A MANUAL FOR RESTORING RAINFOREST IN VOLCANO

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WHY DO RESTORATION IN VOLCANO?

Tall, slender \`ōhi\`a trees with a nearly monotypic understory of tibouchina, a shrub introduced from tropical America and now highly invasive in the Volcano area.

This forest stand may superficially resemble a native forest because of the tall, closed stand of \`ōhi\`a and a few straggling tree ferns. However, as a native forest this stand is doomed. There is no native understory and there is no regeneration of native plants, thanks to the tangled thickets of tibouchina. \`Ōhi\`a is a long lived species, but it too will eventually disappear from the site as the trees senesce and die. To perpetuate \`ōhi\`a and return the full diversity of native species, this site needs restoration. The first step in restoring this forest stand is to remove the tibouchina. The next steps will be to control the grass that will probably invade the site, monitor the recovery of native species, and reintroduce native species that are not recovering on their own. So, the answer to the question above, "Why Restore Native Forest?" is that it gives our local damaged, degraded forests a future as native ecosystems and it returns biological diversity to these systems.

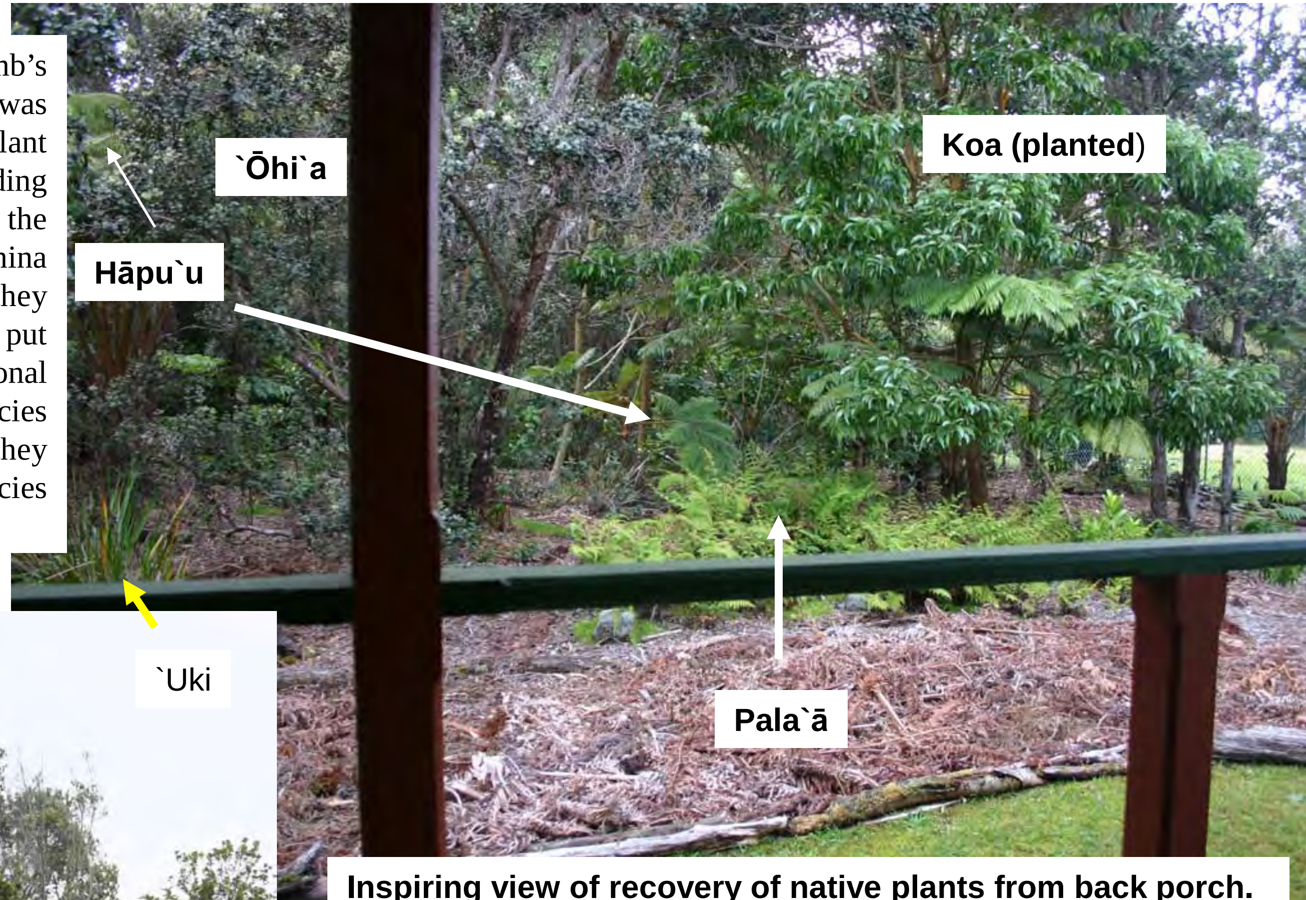
MOST HAWAIIAN FORESTS HAVE NO FUTURE WITHOUT RESTORATION

Young `ōhi`a forest invaded by Himalayan ginger.

This forest is more diverse than the forest stand above invaded by tibouchina. There are more tree ferns, a few `ōlapa, and also uluhe fern. However, it is biologically impoverished compared to undisturbed or restored communities. Without restoration, initiated by Himalayan ginger control, this forest will eventually disappear as the trees age and die without replacement. In short, Hawaiian ecosystems require active management, i.e., restoration, because of the success of invasive species in our islands. Himalayan ginger is more commonly called “kahili” ginger. A Hawaiian word in the plants name may imply it is a native species. It is not; it is from the Himalayan mountains.

EXAMPLE OF RESTORATION AFTER TIBOUCHINA REMOVAL

The forest on John and Pamela Lipscomb's one-half acre lot in Volcano Village was damaged and degraded. The native plant understory had been replaced by invading tibouchina which had nearly destroyed the natural ecosystem. By removing the tibouchina with hand pulling and a small bulldozer, they catalyzed the recovery of native plants, and put the ecosystem back on its natural successional trajectory. All of the native understory species found historically have not recovered, but they have created a habitat in which these species can now become established.



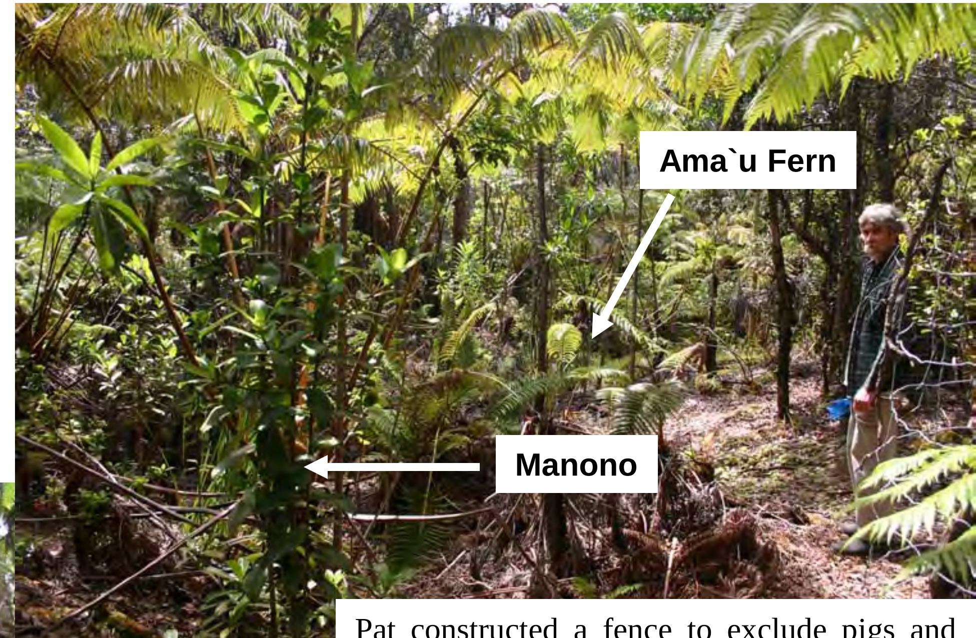
Inspiring view of recovery of native plants from back porch.

A before scene at Lipscomb restoration site in Volcano. Alien invasive tibouchina had displaced the entire understory, with just a few emergent `ōhi`a persisting.

A number of common species are recovering on their own such as `ōhi`a, hāpu`u, māmaki, pala`ā and ama`u. Often these recovered in small dense clusters. Rather than allowing them to self-thin the Lipscombs took advantage of the surplus plants and transplanted some from one part of the property to the other. They are now planting understory species such as `oha wai (*Clermontia* spp.) previously eliminated by the tibouchina invasion. These kinds of plantings will create a local seed source and increase the biodiversity of the site.

EXAMPLE OF RESTORATION AFTER GINGER REMOVAL

Pat Conant's six acre rain forest site was also damaged and degraded, but perhaps more subtly so than the Lipscomb's. The `ōhi`a canopy, subcanopy tree layer, and tree ferns were relatively intact. However, closed stands of Himalayan ginger had displaced native shrubs, ferns, and herbs from the forest floor. Eventually,the overstory trees would have died without replacements because the dense layer of ginger precluded natural regeneration.



(*right*) Natural recovery of `ama`u fern and the small tree, manono, after removal of feral pigs and kahil looking from the photopoint below into the interior of the restoration project.

Pat digging out resprouting ginger plants just inside his property line. The understory was a continuous stand of kahili ginger before he began his restoration project in the foreground.

Pat constructed a fence to exclude pigs and controlled Himalayan ginger with herbicides. These are restoration actions which facilitate the recovery of native plants. The most depleted component of wet forest in Volcano is the shrub layer. Pat is assisting in the recovery of native shrub directly by planting `oha wai (*Clermontia hawaiiensis*). This species has been broadly extirpated by pigs. The plantings will serve as seed sources for natural recovery, now that his invasive species management has created a habitat for native understory species. The understory is not as species-rich or dense with shrubs and ferns as it was prior to the invasions but it is on the trajectory to return to that diverse multi-layered ecosystem.

RESTORATION: IT'S THE TRAJECTORY THAT COUNTS

Before restoration: understory dominated by Himalayan ginger

Restoration is now underway in the forest on the right, by our definition, even though native understory vegetation besides tree ferns are absent. The forest was damaged and degraded by the invasion of Himalayan ginger. Ginger has just been removed, and native tree seedlings, shrubs, ferns, and herbs are expected to recover. Because of this, ginger removal has returned this forest stand to its historical successional trajectory. Without alien vegetation in the forest understory, native plants have the potential to reestablish on the forest floor, potentially returning the composition and structure of the forest to pre-disturbance conditions. It may not be possible to restore the forest to historical structure and composition in detail. Environmental conditions may have changed or historically appropriate species may no longer be available. However, what is important in terms of restoration is the return to the historical successional trajectory.

\`Ōhi\`a/hāpu\`u forest just after ginger removal but before recovery commences.

WHAT ARE THE TRAITS OF RESTORED ECOSYSTEMS?

►CONSIST OF NATIVE SPECIES TO THE EXTENT PRACTICABLE

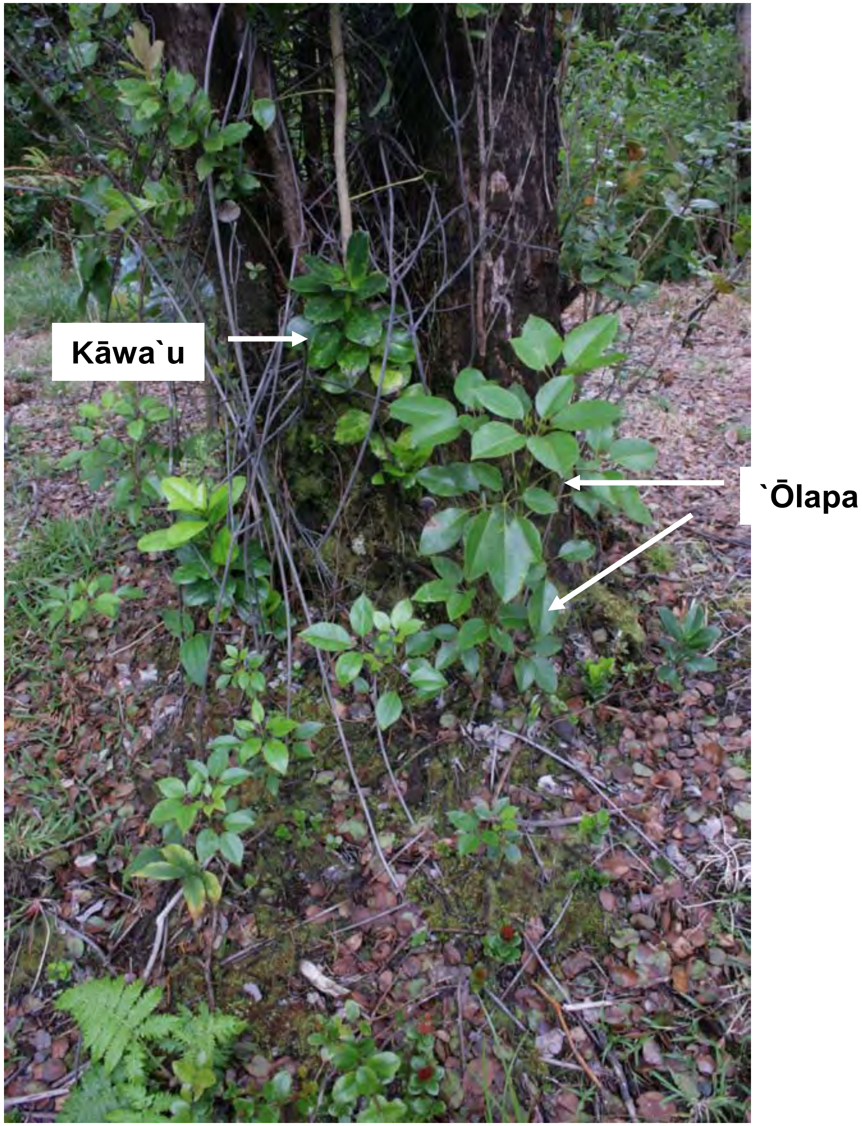
In Hawai`i, there are virtually no natural areas occupied exclusively by native species. Even in pristine sites in the bottoms of pit craters, never disturbed by feral pigs or other invasive ungulates, there are still some non-native plants. Restored ecosystems do not have to be exclusively native. They are dominated by native species, as measured by biomass or plant cover. Alien species may be present but are minor components and have not altered the structure and function of native ecosystems. For example, in the national park's `Ōla`a Forest adjacent to Wright Road (you can enter this from Wright Road in Volcano Village—bring a compass), the biomass and cover of the forest community is overwhelmingly native. There are, however, several species of alien plants. These are minor elements of the flora at this time and probably exert little ecological influence on the forest ecosystem. The park staff works hard to maintain this balance. They built fences and remove feral pigs that breech this barrier. Every three or four years, they systematically sweep each section of `Ōla`a Forest and remove threatening invasive plant species such as Himalayan ginger, strawberry guava, palm grass, banana poka, and yellow raspberry. If left uncontrolled, these invasive, alien plant species, in a matter of decades, create single species stands or understory layers. Portions of `Ōla`a Forest, miles away from Wright Road, have suffered this fate and are dominated by strawberry guava or palm grass. Ecosystems in Hawai`i are considered restored if they consist of native species to the extent practicable. Stand forming weeds may be present but are kept from spreading by active management.

A typical view of native dominated vegetation along the Pu`u `Ō`ō Trail. Even in this plant community dominated by native plants in both the overstory and understory, if you look closely, you will find the occasional strawberry guava and harmless weeds along the disturbed soil by the trail.

WHAT ARE THE TRAITS OF RESTORED ECOSYSTEMS?

►ARE SELF-SUSTAINING

The hallmark of restored ecosystems is that they are self-sustaining, that is, native species are able to reproduce, regenerate, and replace themselves. Of course, reproduction and regeneration of species may naturally fluctuate over time and the composition of restored ecosystems may change over time. In contrast, the hallmark of invasive-dominated plant communities in Hawai`i is that alien vegetation forms mono-dominant vegetation layers and prevents seedlings of native plants from getting established. Even though native overstory trees that overtop a layer of strawberry guava or kahili ginger and rain down fruits with viable seeds, seedlings cannot grow through the thick alien vegetation layer in the understory. Eventually, even long-lived tree species may eventually disappear because they are not being replaced. Plants like kahili ginger and strawberry guava directly compete with native understory and displace them. Small patches of native understory that persist are not able to get established and replace themselves. The requirement of being self-sustaining has to be qualified for Hawaiian ecosystems. These forest will need active management of ungulates and weeds, probably forever, to make them self-sustaining. If this intervention does not take place, alien species will be increasingly successful and will eventually preclude the capacity of native species to be self-sustaining.



Native tree seedlings getting established at the base of an `ōhi`a tree five years after the removal of Himalayan ginger.

WHAT ARE THE TRAITS OF RESTORED ECOSYSTEMS?

►HAVE STRUCTURE & SPECIES COMPOSITION OF UNDISTURBED, NATURALLY OCCURING COMMUNITY OR THE REFERENCE COMMUNITY

A restored ecosystem is not a hodgepodge of native species from diverse ecosystems, thrown together randomly or conveniently based on availability of plant species. Rather, a restored ecosystem contains a characteristic assemblage of plants found in an undisturbed community located in a similar environment with similar rain fall, flow ages, and soil depth. The assemblage of species in a restored ecosystems should also be similar to the composition of your reference community (see definition on last page of manual). The structure or arrangement of different plant life forms or vegetation layers should also resemble those of a naturally occurring or reference community.

Relatively diverse, intact rain forest along Pu`u `Ō`ō Trail with a shrub layer and fern/herb layer, as well as a full complement of trees and tree fern species.

WHAT ARE THE TRAITS OF RESTORED ECOSYSTEMS?

►ARE RESILIENT ENOUGH TO WITHSTAND NATURAL ENVIRONMENTAL STRESS EVENTS

In any environment, there are periodic disturbances or alterations. Examples in Volcano include extreme weather such as 12 inch rains (12 inches in 12 hours), spring time *El Nino* droughts, and episodes of acid rain or vog, A restored ecosystem should be able to endure these stresses without major changes in composition, structure, or ecological processes. Resilience is the term that describes this capacity for returning to the steady state after a stress. These kinds of normal extreme events actually help maintain the integrity of naturally occurring ecosystems whose species have evolved to adapt to normal extremes. These natural stresses help exclude species poorly adapted to them. For example, pioneer communities on recent lava flows are some of the most intact or native dominated ecosystems in Hawai`i. With little soil, this environment has few nutrients and little moisture holding capacity to offer plants. The extreme conditions in this environment and the resilience of the assemblage of native species that colonize recent lava flows helps keep out the weeds.

►POTENTIAL THREATS TO THE HEALTH AND INTEGRITY OF THE RESTORED ECOSYSTEM ARE MANAGEABLE

Hawaiian ecosystems face overwhelming threat from invasive species that could alter them completely, if left unchecked. A community is restored, in the context of Hawai`i, if these threats are kept to manageable levels by active management.

WHAT RESTORATION IS NOT: SOME EXAMPLES

In the two examples illustrated on this page, alien plants have been controlled or managed and some native plants have prospered. However, they are not restored forests.

(*left)* Not self-sustaining, low species diversity not representative of a naturally occurring community or reference community.

(*right)* Overstory trees native but ornamental plantings in understory and vigilant weeding to protect them preclude native plant seedling establishment. Low native plant diversity.

WHAT RESTORATION IS NOT: A MORE SUBTLE EXAMPLE

This forest stand is in the process of being restored but it should not be considered fully restored. It does not support the characteristic assemblage of species of restored or undisturbed natural communities in a similar environment. With the removal of Himalayan ginger, as recently occurred above, there will be natural recovery of some species over time. However, some backyard forest stewards are content with the simple tree fern dominated scene above that lacks a shrub layer and an fern/herbaceous forest floor layer. Other backyard forest managers may be tempted to substitute an understory layer of native plants but not ones found in a plausible reference communities. They may plant any natives that are able to grow, that they can find commercially or that are their favorite plants. An assemblage of naturally occurring species can be reestablished, some by natural recovery and some by reintroduction and outplanting. It is not only feasible to reestablish but superior in terms of restoration. We know that the assemblage of forest understory species found in an undisturbed or reference community is predominantly native, diverse, and self-sustaining, three features of restored ecosystems.

WHAT IS THE MOST EFFECTIVE WAY TO PERPETUATE NATIVE SPECIES?

ANSWER: RESTORE NATURALLY OCCURRING ECOSYSTEMS

Recovering rain forest at Niaulani, Volcano Art Center.

The most effective, long term way to perpetuate native species is to restore native plant communities or ecosystems. By doing so, you create habitat for native plants and animals. You establish an environment in which they can regenerate or reproduce on their own with minimal human manipulation to hold the most aggressive invasive species in check. Native plants and animals evolved in the context of naturally occurring assemblages of native species or in the presence of each other. It makes sense that they are most successful in perpetuating themselves in those assemblages.

STEPS IN RESTORATION

1. KNOW YOUR PLANTS
2. SELECT A REFERENCE ECOSYSTEM
3. REMOVE INVASIVES
4. AUGMENT OR REINTRODUCE NATIVE SPECIES?
5. MONITOR, EVALUATE, AND MODIFY MANAGEMENT

STEP 1. KNOW YOUR PLANTS: Learn the Invasives

You will need to identify the plants in your restoration site to understand which are invasive and need to be managed and which are of lower priority to control. You will probably have to prioritize your control efforts since it is rarely possible to remove all alien species. The destructive impacts of invasives such as Himalayan ginger and tibouchina are readily apparent. In contrast, the ecological impacts of two more subtle invasive weeds are described below.

Gold back fern is non-native and weakly naturalized. It does not spread and form extensive stands displacing native species. This is one alien plant you can probably ignore if you have lots of other more troublesome ones to deal with.

Australian tree fern is very fast growing invasive weed and has become widespread on Maui. It is becoming more invasive in the national park and a potential threat to rainforest in Volcano. An important role for native tree ferns is as a host and establishment site for native trees, shrubs, and ferns. This relationship is very important in Hawaiian rainforest. In contrast, Australian tree fern is a poor host for native epiphytic plants.

KNOW YOUR PLANTS: Learn the Natives

You will need to be able to identify native species to protect them during restoration efforts and monitor their recovery. You will need to not only identify plants in your restoration site but also in your reference community to understand the species composition of a restored community and possible outplanting species for your restoration site. For outplanting, you will need to understand the ecology of each species to understand the proper habitat or microsite in which to plant it.

`Ama`u (*Sadleria pallida*) is found in the not-too-shady understory of wet forest. It recovers after removal of ginger and feral pigs if hāpu`u tree ferns are not too dense**.**

`Ama`u (*Sadleria cyatheoides*) is found on the edge of the forest or more typically in open areas. It establishes in rain forest areas in open, disturbed soil.

STEP 2. SELECT A REFERENCE ECOSYSTEM

Selecting a reference ecosystem or community is one of the most important steps in restoration planning. Having a reference community will inform you about the species composition and forest structure of your proposed restoration site. It will also inform you about the progress of your restoration project and what changes to expect from natural recovery. This will tell you what species to consider for reintroduction. You really need to know your plants to select a reference community. In settling on a reference community, start by searching nearby sites with similar rainfall, elevation (temperature), lava flow age, and soil depth. In many cases, you will be focusing your restoration efforts, and search for a reference community, on understory vegetation; tree canopies are still partly intact in many residential sites to be restored. You will need to develop an eye for more diverse, recovering, or less disturbed patches of native vegetation. Keep in mind that introduced alien ungulate and monotypic stands of introduced vegetation have severely depleted the native shrub, herb, and fern layer in Hawaiian forests. If you find intact or more species-rich patches of understory vegetation, these are insights into what a restored understory should look like. Even though these patches of diverse native understory may not be extensive they provide insights into the composition of communities further along on a successional trajectory. Also keep in mind that reference communities are models, not a categorical list of target species to be planted. You are doing restoration if you return your restoration site to its historical successional trajectory.

A patch of forest understory vegetation in Volcano Village within a one acre stand of old growth `ōhi`a. Small patches of native woody understory shrubs, kanawao, `ie`ie, and ha`iwale, were exposed when kahili ginger was removed. In other places ginger removal uncovered the native herbs pa`iniu and `ala`ala wainui and the native fern hō`i`o kula. Similar patches of understory native shrubs, ferns, and herbs were found persisting among the kahili ginger at Niaulani. Compositing these small understory patches into a single image for forest understory gives you a picture of at least a portion of the understory composition of a reference community. If you looked at other recovering sites in wet forest in Volcano, you could probably add to the biodiversity of your reference community.

HERE ARE SOME OTHER IMAGES OF THE REFERENCE COMMUNITY

Volcano's rain forests vary in elevation, rain fall, age of underlying lava, and depth of soil. Two additional images from sites at the extreme ends of rainfall, elevation, substrate age, and soil depth gradients are presented below to suggest variants of a Volcano wet forest reference community. The commonality of these relatively undisturbed sites is the abundance of native shrubs and/or ferns, with a strong overlap of common shrub and fern species across sites.

**Along the Pu`u `ō`ō Trail, just makai of Volcano community.** The understory of this forest, located on approximately 500-600 year old lava flows overlain by thin ash deposits, is dominated by `ie`ie, kanawao, and *Cyrtandra* spp. Underlying `ā`ā may have partially protected this area from grazing and browsing ungulates. The substrate age, rain fall, and depth of soil is similar to that of the neighborhoods of Volcano west of Highway 11.

`Ōla`a Forest, off Wright Road. The understory in this site is dominated by herbaceous native ferns. Other nearby sites have an admixture of native shrubs. The forest developed on deep ash deposited approximately 2,500 years ago. The substrate age, rain fall, and depth of soil is similar to that of Volcano on upper Wright Road and Ama`uma`u Road.

STEP 3. REMOVE INVASIVES: Control Ungulates

In conservation areas of Hawai`i such as national parks, Nature Conservancy preserves, and state natural area reserves, the first step in restoration is to fence and remove alien ungulates including feral goats, sheep, pigs, and cattle. Fencing and removing ungulates initiates recovery of native species. Feral pigs are a frequent to occasional disturbance source on residential forest lands. Stray cattle are a problem in some neighborhoods. Typically, ungulates uproot and trample vegetation and disturb soil for one night or are resident for a few days or weeks and return weeks or months later. Fragile shrub species such as ha`iwale are especially prone to pig digging because of their underground stems that account for much of the reproduction. Pigs will also hollow out tree ferns lying on the ground, not only killing or injuring the ferns but creating pools of standing water and mosquito breeding habitat. They will be attracted to sites where you do manual weed control, plant out native plants, and lay down mulch. Plantings of rare species are inherently vulnerable because of their numbers. The most effective way of dealing with feral pigs is to fence your property. However, fencing is very expensive, especially in light of the typical infrequent visitation pattern of pigs. Alternatives methods are trapping, snaring. or hunting. Often there are skilled pig controllers in each neighborhood. These are sometimes effective although some pigs are wary of traps and snares and it may not be possible to use dogs and firearms to hunt pigs in densely settled areas.

To fence or not to fence. The partial construction of this fence reflects the forest steward's indecisiveness about fencing and the cost of materials and construction. Pig activity on and off for nearly a year, along with the complete Ineffectiveness of trapping and snaring, provoked a decision to clear the fence lines of vegetation, pull a string line between the corner pins, purchase fence materials ($5,000 for 1,800 lineal feet!), and bring the posts and hog wire on-site. The absence of pig activity for the next six months rationalized taking a holiday from this project which will also require drilling to install many of the 200+ posts.

The frequency and intensity of pig disturbance in your backyard forest may not warrant installing an expensive fence. Some makai areas of Volcano with shallow soils and some of the more densely settled areas may have rather infrequent pig activity, or the cost of fencing could be simply prohibitive.

REMOVE INVASIVES: Control Weeds

Weed control is the heart and soul of most backyard restoration projects in Volcano. Restoration cannot proceed until the burden of invasive vegetation is removed and native plants can recover naturally or planting of natives becomes feasible. In many case, weed removal results in recovery of native understory species over several years or decades. Specific recipes for controlling weeds in Volcano are presented in the handout "A Manual for Controlling Volcano's Worst Weeds" available on the Volcano Community Association website (www.volcanocommunity.org).

Uprooting tibouchina. There are alternative, non-chemical control methods for many alien plants. Some may be impractical for landscape level restoration but appropriate for backyard forest restoration.

Treating the cut stump of a faya tree with herbicide. An alternative is to use a cane knife to frill and girdle the trunk near the base and apply herbicide. The latter results In the slow kill of a standing tree that will eventually decompose and fall. In wet forest, the opening created by a dying tree is invaded by tree ferns and other native plants. Faya can also be killed by cutting it as close to the ground as possible and covering it with tin foil or black plastic.

A RECOMMENDATION ON HERBICIDE USE: TRY TO MAKE IT A ONE-TIME THING

Sheet mulching. For small areas, sheet mulching may be effective in suppressing weeds. First, pull grass and other herbaceous weeds by hand to knock them back or treat them with herbicide and let the herbicide work for several months until the plants are brown. Then apply a layer of newspaper topped by a layer of cardboard. Then apply a layer of vegetative matter such as ginger shoots or banana leaves topped by dead tree fern fronds. The mulch will decompose in six to eight months, providing long-term weed suppression. Be aware that pigs may be attracted to your sheet mulching sites because of the earthworms.

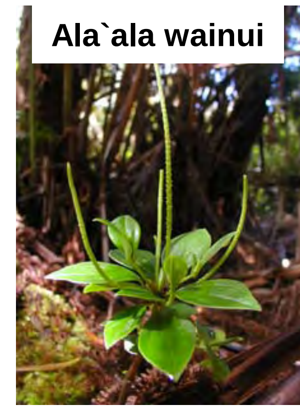
Plantings of natives. Cultural techniques (plantings) are the long-term alternative to herbicide use. In this case tibouchina was removed by hand leaving a thick layer of leaf litter in place. All the plants in the photo except for the tree in the middle of the shot were planted. The dense shade and litter that resulted has effectively controlled all weeds except for grass on the well-lighted margin of the plantings.

STEP 4. AUGMENT OR REINTRODUCE NATIVE SPECIES?

Himalaynginger prior to clearing from forest understory.

When Himalayan ginger was controlled on this lightly disturbed stand of old growth forest in Volcano Village many native plants were found in the restoration site buried in the ginger. These have started to spread naturally, along with native tree species on nurse logs or as epiphytes. The restoration managers have the option of accelerating this natural recovery by augmenting recovering species with plantings. They also have the option of increasing biological diversity by reintroducing species that could have been present historically such as additional species of ha`iwale and ala`ala wainui, among others.

Ha`iwale



Ala`ala wainui

Relictual patches of kanawao, `ie`ie, and pa`iniu in the understory which show signs of spreading after ginger control.

THE SHRUB AND FERN/HERB LAYER NEED THE MOST HELP

`Ōla`a Forest in Hawai`i Volcanoes National Park. Native shrubs, ferns, and herbs are common here after several decades of recovery following cattle and pig control and little exposure to stand-forming alien plants in the understory. Herbaceous understory ferns account for a significant portion of the native plant biodiversity in undisturbed forest.

Hawaiian rain forests have been called the "upside-down rainforest" because the vegetation layers with the greatest biological diversity are the shrub layer and the layer of ferns and herbs beneath the shrubs. Unfortunately these layers of vegetation near the forest floor tend to be inhabited by ungulates and weeds. As a result, cattle, feral pigs, and stand-forming invasive plants have had a disproportionate impact on the understory of Volcano's rain forest. Many of the common shrub species spread by shoots arising from underground creeping rhizomes. Fragile shoots and rhizomes close to the soil surface are readily damaged by pigs rooting or cattle trampling. The bottoms of forest pit craters with steep sides and no history of ungulate disturbance tend to have an abundance and diversity of understory shrubs, ferns, and herbs.

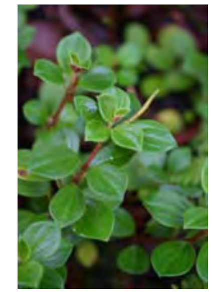
SOME OF THE MOST IMPORTANT CANDIDATE SHRUBS, FERNS, AND HERBS TO RESTORE TO THE UNDERSTORY

There are a number of understory shrub, fern, and herb species that may persist after decades of kahili ginger dominance. These are typically very common species in undisturbed or lightly disturbed areas. Because of their former abundance in undisturbed sites, they are good candidates for understory restoration. If successfully established and spreading, they may serve as matrix species in restoration. Unfortunately, many are difficult to propagate or propagules are not accessible to the public. See **A BEGINNER'S MANUAL FOR PROPAGATING VOLCANO'S NATIVE PLANTS** available on the Volcano Community Association website (www.volcanocommunity.org).

Kanawao. Very abundant In undisturbed sites. Can propagate from seed, air layers, and "snaplings."

Hō`i`o kula. Very abundant in undisturbed understory. No published propagation techniques. Mostly grows In inaccessible parks and preserves.

`Ala`alawainui. Several species of this herb in wet forest. Readily propagated by cuttings.



`Ōhā wai (*Clearmontia* spp). Terrestrial or epiphytic. Easy to propagate by seed and direct seeding.

Pi`ipi`ilau. Several species. No published propagation techniques.

Pa`iniu. Fairly common. Propagation by seeds and divisions.

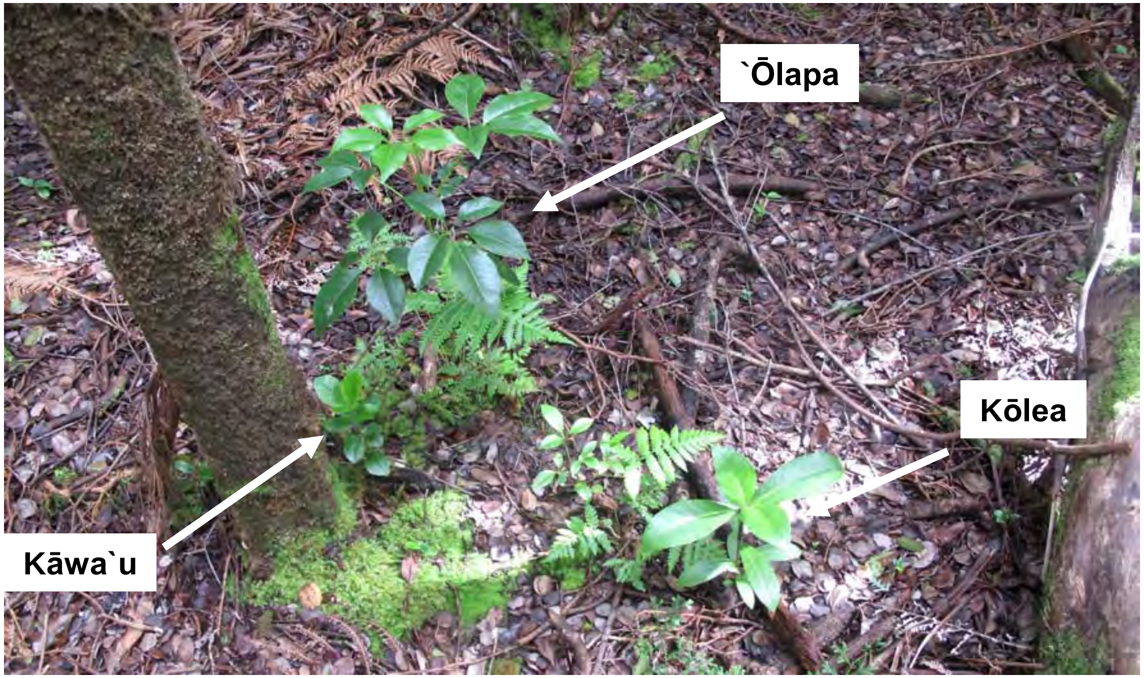
`Akōlea. Common fern in undisturbed forest in protected areas. Propagated by divisions?

Hai`wale. Several species. *Cyrtandra platyphylla* (illustrated here) is the most common one persisting in partly disturbed forest. Can be propagated from seed.

`Ie`ie. Formerly very abundant shrub/vine. Rarely sets seed. Can be propagated by cuttings.

Hoe a Maui. This is one of many epiphytic ferns inrain forest depleted by weed invasion. Difficult to successfully transplant epiphytes because of subtle microsite differences.

USUALLY, BUT NOT ALWAYS, NATIVE TREES RECOVER ON THEIR OWN AFTER WEED REMOVAL



Native tree seedlings establishing on their own seven years after Himalayan ginger removal.

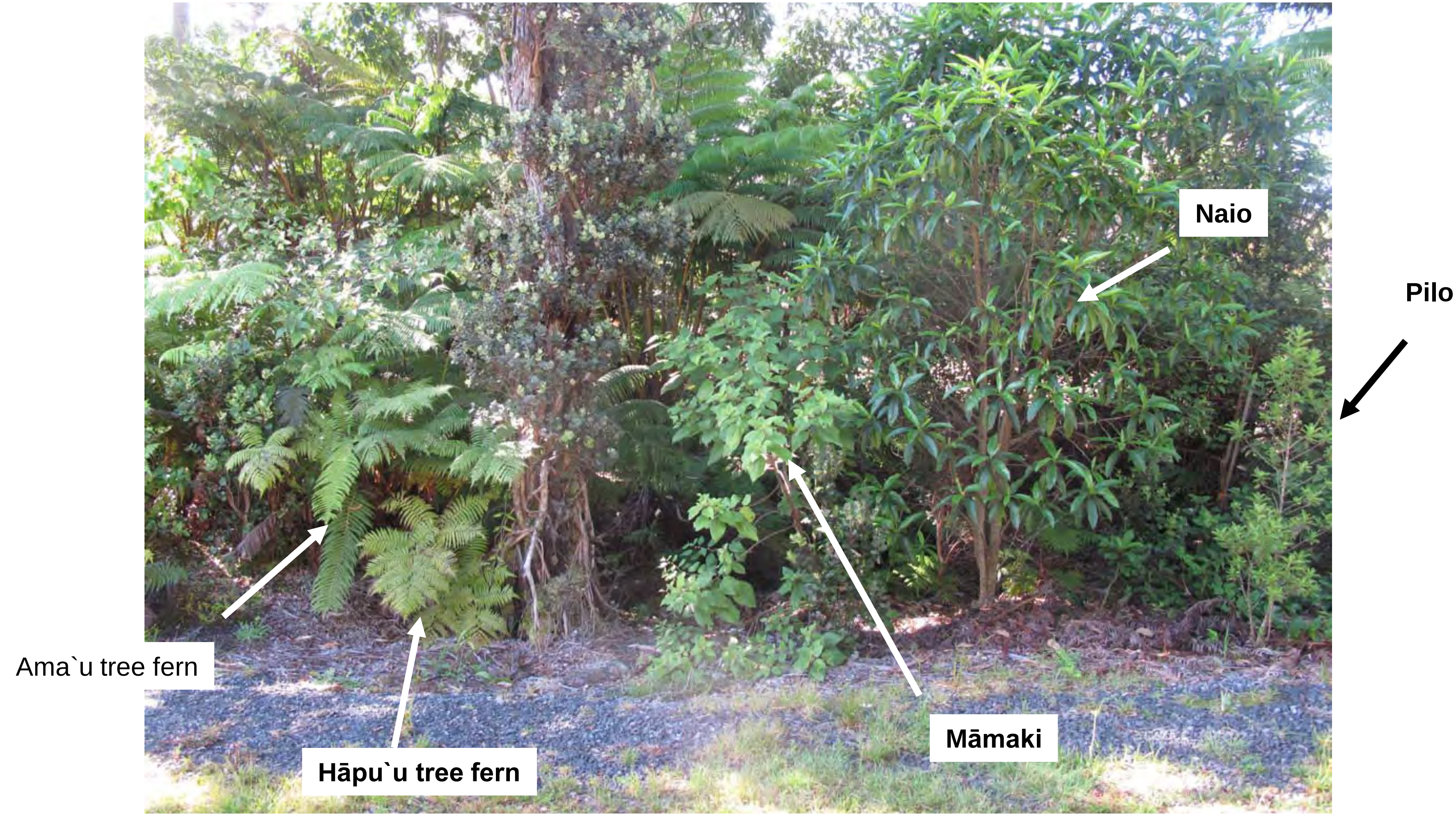
Typically, after removal of kahili ginger, tibouchina, and other stand-forming weed species, common native trees will become established from seed. In this frame, seedlings of the three tree species, ōlapa, kōlea, and kāwa`u, which grow into the forest canopy just below the upper reaches of `ōhi`a, are present. In some areas of Volcano such as portions of Mauna Loa Estates, native trees, particularly ōlapa, are largely absent from the canopy because of a history of cattle grazing in the forest. The three tree species above do not form seed banks and rely on seed rain or dispersal for seedling establishment. If there are no or few trees on site, dispersal from other areas, carried out by fruit-eating birds such as the native `Ōma`o or the introduced Northern Cardinal, is necessary. Unfortunately, frugivorus birds are not attracted to this kind of site because of the paucity of fruiting trees, their food resource. In this case, it may be necessary to begin establishment of native trees by transplanting. Fortunately, `ōlapa seedlings are plentiful in many forest areas of Volcano and readily transplanted. In fact, even large ōlapa, up to 10 feet tall can be successfully transplanted. Kōlea and kāwa`u, however, are much fussier species to transplant; smaller specimens are more likely to survive when transplanted. The small trees, pilo and manono, also typically become established on their own, after ginger removal, often from the seed bank.

AUGMENT OR REINTRODUCE NATIVE SPECIES? YES!

Bulldozed lot in Volcano surrounded by native forest.

There is little question about the role of outplantings in a restoration site like this. Restoration managers should start with fast-growing, light-requiring species such as `ama`u fern, māmaki, naio, naupaka kuahiwi, `uki, pilo, and others. These species will act as facilitators, creating shade and litter for other species to follow such as `ōha wai, and the native trees `ōlapa, kāwa`u, and kōlea. You can expect to find some natives naturally pioneering into the open, disturbed soil of this site, including `ōhi`a, `uki, māmaki, uluhe, and `ama`u and hāpu`u ferns. These can be transplanted to desired locations.

AN EXAMPLE OF SUCCESSFUL AUGMENTATION WITH PLANTINGS



A restoration site with successful plantings of fast-growing, shade-producing, light-loving or tolerant, weed-inhibiting native plants. These species are ideal for “starting from scratch” restoration with little or no overstory (this site had some scattered `ōhi`a trees). Native trees such as `ōlapa, kōlea, and kāwa`u can then be planted beneath this canopy in partial shade and light-requiring `ōhi`a can be planted on the edge of the restoration stands**.**

STEP 5. MONITOR, EVALUATE, AND MODIFY MANAGEMENT

One of the most neglected tasks in restoration is monitoring the results of restoration efforts. Monitoring can provide information about the effectiveness of restoration efforts and suggest new approaches and techniques. Conservation agencies and organizations use field techniques developed by plant ecologists to quantify vegetation. The easiest monitoring method for backyard forest restoration is photography. You can set up permanent photo stations in your restoration project. You can take photos prior to restoration and at intervals thereafter. If nothing else you should end up with proudly displayed before and after pictures. Another monitoring technique that is informative and not too labor intensive is to describe vegetation at different stages of restoration, including species lists, notes about abundance, and perceived trends.

Park resource managers quantify vegetation recovering after ginger removal by using a measuring tape to record plant cover along permanent transects first established before ginger was removed.

SOME RESTORATION ISSUES AND QUESTIONS

The following questions sometimes arise during backyard restoration projects in Volcano.

►Is koa an appropriate restoration species for Volcano?

►What good is uluhe?

►How can I get beyond uluhe?

►Where should I collect seed or get plants?

►What if I can only restore a small patch of forest?

►Can I plant a native species out of its current range?

►How can I plant non native ornamentals for color and do native forest restoration too?

►What about restoring wildlife species?

IS KOA AN APPROPRIATE SPECIES FOR ALL OF VOLCANO?

Koa is an ecologically appropriate species in parts of Volcano, based on current knowledge of its historical range. Koa occurred naturally in Volcano Village area, as documented historically by Joseph Rock in *Indigenous Trees of the Hawaiian Islands (*1913*)*. It also grows naturally in the Volcano Golf Course Subdivision. The only old growth koa in Volcano may be at the Volcano Art Center's Niaulani Forest in the village. There are also many large planted koa in the village. Koa does not occur naturally on Kīlauea volcano below Volcano Village. If your goal is to restore naturally occurring forest communities, then you should not use koa in backyard forest restoration in the lower elevation neighborhoods of Volcano. If you plant it there, pick a deep pocket of soil; it tends to grow poorly in the thin soils of Volcano makai. In all cases, it is prudent to plant koa away from structures and septic systems. It has prolific shallow penetrating roots. Koa also tends to drop large branches or uproots from the base. You will probably have to constantly remove the prolific root sprouts of koa. With the advent of ROD (Rapid `Ōhi`a Death) fungal disease, koa might be an effective surrogate species to plant in well-lighted areas where `ōhi`a has died off.

Mature koa with flowers. The naturally occurring koa in Puna and Ka`ū have broad "leaves" (actually plyllodes, expanded leaf bases). Many koa from other islands have been planted on the Big Island. These usually have narrower, more curved phyllodes. Use seeds from koa found as close to your restoration site as possible to get locally adapted genetic material.

WHAT GOOD IS ULUHE?

Patch of uluhe in a young `ōhi`a forest.

Uluhe is native to Hawai`i and is naturally abundant in younger rain forest. It is therefore considered an early successional species. As a forest ages, uluhe is gradually replaced by tree ferns, mid canopy trees, and other native species which eventually grow up through small gaps or thin spots in the uluhe mat. Under natural conditions, the only time uluhe "takes over" is early in succession or late in succession during a wave of dieback in ōhi`a. If you observe closely, you will notice that uluhe does not overtop `ōhi`a, even though it may grow in dense patches; it invariably stops short of covering the higher branches of the trees. In the Hawaiian forest, it provides excellent suppression of invasive species while inhibiting but not precluding the eventual succession of native rain forest plants found in the older, more biodiverse rain forests of Volcano. Uluhe is called the healer fern in some parts of its natural range outside Hawai`i because it invades disturbed sites such as landslides. Uluhe is most abundant in the neighborhoods of Volcano makai, largely because it is acting as the "healer" fern there, in those forests recovering after the termination of cattle grazing in the 1960s when the subdivisions were established or in other sites in Volcano where forests have been logged. Uluhe is the only vegetation that acts as a fire fuel in Volcano rain forests. It will carry the spread of fire after a couple of weeks of drought, especially if combined with high winds. Uluhe should be cleared from around structures to address this hazardous fuel problem.

HOW CAN SUCCESSION IN ULUHE BE ACCELERATED WITHOUT STIMULATING THE ESTABLISHMENT OF INVASIVE PLANTS?

Patch of uluhe invading a gap created by road construction.

Patch of uluhe in a forest recovering after removal of logging and kahili ginger. Uluhe invaded this forest when it was logged In the 1920’s. The uluhe patch is being replaced by the development of the tree canopy and the establishment and growth of tree ferns, stimulated by the removal of ginger.

Backyard forest restoration managers, desiring greater biological diversity and access to the forest, may be tempted to accelerate plant succession by thinning out or removing uluhe stands. This seems perfectly appropriate in Volcano where most uluhe is due to previous disturbance. When undertaking this project, backyard restoration managers should realize that uluhe not only inhibits native plants, it also suppresses invasives plants. You can expect that removing large patches of uluhe may result in a grass invasion. Uluhe grows best at higher levels of light, an ideal habitat for invading alien grasses. The most ecologically effective approach to managing uluhe is incremental. Remove it in small patches, to minimize light penetration to the forest floor and allow native plants to establish in the small gaps created by uluhe removal, rather than grass. It is best to clear uluhe by hand and leave the dead fronds as mulch to inhibit grass invasion. Clearing with machinery not only removes the littler/mulch but disturbs the soil and this favors weed invasion too. Usually there are no weed problems following removal of very small patches of uluhe. These tend to be on their way out anyway in shady forest environments. If larger patches of uluhe are removed, then be prepared to install native plantings in the new gaps to reduce grass invasion. Some of the best are hāpu`u, māmaki, pilo, and `ōha wai which grow rapidly in well lighted sites. Under natural conditions, tree ferns and subcanopy native trees, layered under an `ōhia canopy, eventually replace uluhe over time. For example, there are only three minute patches of uluhe on the edge of the 300 year old, ` ōhi`a/hāpu`u forest at Niaulani.

WHAT IF I CAN RESTORE ONLY A SMALL PATCH OF FOREST?

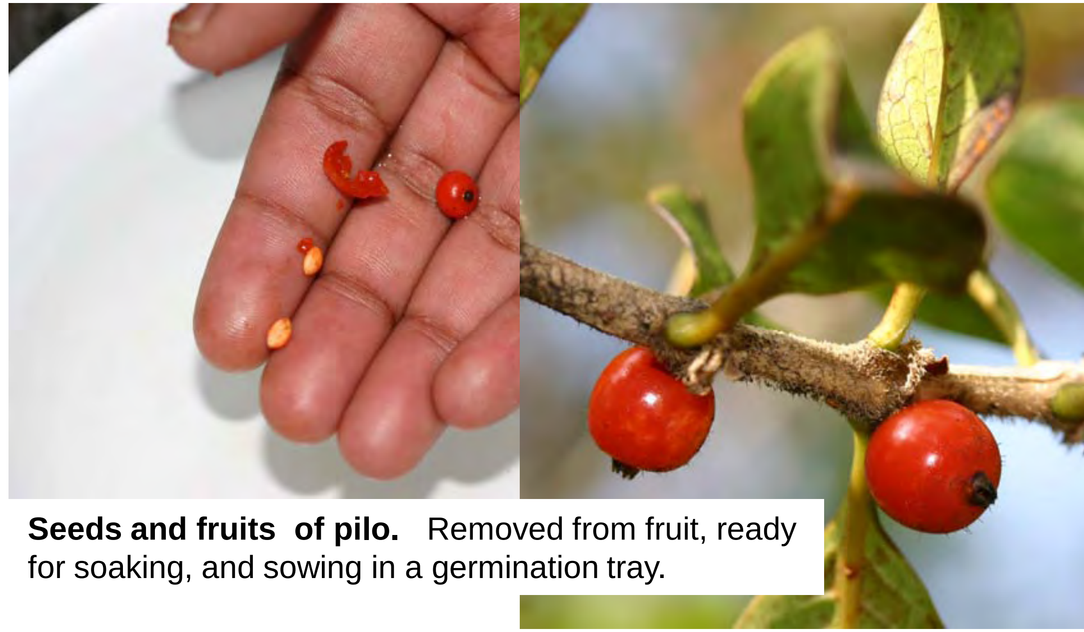
An approximately 600 square foot patch of forest under restoration in an old agricultural field and now between two building sites, March, 2008.

Expansion of this restoration stand through natural growth and establishment, June, 2011.

Small forest fragments are not sustainable. The populations or plants and animals in them are small and easily extinguished by chance demographic/reproductive events or chance environmental events. For example, by chance you may have just one individual or an uncommon plant and it requires cross-pollination. Also, by chance, there may be very strong winds and your only individual of the small tree kōlea snaps off at the base and perishes. Bigger is better in terms of sustainability of native forest. Another drawback about small patches is that there is a high ratio of edge to interior so that there is a lot of light penetrating the restoration kīpuka so that light-loving weedy species such as alien grasses can get established on the forest margin. One tactic to reduce light on the edge of a small restoration site is to plant small tree ferns on the forest edge. What you do not see in this photograph is the several acre stand of forest 100 feet away that is also being restored and the over 50 acres of semi-native forest with an intact canopy within one-quarter mile. There may be gaps in the forest but the other fragments are close enough for plants and animals to disperse or move from one patch to the other. In an ideal world, all the patches can be restored and expanded, increasing connectivity and the diversity of the sites. Small restored patches can serve as models and inspiration for restoring larger forest stands. In addition, if many of us restore our small vestiges of native forest, this will enhance connectivity and available habitat for native birds and invertebrates.

WHERE SHOULD I COLLECT SEEDS OR GET PLANTS?

Let's assume you want to plant an appropriate species for your restoration project. This means that it is a constituent of the naturally occurring community you are restoring. For example, the pilo for much of windward Volcano is *Coprosma ochracea*. It is a common plant and you may find growing specimens at your restoration site or neighboring lands. Now, where should you collect propagules of this species from? Ideally they should come from your local area. In many cases in which the genetics and adaptiveness of local populations has been studied, it has been found that there is genetic variation of a single species across a landscape. Common garden experiments (growing plants from different areas under the same conditions at the same site) indicate that often the locally adapted plants grow best in the sites in which they occur. The short answer, then, is that you should collect propagules from local sources. That being said, you should try to avoid taking all your propagules from one source or plant, in spite of the convenience or desired qualities of that individual. You should collect propagules from as many locally adapted individuals as possible to maximize genetic diversity and the ability of your plantings to deal with environmental stresses that will inevitably occur.



Seeds and fruits of pilo. Removed from fruit, ready for soaking, and sowing in a germination tray.

Trays of pilo seedlings ready for outplanting. These seedlings were salvaged from a neighbors yard about one-quarter mile from the target restoration site. Pilo should also be collected from other local sources to increase genetic variability and long term fitness.

CAN I PLANT A NATIVE SPECIES OUT OF ITS RANGE?

You can often plant a native species considerably out of its range and it will thrive. For example, ma`o hua hele is planted in landscaping in wet forest in Puna and does well, particularly if it is planted in well drained soil in full sunlight. It grows particularly vigorously in the Volcano Golf Course subdivision. I know a population of beach `akai and the prostrate coastal form of naio in windward Volcano. The same neighbor also has native pili grass, which occurs naturally in lowland areas of Hawai`i. It is growing vigorously and flowering. If they are planted out of their range they are obviously not essential elements of a restoration project; they are not constituents of a naturally occurring community in your area. Often these plants are highly attractive and make excellent native landscaping plants.

Ma`o Hau Hele (*Hibiscus brackenridgei), a* very rare species in the wild and found naturally in leeward, dry lowland locations.

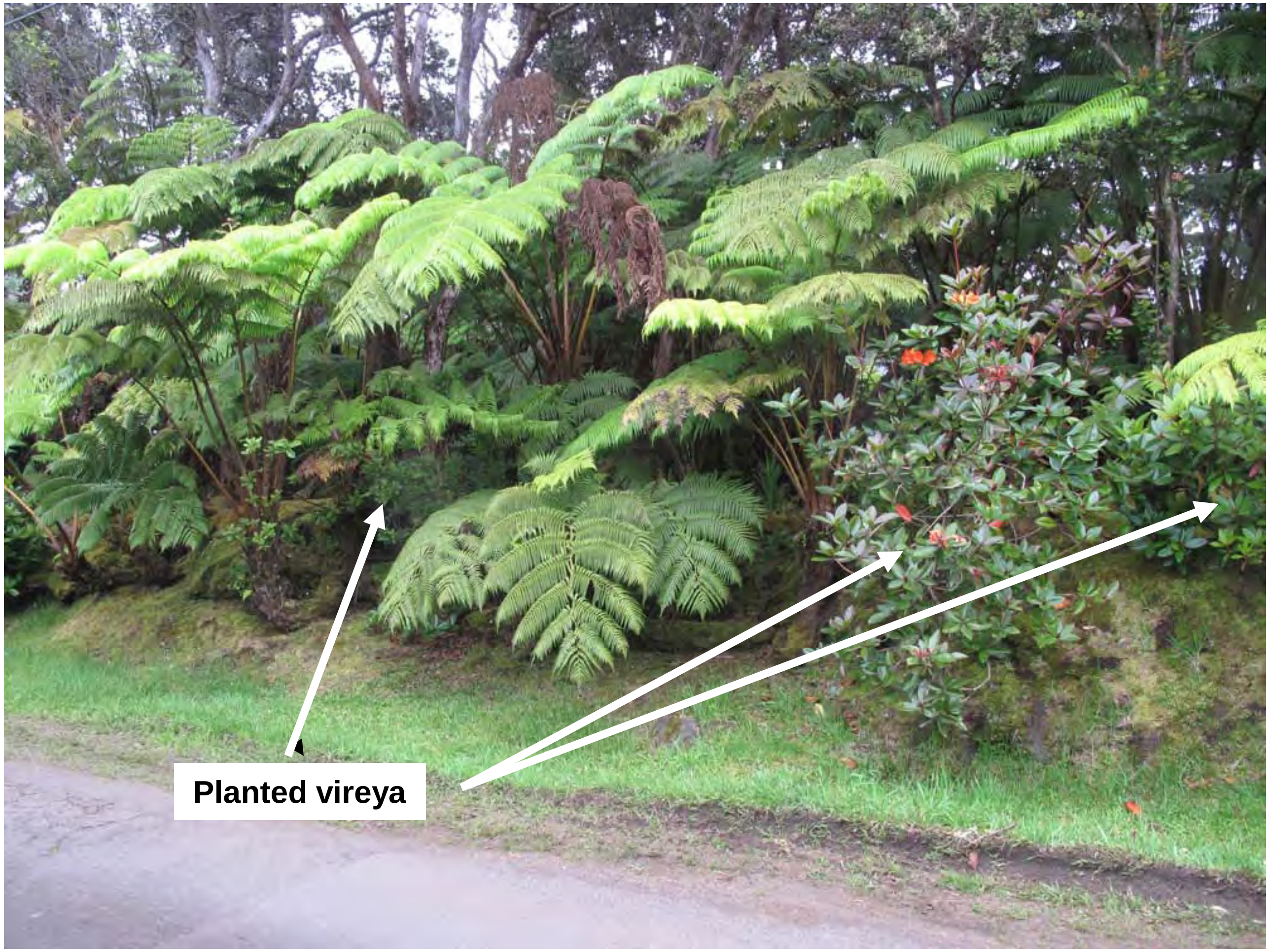
NATIVE PLANT LANDSCAPING—THE NEXT BEST THING

Objectives for using native plants can vary, and your objectives may be a large factor in species selection and planting strategies. You may simply want to landscape with native plants, placing them into your garden, up against your house, as islands in a lawn or artificial cinder field, or as vegetative screening from the road or neighbors. One positive result of landscaping with native plants is that it creates seed sources.

Mix of planted ma`o hau hele and other natives such as a`a`li`i found naturally in this local area of the Volcano Golf Course Subdivision

Hedge of ma`o hau hele and māmaki planted as a privacy screen in the Volcano Golf Course subdivision.

HOW CAN I PLANT NON-NATIVE ORNAMENTALS FOR COLOR AND DO NATIVE FOREST RESTORATION TOO?



Non-native but non-invasive vireya shrub planted on the edge of a native forest stand undergoing restoration. The colorful ornamental was planted only along the roadside in a visible location. Himalayan ginger and tibouchina were removed from the interior of the forest and restoration is slowly occurring there through natural recovery.

WHAT ABOUT RESTORING WILDLIFE SPECIES?

`Apapane foraging for insects on a young koa tree.

"Build it and they will come." Create habitat for wildlife and they may utilize it for food, shelter, and nesting. Wildlife evolved in natural communities, the recurring, self-perpetuating assemblages of species. All of the patches of restored forest create habitat. These patches are especially valuable in Volcano which serves as a bridge between the national park to the west and other protected and managed forest to the east. There is one qualification to this simple formula. You may create native wildlife habitat but it may not become occupied. Hawai`i's native forest birds are limited by a number of factors including predators and especially introduced avian diseases. You may build a native forest in Volcano but do not expect malaria-sensitive `I`iwi to take up residence (although there have been more sightings of `I`iwi in Volcano).

RESTORATION AFTER RAPID `ŌHI`A DEATH

Volcano residents should be prepared with a forest restoration strategy in the event the Rapid `Ōhi`a Death (ROD) fungus wipes out most of the `ōhi`a trees in the community. ROD is a new, highly lethal disease attacking and killing `ōhi`a on Hawai`i Island. ROD-killed trees are now highly scattered in the Volcano community but increasing in number. We do not know yet if ROD will be as devastating and widespread in higher elevation forests as it is in lower Puna. It may spread more slowly because of the cooler temperatures of the Volcano area. In any case, widespread ROD presents another daunting challenge to forest restoration. Bad enough to have native understory almost completely replaced by invasive plants such as Himalayan ginger and strawberry guava; worse still would be to lose our main canopy tree and the ecological keystone of species of Hawaiian rainforest. With the loss of canopy trees, invading species will have an even freer hand to expand. Ultimately, native ecosystems will disappear in Hawai`i without `ōhi`a pioneering on new lava flows and ash deposits to begin the establishment of naïve plant communities. Most of Volcano is located on lava flows about 550 years old or ash/gravel deposits about 300 years old. However, in the short-term we can try to maintain native dominated rainforest stands by carrying out restoration both before and after ROD takes its toll. I offer some suggestions below for doing this.

**Stand of mostly dead ‘ōhi`a in lower Puna, killed by the ROD fungus.** In lower Puna, where ROD was first noticed in 2012, it has killed up to 90% of the `ōhi`a trees in some infected stands. ROD has now caused significant mortality in over 75,000 acres of `ōhi`a forest on Hawai`i Island and is spreading rapidly on both the windward and leeward sides of the Island. Researchers are investigating whether any `ōhi`a trees have genetic resistance to the disease. Explore this website (https://cms.ctahr.hawaii.edu/rod/Home.aspx) for details about the disease, research being conducted, what you can do to slow its spread, and what you can do about ROD killed trees on your property.

The first step in post-ROD restoration actually takes place pre-ROD, before the `ōhi`a canopy has begun to die off. What you need to do is control understory invasive plants, especially Himalayan ginger, strawberry guava, tibouchina, Himalayan raspberry, blackberry, faya tree, spreading selaginella, knotweed, and other invasive species. The extra light reaching the understory after the decline of the `ōhi`a canopy, and the loss of competing `ōhi`a roots may stimulate invasive species to spread. For control methods and images of other invsive plants, see ***A MANUAL FOR CONTROLLING VOLCANO'S WORST WEEDS***.

Strawberry guava

Tibouchina

Himalayan raspberry

Blackberry

Faya tree

Spreading Selaginella

Knotweed

Photos of tibuchina, strawberry guava, Himalayan raspberry, blackberry, and faya tree above are courtesy of Forest and Kim Starr

Controlling Himalayan ginger may be one of the most important tactics in a pre-ROD strategy. It is true that ginger is often very dense and this shade-loving may not spread following the loss of the `ōhi`a canopy. However, ginger removal stimulates the establishment of native tree seedlings, especially `ōlapa, kōlea lau nui, kāwa`u, pilo, manono, and other trees, as well as tree ferns. Encouraging `ōlapa, kōlea lau nui, kāwa`u, secondary canopy tree species, capable of growing just beneath the emergent `ōhi`a canopy, may help establish a surrogate tree canopy above the tree ferns, replacing the loss of the `ōhi`a canopy above. This is especially true if their density and abundance are enhanced by the forest stewards.

A dense, single species understory of Himalayan ginger. Ginger displaces native understory shrubs, ferns, and herbs and prevents overstory trees from regenerating. A stand like this, found in many parts of Volcano is a forest without a future, unless control is undertaken. Notice how dense the tree ferns are in this image? You may need to do some selective thinning of hāpu`u to create some light gaps for natural recruitment or planting of tree seedlings. See pp. 11-12 in ***A BEGINNER'S GUIDE TO PROPAGATING NATIVE PLANTS OF VOLCANO****.* for recommendation on how to transplant larger tree ferns.

Seedlings of `ōlapa, kāwa`u, and kōlea lau nui These seedlings became established In this site after Himalayan ginger was removed with herbicides about five years previously. The most abundant seedlings after ginger control are often those of `ōlapa, dense enough that they will eventually self-thin. The surplus of `ōlapa and other native tree seedlings provides opportunities for seedlings to other areas on-site or transplanting them into pots, growing them in a nursery, and then planting them out in areas with fewer tree seedlings. Of course, you can also germinate seeds and grow them in a nursery for eventual outplanting. Notice the resprouting ginger plant in the upper left corner of the image, a reminder to the forest steward that it is time for a follow-up control session.

**Thick cluster of small hāpu`u tree ferns established after Himalayan ginger removal.** Tree ferns often establish in dense patches with the inevitable fate of self-thinning. You can do the thinning and transplant small hāpu`u into areas where tree ferns are sparse. Encouraging tree fern establishment may help compensate for the loss of shade when `ōhi`a disappear.

**Four, 30 foot tall `ōlapa trees planted 10 years previously.** `Ōlapa is a fast-growing tree and the crowns of these individuals are now well established in the secondary tree canopy layer, above the tree ferns and below the emergent `ōhi`a canopy. They are forming a small, nearly closed canopy patch. Fast growth and a life above the tree fern layer make `ōlapa an ideal surrogate canopy tree species, if `ōhi`a is lost to ROD. But, do not forget about the other secondary canopy trees. For example, kāwa`u's fast growth rate makes it a good canopy for the post-ROD tree canopy. In some young rainforests it grows into the `ōhi`a canopy.

Keep in mind that this post-ROD restoration strategy and tactics are theoretical recommendations, based mostly on the ecology of the species involved; no one has conducted post-ROD restoration in Hawaiian rainforest. Other and more creative empirically-based strategies and tactics may arise from trial restoration efforts. The recommendations are also rather conservative. Basically, the goal of the suggested strategy is to enhance the secondary tree canopy, especially with the fast-growing \`ōlapa. The most radical suggestion is the use of koa as an emergent canopy species in areas where koa is not known to occur historically in Volcano rainforest. The recommendations above also are given in a context of rainforest with a significant tree fern canopy. Some ideas for restoration in uluhe dominated rainforest are presented below.

A 50 foot tall koa tree planted 10 years previously. It was planted as a seedling in a well-lighted gap between then smaller planted tree ferns. Koa is found naturally in the emergent \`ōhi\`a canopy in just a few areas of Volcano. However, it grows well when planted in other areas of Volcano, provided there is sufficient soil. Its rapid growth and presence in the emergent \`ōhi\`a canopy make it a good candidate as a surrogate overstory species. As a bonus, after about 4-5 years a vigorously growing, planted koa will spread by root sprouts in big light gaps or on the edge of the forest.

Uluhe rainforest. The main pre- and post-ROD restoration strategy in uluhe dominated rainforest is to speed up succession from uluhe to tree fern rainforest with plantings of hāpu\`u and \`ama\`u tree ferns and secondary canopy tree species, \`ōlapa, kāwa\`u, and kōlea lau nui, as well as trees that grow in the tree fern layer, e.g., pilo. These may have to come from nursery stock or ones you grow at home. Unfortunately, koa may not be a useful surrogate upper canopy tree. Koa does not thrive on the thin soils of many of the uluhe dominated areas of Volcano-makai but you may have some success if you carefully select microsites with deeper soil, if present.

RESTORATION

WE CAN DO IT!!

RESTORATION AND ECOLOGY TERMS EXPLAINED

Alien species: non-native**;** arrived in Hawai`i with the aid of man; deliberately or accidentally introduced**.**
Biomass: the total quantity of living matter in a given area or ecosystem.
Climax: the culminating steady state stage of plant succession in a given ecosystem. Climax communities tend toward maturity because of having attained harmony with their surroundings through years of experimentation and adaptation. Many modern ecologists think there is no such thing as climax ecosystems, that there is always change and that different climax communities may be reached in the same environment. See Succession.
Community: populations of all organisms living together in an ecosystem. Community may also refer more specifically to a particular assemblage of populations that repeats itself over the landscape in similar habitats, for example, the `Ōhi`a/hapu`u rain forest.
Ecology: from the Greek *oikos* (household) and *logos* (study): the study of interrelationships between organisms and their environment.
Ecosystem: a biotic community and its surroundings, part inorganic (abiotic) and part organic (biotic), the latter including producers, consumers, and decomposers.
Establish: **s**uccessfully growing from a seed, spore, or other propagule of a plant.
Facilitator: a species encouraged to spread by restoration or planted that modifies the habitat and thus facilitates the establishment of other plant species.
Invasive species: alien species that spread on their own.
Matrix species: a species encouraged in restoration or planted to become abundant or potentially a facilitating or an ecologically controlling species.
Monotypic/Monodominant: highly simplified stands of vegetation dominated almost and exclusively by one species.
Native Species: arrived in Hawai`i without the aid of humans and adapted and evolved here.
Naturally Occurring: occurring in nature through natural regeneration or spread.
Overstory: higher layers of vegetation in a forest.
Recruitment: successful establishment of plants from one life stage to another or from one size class to another, e.g., seedling recruitment is the successful establishment of seedlings from seed.
Regeneration: replacement of plant species by seedlings or by vegetative spread. Reproduction is formation of seeds or propagules and is the precursor to regeneration.
Replacement community: an artificial assemblage or community, not found in nature but developed by the restoration manager based on knowledge of plants to have a chance of being self-sustaining. Replacement communities are developed if there are no natural communities available as reference ecosystems.
Restoration: ecological restoration is the process of assisting the recovery of a native ecosystem that has been degraded, damaged, or destroyed**.**
ROD: Rapid `Ōhi`a Death. A new, highly leathal fungal disease of `ōhi`a.
Stratum/strata (pl): a layer of vegetation.
Structure: as used here, the spatial arrangement of an ecosystem. e.g., restored Hawaiian rain forests typically have an overstory of `ōhi`a with a subcanopy of other native trees, a layer of tree ferns and native shrubs, and forest floor layers of herbs and ferns..
Succession: the gradual replacement of one plant community by another. **Primary succession** occurs on lava flows, behind retreating glaciers, or on landslides. **Secondary succession** occurs in sites in which some vegetation remains such as after a fire. Plants are called **early successional** if they occur early in succession and **late successional** if they occur late on a successional trajectory.
Successional trajectory: a pathway, sometimes predictable, sometime affected by random environmental elements, of replacement of one plant and animal community by another.
Understory: Lower layers of vegetation in a forest.