Restoration of tropical dry forests in Hawaii: Can scientific research, habitat restoration and educational outreach happily co-exist within a small private preserve?

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Abstract

Tropical dry forests were once the most common of all tropical forest types, but today they are among the most endangered and degraded of all ecosystems in the world. Since these ecosystems also contain highly diverse and unique species assemblages, failure to preserve and restore dry forests will also clearly result in significant biodiversity losses. Aggressive alien species have already invaded most of what remains of Hawaii's once diverse and extensive dry forests, and the continuing spread of fire-promoting exotic grasses may ultimately convert these ecosystems into permanent, low-diversity grasslands. For the past eight years, we have been investigating methods for simultaneously controlling these alien species invasions and re-establishing key native species within remnant dry forest stands in the North Kona region of the island of Hawaii. This research is conducted in close collaboration with the North Kona Dryland Forest Working Group. This group, comprised of numerous agencies, land owners and ranchers, scientists, local citizens, and native Hawaiians, has been actively involved in dry forest research, restoration, and outreach activities for over 15 years. This paper focuses on the practical and philosophical issues involved with conducting research within a globally endangered ecosystem in close collaboration with a diverse coalition of agencies, stakeholders, and concerned citizens.

Introduction

Tropical dry forests are among the most threatened and endangered ecosystems in the world (Murphy & Lugo 1986; Janzen 1988; Lerdau et al. 1991; Sussman & Rakotozafy 1994). Because these forests also tend to be extremely diverse communities, their loss significantly contributes to the steady erosion of the Earth's biodiversity. In the Hawaiian Islands, for example, lowland dry and mesic forests once were considered to have more total and native tree species than any other region in the state (Rock 1913). Today, over 90% of the original dry forests have been destroyed (Bruegmann 1996), and over 25% of the officially listed endangered plant taxa in the Hawaiian flora (which represents 38% of all threatened and endangered plant species in the United States) are from dry forest ecosystems (A. K. Sakai and W. L. Wagner, unpublished data). Since many of these endangered species were also extensively used by native Hawaiians, preserving these dry forests is important for both biological and cultural reasons. For example, the dry forest canopy tree Kauila (*Colubrina oppositifolia)* was used to make weapons, kappa (cloth), agricultural tools, and fishing lures. Other culturally important but currently endangered dry forest trees include halapepe (*Pleomele sandwicensis*), koki`o (*Kokia drynarioides*), and uhiuhi (*Caesalpinia kavaiensis*).

The original distribution and diversity of Hawaiian dry forests was the product of physical and biological interactions that resulted in a checkerboard of forest fragments with different substrate ages and species compositions (Figure 1). However, since the human discovery of the Hawaiian Islands approximately 1500 years ago, the distribution and structure of these forests have increasingly reflected the direct and indirect effects of human disturbances such as deforestation, fire, land development, and invasions by exotic species (Cuddihy 1989; Stone et al. 1992; Stemmermann & Ihsle 1993; Bruegmann 1996; Cabin et al. 2000). At present, these kinds of human-mediated disturbances have largely superceded the historically important natural disturbance regimes (Figure 1) and created a new set of forest dynamics with largely unknown ecosystem properties and successional pathways.

Dry Forest Restoration at Kaupulehu, North Kona, island of Hawaii

Today much of the vegetation on the dry, leeward side of the island of Hawaii consists of dense monocultures of fountain grass (*Pennisetum setaceum*), a globally distributed, phenotypically plastic, highly invasive alien species (Williams et al. 1995). Like many other invasive grasses around the world (Soriana & Sala 1983, Gordon et al. 1989, D'Antonio and Vitousek 1992), fountain grass appears to have altered the ecological and ecosystem dynamics of this region in three majors ways: first, its dense root system may inhibit nutrient and water acquisition by other species; second, its extensive above-ground biomass can thwart the ability of other species to germinate and establish; and third and perhaps most importantly, the presence of fountain grass may catalyze a devastating grass/fire feedback loop.(Because most Hawaiian plants evolved in the absence of regular fires, few native species possess adaptations for surviving them.) On the dry, leeward side of the island of Hawaii, this grass/fire cycle has effectively converted large, formerly forested areas into fountain grass monocultures as follows: during extended droughts, the above-ground fountain grass biomass dries and readily burns, which leads to further reductions of woody vegetation and corresponding increases in the spatial distribution and biomass of fountain grass, which in turn leads to ever-more frequent and widespread fires.

Dry forests once covered virtually the entire North Kona area (ca. 128,000 hectares or 316,160 acres) of the island of Hawaii with a rich mosaic of unique species assemblages. Although North Kona still contains some of the largest and highest quality native dry forest remnants left within the entire archipelago, today even within this region this ecosystem is largely represented by isolated, depauperate, and senescent patches of trees scattered across pastures dominated by fountain grass. Feral and domesticated cattle and goats also continue to destroy forest remnants and increase their vulnerability to further invasion by fountain grass and other exotic weeds, and introduced rodents consume the seeds and seedlings of many species.

In 1993, the U.S. Fish and Wildlife Service agreed to coordinate conservation efforts for the long-term management and protection of remnant dry forests in North Kona. This effort eventually coalesced into the "North Kona Dry Forest Working Group" which now includes local residents and volunteers, native Hawaiians, scientists such as ourselves, and over 40 other members representing more than 25 agencies ranging from a local ethno-botanical garden to the U. S. Army (see http://www.hawaii-forest.org/reports/dryland.html for more information about this group).

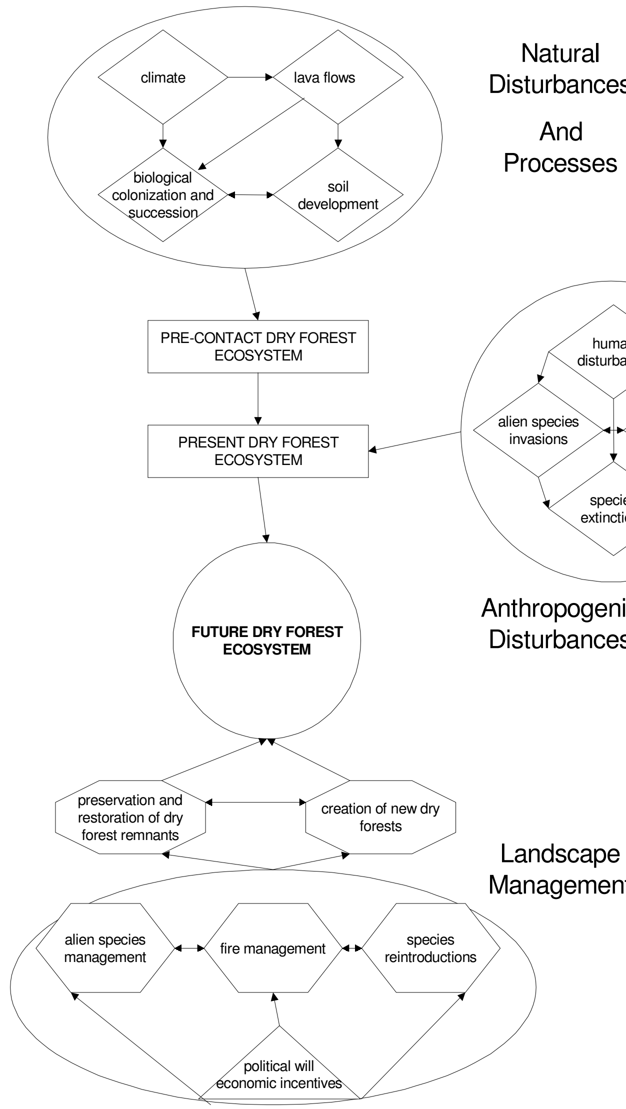

Figure 1. Flow chart illustrating the major impacts on dry forests during the pre-contact era, at present, and in the future.

After an extensive search for an economically and politically feasible site to undertake an on-the-ground dry forest restoration/demonstration project, this Working Group selected a remnant dry forest parcel within the Kaupulehu region of North Kona. This area of Kaupulehu, located at approximately 500-600 meters (1640 – 1969 feet) elevation, rests upon an a'a lava flow between 1500 and 3000 years old (Moore et al. 1987). Average annual rainfall has been estimated at approximately 50 cm (19.7 inches) (Giambelluca et al. 1986), although precipitation in this part of the island is notoriously patchy and unpredictable over space and time (Cabin et al. 2002a).

Figure 2. The upper, smaller parcel at Kaupulehu as seen from the highway.

Today this Kaupulehu Dry Forest Preserve consists of two adjacent and actively managed dry forest remnants owned by Kamehameha Schools and leased by the National Tropical Botanical Garden and the Potomac Investment Association Kona Limited Partnership (all three of this entities are also members of the Working Group). The upper, smaller (2.3 hectares or 5.7 acres) parcel was fenced by the Territory of Hawaii in 1956 to protect its rich diversity of native species from damage by non-native ungulate and human disturbances (Figure 2). The lower, larger (25 hectares or 61 acres) parcel at Kaupulehu still has some relatively diverse stands of native canopy trees within the higher elevation sections, but tree density steadily declines with decreasing elevation to only sparsely distributed bands of scattered individual trees (Figure 3).

Figure 3. The lower, smaller parcel at Kaupulehu. Note how tree density increases with elevation, and how fountain grass dominates the entire understory.

A Forest of the Living Dead

When we first began working within the upper Kaupulehu parcel in 1996, we found that despite the long-term fencing there had been virtually no regeneration of native canopy tree species (Cabin et al. 2000).Comparisons of this parcel's flora at that time with past surveys also showed that this regeneration failure had already caused substantial changes in the abundance of the dominant species, and that some trees considered common only 25 years ago were now down to their last few individuals. While we were encouraged to find that numerous native understory species were still present, it appeared that the thick stands of fountain grass that blanketed most of the ground of this forest remnant would inevitably thwart their regeneration as well. We also found that fountain grass dominated virtually the entire lower, larger Kaupulehu parcel and that native understory species were almost completely absent, perhaps due in part to previous ungulate activity (this area was not fenced until 1997).

It was clear to all the members of the Working Group that aggressive, active management would be required to ensure the integrity and long-term survival of the forest remnants at Kaupulehu. After much discussion we agreed to focus our initial efforts on the upper parcel and then later apply what we learned there to the restoration of the lower parcel and/or other suitable areas within and beyond the Kaupulehu region. We also agreed that the overall goals of the Working Group should include preserving and restoring native Hawaiian dry forests, developing educational outreach programs, and supporting scientific research.

The Joys and Frustrations of Doing Science at Kaupulehu

As scientists we have strived to conduct rigorous, first-rate research that addresses academically interesting questions, enhances our basic ecological understanding of tropical dry forests, informs the Working Group of the likely ecological consequences of various management strategies and practices, and facilitates the general preservation and restoration of dry forests within and beyond the Hawaiian Islands. The results of our research program at Kaupulehu to date have been reported elsewhere (e.g., Cabin et al. 1999, 2000, 2002a,b; Cordell et al. 2002a, b); here we focus on some of the practical and philosophical issues involved with conducting research within a globally endangered ecosystem in close collaboration with a diverse coalition of agencies, stakeholders, and concerned citizens.

At its best, working at Kaupulehu can be a highly rewarding, stimulating, and mutually beneficial and productive experience for everyone involved. As scientists, we know that at least some of our research is "making a difference," which is why some of us decided to become scientists in the first place. Our research program has also directly benefited from the Working Group's considerable logistical, financial, and political support. For example, there is simply no way we could have performed many of our experiments without the direct help of numerous highly skilled and dedicated volunteers (Figure 4). Similarly, it would be difficult, if not impossible, to perform research at Kaupulehu without the Working Group's ongoing efforts to develop and maintain the site's critically important infrastructure (e.g., fire breaks and access roads, ungulate fences, irrigation networks, volunteer coordination, site security, etc). Finally, some of our projects that have yielded scientifically valuable data and insights have been funded by sources that most likely would not have supported a group comprised only of research scientists.

At its worst, working at Kaupulehu can be frustrating for scientists and non-scientists alike. This is due in part to the difficulties of working within this biologically degraded and desperate ecosystem and the inevitable political and bureaucratic challenges that arise from so many people and organizations attempting to work together. The bottom line is that the type of science we can do at Kaupulehu is often constrained by both biological and political realities..

An example of a biological limitation arose when our initial efforts to control the dominant alien species within the upper forest remnant (fountain grass and rodents) appeared to facilitate the regeneration of both key native species and new and potentially invasive alien plant species. These results in turn raised several intriguing and fundamentally important new scientific questions (discussed in Cabin et al. 2000) that could have been rigorously and elegantly addressed within this study system. In the end, however, we decided that it would be unethical to give these new weeds the opportunity to invade this high-quality dry forest preserve after all the time, labor, and money that had already gone into controlling the existing alien species.

Figure 4. Volunteers help launch another experiment at the lower parcel at Kaupulehu.

Our attempts to do science at Kaupulehu have also occasionally conflicted with the goals and values of other members of the Working Group. For instance, to date we have performed several experiments in which we transplanted or direct-seeded native species into various experimental treatments. In order to collect scientifically rigorous and meaningful data from these experiments we had to include appropriate control treatments (e.g., growing these plants in highly unfavorable conditions such as within dense stands of fountain grass or barren lava outcrops) that to non-scientists often appeared illogical, wasteful, counter-productive, and/or downright stupid! Similar problems also arose when we destructively harvested experimental native plants or employed research protocols that may have indirectly lead to their death (e.g., ending supplemental watering and weeding treatments). In addition, we sometimes had to abandon potentially promising research directions (e.g., attempting to control fountain grass via prescribed fires followed by aerial grass-specific herbicide applications) or limit the use and development of a particular experimental treatment. For instance, after considerable debate, we were eventually allowed to experimentally investigate the efficacy and ecological consequences of using bulldozers to control fountain grass within a small region of the lower Kaupulehu parcel in which no native species were present. However, the attitudes of the members of the Working Group who were initially skeptical about this management technique did not change even after this experiment showed that bulldozing appeared to be the most economically and ecologically effective treatment (Cabin et al. 2002a). This outcome revealed a more general phenomenon we have observed and experienced at Kaupulehu and elsewhere: many people will claim to want their particular project to be “science-driven” until that science suggests something that directly conflicts with a strongly held personal belief.

Science and Restoration Under a Big Tent

In our experience, the design and implementation of the dry forest restoration program at Kaupulehu has been the product of a complex interplay of scientific, conservation, and land management objectives; economic, logistic, and biological realities; and personal ethics, values, and egos. Performing science within this context has often forced us to at least listen carefully to many ideas that are rarely heard and discussed within the world of science. On both a personal and professional level, we have also had to struggle to balance the demands made by our employers and the scientific community in general (e.g., performing the kind of novel, rigorous, basic research favored by the highly selective and prestigious academic publications and funding organizations) with the urgent conservation needs of Hawaiian dry forests and the understandable desires of the Working Group to design and implement management plans as quickly as possible. Other active participants in this project have also had to struggle to balance the needs of the Working Group with the expectations and interests of their particular organizations and professional communities.

Resolving these kinds of issues has led the Working Group as a whole to periodically grapple with the larger questions of what our ultimate purpose, goals, and priorities at Kaupulehu actually are. For example, is our primary mission to preserve and restore Kaupulehu in particular and native Hawaiian biodiversity in general? Or is it to develop effective outreach programs that educate the public about the biological and cultural value of these forests and lobby for their protection? Is achieving on-the-ground restoration “success” and/or scientific breakthroughs more important than developing tools and strategies for encouraging and facilitating the preservation and restoration of native dry forests beyond Kaupulehu? Should our efforts to save this ecosystem be guided by aesthetic and moral arguments (e.g., dry forests are beautiful, the species that live within them have a right to exist, and our studies of these forests will add to our basic intellectual knowledge of the world) or more utilitarian and economic concerns (e.g., controlling fountain grass and re-establishing forests in this region may decrease the occurrence of costly and dangerous fires, increase the annual precipitation and decrease the average temperature of the leeward side of this island, and help develop a viable forestry and eco-tourism industry)?

It is often tempting and expedient to argue that a good restoration program should be an all-inclusive effort that strives to accomplish all of the above objectives. Of course ideally, and occasionally in actuality, a particular course of action will simultaneously advance multiple and diverse goals in a complementary fashion. However, we have found that given the realities of limited time, money, labor, and patience, the Working Group has on numerous occasions been forced to make decisions that inevitably and sometimes irreversibly favor one objective at the expense of another.

As an illustration of this process, consider the following three examples involving alien species at Kaupulehu:

1: In the 1950's foresters planted several alien tree species within the upper Kaupulehu parcel. One of these trees (*Callitris endlicheri*) eventually grew substantially taller than all the other trees in this general area and thus became a prominent and important local landmark. Some local members of the Working Group felt that because this tree was culturally important and biologically harmless (it had apparently failed to regenerate since it was planted), killing it was not only unnecessary but actually insensitive and counter to our larger mission. Other, mostly non-local members of the group argued that this tree had no place in a Hawaiian dry forest preserve and thus should be removed immediately.

2: Although the kukui or candlenut tree (*Aleurites moluccana*) is the official state tree of Hawaii, it is actually an alien species that was brought over to the islands by the early Polynesians in their sailing canoes because of its practical and cultural importance. Although at present wild kukui trees can be found in many different habitats throughout the Hawaiian Islands (including parts of North Kona but not within the Kaupulehu Dry Forest Preserve), they tend to form dense stands only within riparian areas. Because of its cultural importance, beauty, hardiness, and ability to grow relatively quickly and provide substantial amounts of shade, some of us proposed experimentally investigating whether kukui might be used to create favorable nurse environments for the eventual establishment of native dry forest canopy trees. Given the desperate situation of Hawaiian dry forests, some members of the group were even willing to try experimenting with any promising, non-invasive species regardless of its geographic origin. Other people were willing to consider trying kukui and other appropriate species originally brought by the early Polynesians but would not consider using any other exotic species. Finally, some members of the group (although not necessarily the same members who advocated killing the *Callitris* tree) strongly objected to the idea of ever planting kukui or any other alien species at Kaupulehu no matter how useful and controllable they might be.

3. The beautiful Blackburn's sphinx moth (*Manduca blackburni*) is Hawaii's only federally listed endangered insect. Like many other native insects, the rarity of this species is due in part to the rarity of its key host plant, which in this case is a native dry forest canopy tree (aiea or *Nothocestrum breviflorum*). While there are a few mature aieas scattered across the Kaupulehu Preserve, we have never observed this moth on these trees. (This is not surprisingly because we have been unable to carefully monitor these trees due to their size and location and our limited expertise.) However, we and others have observed this moth in North Kona on tree tobacco (*Nicotiana glauca*) which is in the same family as aiea (Solanaceae) but is actually an alien and invasive species in North Kona and other arid regions of Hawaii. While we have been outplanting aieas throughout the preserve for several years, this species is much less hardy and grows much more slowly than tree tobacco. To support at least the short-term survival of this moth, should we plant new and/or at least not eradicate existing populations of tree tobacco within the Kaupulehu Preserve? (Although this species is already present, it mostly grows along the access roads and firebreaks and thus has been relatively easy to control)

The resolution of these and many other dilemmas has required careful, prolonged, and often emotional discussions of our restoration objectives and priorities. We believe that despite these kinds of potentially divisive issues and the formidable biological and economic challenges, the North Kona Dry Forest Working Group has thrived because we are united in our collective desire to save this ecosystem from extinction. Along the way we have all had to learn to respect values and priorities that may differ radically from our own. Perhaps this process may ultimately prove to be as valuable as all our conservation, restoration, outreach, and scientific accomplishments.

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