosystems. Although the devastating effects on community composition wrought by fountain grass are obvious, the underlying causal mechanisms and subsequent ecosystem consequences of this invasion remain unclear. To date much of the research in invasive species biology, including our own restoration project, has focused on changes in species assemblages and, therefore, management decisions have largely centered on eliminating invaders and restoring native community composition. However, few studies have addressed the impacts that alien species have on function of ecosystems and the services that they provide (e.g., cycling of water, carbon, and nutrients). Our data show that the presence of an invasive grass has significant impacts on ecosystem function, both in terms of water availability to native tree species and carbon cycling. Notably, tree foliage NPP was significantly higher (62%) in grass removal plots (Litton and others, unpublished data) (Fig. 6), and removal of grass also resulted in a 42% increase in

aboveground basal area increment (i.e., wood production) for native trees (Sandquist and others, unpublished data) (Fig. 7).

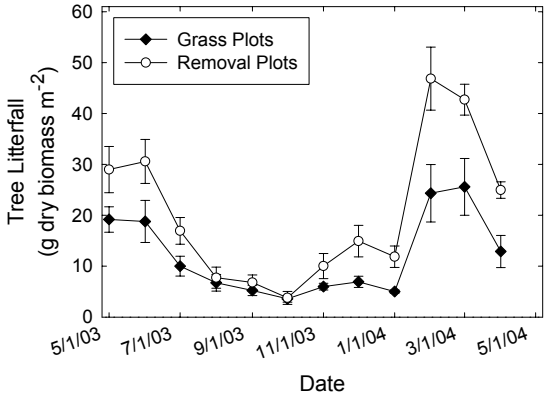

Figure 6. Native tree litterfall is significantly higher throughout the year when fountain grass is removed from an ecosystem

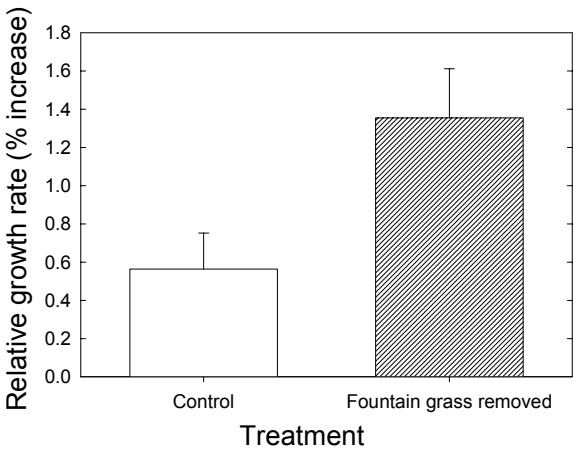

Figure 7. The native tree species *Diospyros sandwicensis* almost doubles its growth rate when fountain grass is removed from the ecosystem ($P < 0.001$).

These findings highlight the need to incorporate how invasive species affect important ecosystem processes so that management decisions may take into account the maintenance of desirable ecosystem functions.

Finally, it is in our best interest to amass community support for our restoration efforts and to convince decision makers and politicians that protection and restoration of Hawaiian tropical dry forests are necessary for healthy communities. The expansion of fire-promoting grasses not only leads to forest decline, but also threatens the health and safety of urban areas. We have quantitatively shown that native forests not only significantly reduce invasive grass biomass, but also the flammability of these grasses (Bishaw and others unpublished data) (Figs. 8-9).

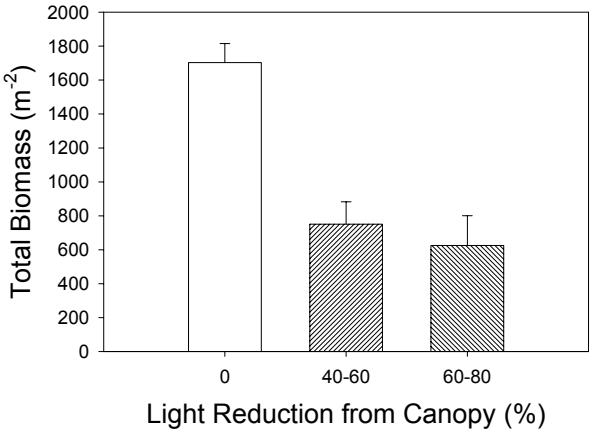

Figure 8. Fountain grass biomass is significantly reduced under tree canopy ($P < 0.001$).

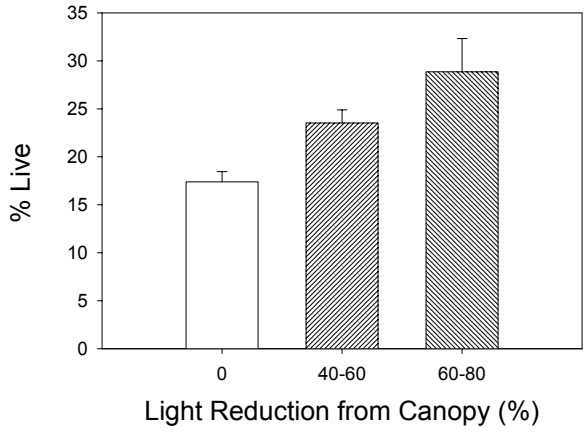

Figure 9. The ratio of live to dead fountain grass (an indicator of flammability) is significantly higher under tree canopy ($P < 0.05$).

In the future we hope to provide an economic analysis of the detrimental effects of fountain grass in Hawaii and how restoration of native Hawaiian dry forests can pay for itself and ultimately save tax dollars by reducing the costs of wildfire suppression.

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