6.0 NATIVE REVEGETATION

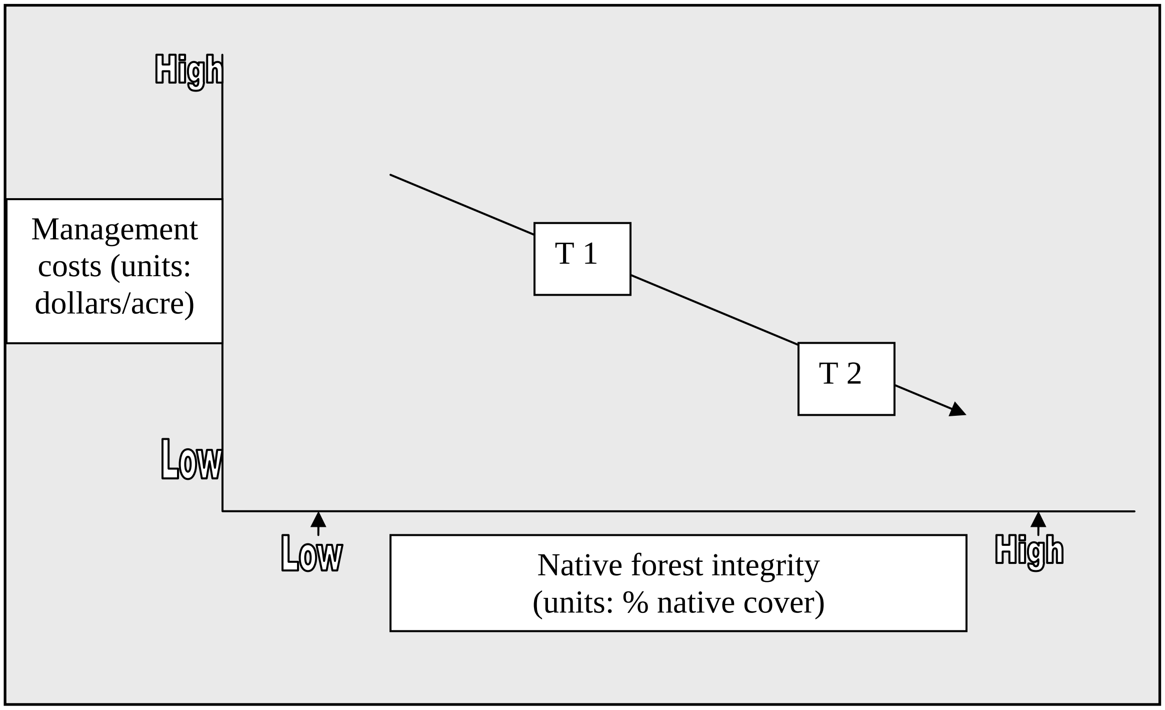
Photopoints over two year period. From solid *Clidemia hirta* to an endangered species garden. Kaluaa Gulch, Honouliuli Preserve, Oahu

6.1 INTRODUCTION

As emphasized in the chapter on site planning, restoration sites should ideally require only minimal levels of effort to bring native areas back to being fully intact. This ideal is not so much additive restoration, but rather subtractive restoration. Ungulates and low level infestations of weeds are removed and the forest primarily heals itself. Protecting and restoring these relatively intact sites should be a priority. Subtractive restoration efforts are generally a wiser use of scarce monetary resources for reasons outlined in the restoration site planning chapter. Allowing the native forest to regenerate itself native is one method of revegetation.

However, additive restoration efforts are often necessary for mesic forest areas given their high level of decay. In many areas, only the native canopy remains with alien weeds such as Koster's curse (*Clidemia hirta*) dominating the understory. Given the right weed control and planting strategies, even lower quality sites can be restored to largely intact native forests over time.

For these high intensity management areas, planting is used following weed removal. This chapter highlights various revegetation strategies, and lays out numerous considerations regarding more technical aspects of restoration such as planting site selection, site preparation, and planting techniques. The following graph illustrates the costs associated with restoration at various levels of management intensity.

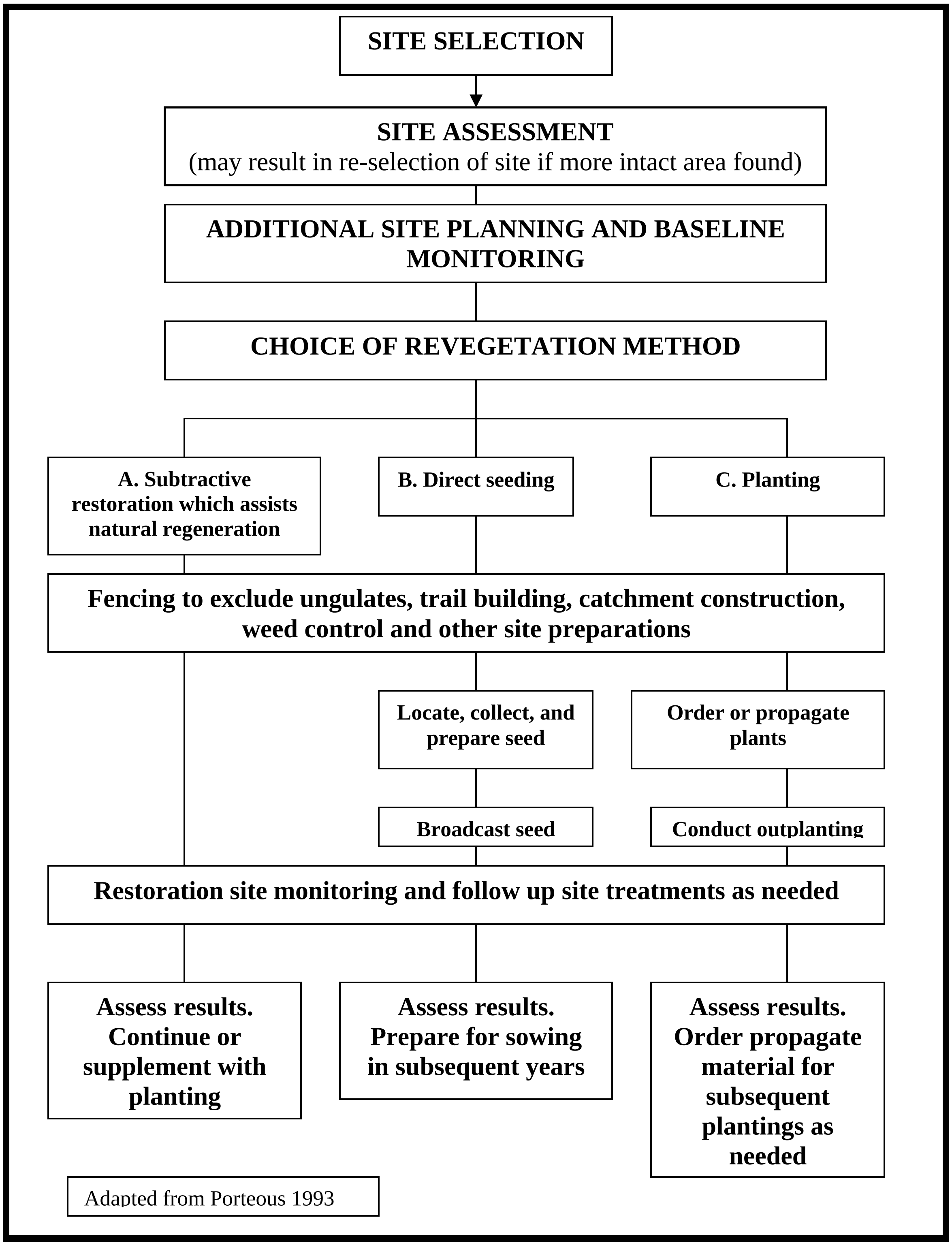


At the beginning of site management (Time 1), management costs are moderately high given the fairly degraded condition of a restoration site. As management efforts result in native canopy and understory closure, associated weed control and planting costs should drop (Time 2). Management costs will never be zero given the need for ongoing fence maintenance and vigilant monitoring for newly established weed populations.

8.1 PLANNING

Since restoration projects often span many years, the success or failure of a restoration site hinges on the level of thought and planning brought to an area. Proper planning will not only secure adequate financial resources, but will also ensure that other important aspects are not overlooked (Porteous 1993).

See also Chapter 2 on Restoration Site Planning for a more in depth discussion on site planning. Generally, your revegetation strategy will implement the goals for your restoration site. One way of determining goals is to ask what one is hoping to accomplish. The purpose of restoring an area should be made explicit from the onset. From those goals, specific objectives are generated dictating the methods of revegetation. Objectives detail how the area will be restored. In other words, objectives are the strategies used to implement the goals. For example, species selection, plant sizes, distribution patterns, and the method of planting are all important planting strategies. Decisions regarding these mechanics of restoration should flow directly from the goals and objectives laid out in a management or restoration site plan for an area. **Appendix 6A** is an example of a restoration site plan which outlines the overall goals for a site at Honouliuli Preserve and the restoration objectives over a 3 year time period. The following flow diagram illustrates the essential stages and considerations of a revegetation program (Porteous 1993)



One often overlooked planning decision is the distribution of plantings. If one observes an intact native forest, plant species are commonly not distributed evenly. As with most vegetative and animal communities, plant species are instead naturally distributed across areas, regions, and landscapes in patches. Distributing plantings according to natural distribution patterns should bolster project success and increase the authenticity of restoration efforts.

6.2 RECORD KEEPING

The importance of recording as much information as possible about all aspects of a revegetation program cannot be overstated. This information will not only assist managers in their assessments of restoration efforts, it will also assist others who are embarking on similar efforts The following list highlights important aspects that need to be recorded in an organized database (Porteous 1993).

a) Restoration site assessment (see also **Appendices 6A** and **6B** for examples of a restoration site plan and a restoration site assessment form)
   - Site location
   - Size
   - Protected status, ownership
   - Goal of restoration
   - Baseline vegetative cover and composition (i.e. before management)
   - Surrounding vegetation, seed sources
   - Surrounding threats
   - Soil type
   - Rainfall levels
   - Aspect and wind exposure

b) Plant Material
   - Species and sources of propagules
   - Plant size and container size if using container grown plants
   - Condition of plants (e.g. healthy, moderate, poor)

c) Planting
  - Site preparations (weeds controlled, herbicides rates and quantities used, fencing etc.)
  - Planting dates
  - Weather and soil conditions
  - Treatment (e.g. fertilizers used and application rates)
  - Labor effort required (e.g. person hours)
  - Planting method (augered holes, hand dug dibble holes)

d) Follow-up maintenance requirements
  - Weed, rodent, ungulate control etc.
  - Labor required (person/hours)

e) Monitoring
  - Assessing success of the project
  - Survival rates after 12, 18, and 24 months
  - Lesson learned for the future

(Porteous 1993)

6.3 SELECTING THE REVEGETATION METHOD

There are three main methods to revegetate an area. A combination of the methods is often used given the levels of intactness of restoration sites.

1) Assisting natural regeneration.
2) Direct seeding.
3) Planting.

One could argue that a fourth method also works in Hawaii, establishing a nurse crop. A nurse crop is a temporary cover that eventually dies out on its own as trees and shrubs overtop it over time. As most native plants are fairly slow growing, the value of using a native nurse crop for forest restoration may be fairly limited in Hawaii. Non-native trees do harbor significant native diversity beneath their canopies (e.g. Sugi pines, Kukui trees). The utility of these non-natives for restoration (and other commercially valuable exotic trees) should be further explored in test plots. As being tried on Kahoolawe and other areas, sowing or planting shrubby native 'weeds' such as *Bidens* sp., *Chenopodium* sp., *Rumex* sp., and *Dodonaea* sp. can help to quickly stabilize sunny, disturbed areas, essentially copying natural native succession patterns. After these species are established at a site, canopy reaching elements can then be reintroduced to extend or re-establish forest cover.

6.3.1 ASSISTING NATURAL REGENERATION

As mentioned previously, this method of revegetation is essentially a subtractive approach to restoration. Practiced for decades in Hawaii by the State, National Park Service, National Wildlife Refuge Service, The Nature Conservancy and more recently by the U.S. Army and National Guard for their military training areas, natural regeneration is the most cost-effective form of restoration. Sometimes called threat abatement resource management or even ‘passive restoration’ (although ungulate removal is never passive), areas damaged by ungulates are naturally restored to their former state due to the resiliency of a relatively intact forest.

For success, this method requires:

a) Sufficient adjacent seed sources of quick-growing colonizing species.
b) An absence of grazing animals, feral pigs, and control of other animal pests.
c) Control of competing grasses and weeds.
d) Absence of catastrophic fires. (Porteous 1993)

Protection of the largest, most viable, functioning native forest systems remains one of the highest priorities for Hawaii’s resource managers. Unfortunately, as noted in the introduction to this manual, mesic forests suffer from a lack of more intensive management given their status as largely non-viable native forests as seen from a 100-500 year future time frame. Nonetheless, as with native upper elevation wet forest areas, mesic forest recovery following ungulate removal is often just as dramatic, giving hope to the linkage of mesic forest fragments within the larger landscape.

6.3.2 DIRECT SEEDING

This section is adapted from: Native Forest Restoration (Porteous 1993).

Direct seeding is a relatively cheap supplement to hand planting native trees and shrubs. For success, this method requires:

- Sufficiently large quantities of viable seed
- Right seasonal conditions for germination and seedling establishment
- Control of competing weeds (especially grasses)

Direct seeding involves the broadcasting or placing of seed directly into a prepared site suitable for the sown species. Because conditions are inevitably less suited to germination and seedling establishment than in a nursery situation, only a small percentage of seeds will 'take.' As with many seeds, especially larger ones, there is the risk of damage by insects, birds, rodents, and drying out. However, where seed material is plentiful and easily brought to a site, direct seeding can be a useful method for establishing a quick cover or for longer term tree establishment.

The most critical factors in direct seeding are the elimination of competing plants, and the maintenance of a climate suitable for seed germination and growth. The ground can be prepared by spraying with a knockdown herbicide, ripping or plowing. Good seed to soil contact and favorable temperature and soil moisture levels are essential for germination.

Finding large quantities of seed material is often problematic when collecting from the wild. Several agencies and nursery companies in Hawaii obtain their seeds from planter boxes and farmed fields of native species grown specifically for seed stock production.

Suitable species for direct seeding of mesic areas include:

Shrubs:

Bidens sp.
Dodonaea viscosa
Chenopodium oahuense
Dubautia ssp.
Rumex albescens

Trees:

Acacia koa
Metrosideros polymorpha
Myoporum sandwicense
*Myrsine*sp.
Pisonia ssp.
Sophora chrysophylla
Tetraplasandra sp.

The preceding species were chosen based on high seed production rates and observations of high germination and growth rates in protected mesic forest areas as well as in nursery conditions.

6.3.3 PLANTING

Planting as a method of revegetation is what commonly comes to mind when the term forest restoration is used. Hawaii has about a 70 year history of reforestation. Mostly non-native species were used to reforest watershed areas beginning around the 1930's. The following sections detail the issues surrounding planting as a method of revegetation. The following chapter on plant propagation discusses the issues of growing native plants for restoration purposes.

6.4 PLANTING SITE SELECTION

If you are unsure if a plant will thrive in its new home or are concerned about biological pollution of gene pools in the wild, do some research first. A plant in the wrong home may be able to stay alive in an inappropriate environment, but it will not thrive. Test trial plantings are a good idea if you are uncertain about the habitat requirements for a particular species.

6.4.1 IMPORTANT CONSIDERATIONS ABOUT SELECTING PLANTING SITES

- Think like a plant. Carefully observe where your desired plants naturally thrive and under what environmental conditions and match planting sites appropriately. Pay particular attention to where seedlings of your target species are germinating and surviving naturally. Also note the general distribution pattern of native species. The future composition of a forest can be determined by observing the age structure and seedling density of constituent species. Reference sites of intact native forest areas contain key information about forest composition, succession patterns, resiliency, soil composition, moisture gradients etc. Applying the lessons learned from intact areas to areas under restoration is a sound strategy for success.

- Microsites (the actual immediate growing environment) often determine the success or failure of plantings. For example, low spots naturally collect water and debris and can have higher humidity, cooler temperatures, and more nutrients than nearby raised, exposed areas. Soils along ridgelines and crestlines typically have had certain nutrients stripped away by weathering. Large trees with shallow root systems and grass often consume all the available surface moisture in their immediate area. However, other large tree species actually assist with surface moisture levels at night through a process of deep water uplift whereby root systems deposit excess water near the soil surface. Some species cannot tolerate growing immediately next to another tree; other shrub species may actually prefer growing at the base of large trees in deep shade. Again, careful observations of the life strategies of native plants will inform planting decisions and increase plant survival rates.

- Accessibility of planting sites is critical to regular site monitoring and maintenance. Trails, steps, and roads may need to be constructed or improved prior to planting in order to avoid site degradation and personal injury, particularly when planting on steep slopes in wet conditions.

- Soil for most plants should drain well. To test, dig a hole and pour water in. If it doesn't drain out fairly quickly, amendments may need to be added or another site chosen. Terrestrial plants and their root systems need oxygen gas for respiration, without air spaces in the soil, plants will not thrive.

- Testing the soil for nutrient levels is pretty cheap and could prove to be valuable information for matching plant species to specific soil conditions.

- Understanding the soil type and variations of soil condition within a site will also greatly assist the success of plantings. Plants and decomposers (soil microorganisms and bacteria) are the main driving forces behind energy transfers in an ecosystem. Soil fertility (including mychorrizal associations), decomposer diversity, and plant vitality are all inextricably linked in an ecological system.

- Ideally, water should be available for irrigation, hand watering, and follow-up weeding using herbicides. Relying on rainfall can be pretty risky and could lead to wasted plant material and resources.

- Appropriate sunlight levels should be considered not only throughout the day (e.g. north facing or south facing slopes), but seasonally as well. A moderate light gap in the winter months can become a brutal growing environment in the summer months for more shade loving species. Removal of canopy trees as part of prior or future restoration efforts should also be considered when planting high value species beneath large limbs or when using species intolerant of hot and sunny conditions.

- Long-term maintenance and protection of the planting site should always be taken into account. Acres of koa plantings were destroyed at one reforestation site on the island of Hawaii because cattle were inadvertently allowed into the planting area. Adequately plan for disasters to avoid catastrophic losses.

- On site invertebrate pests should also be considered. While ants can assist in pollination, because Hawaiian forests evolved without ants, ant infestations are generally detrimental for restoration efforts given the multitude of other plant pests like aphids, scales, and mealy bugs that are associated with ant colonies.

- Lastly, take the time to carefully plan logistics. It’s better to plant 10 trees correctly and have them all survive and flourish, than to plant 100 trees incorrectly and waste time, effort, and plant material.

6.5 SITE PREPARATION

Following site selection, usually some degree of site preparation is needed. **Appendix 6C** contains a checklist that TNC-Oahu uses for their plant reintroductions. In addition to infrastructural needs such as fences, trails and irrigation systems, restoration sites often require a fair degree of weed control. See also the chapter on weed control for planning and implementing weed control efforts. Some of the important considerations regarding site preparation follow:

- Determinations of when sites are ready for planting are dependent on the level of weed infestations and the status of any infrastructural improvements. At Honouliuli Preserve, 'high intensity' restoration sites with a solid understory of *Clidemia hirta* required 12-24 months of weed removal and follow-up weed control before native plants were reintroduced. This long period of time was needed for the exhaustion of much of the weed seed bank and to determine the levels of natural recruitment of native species at the site. This long preparation period also allowed for adequate planting stocks to be grown and for infrastructural improvements to be made such as trails, fences, and supporting irrigation systems. At other more intact native forest areas, 'low intensity' restoration sites required only minimal weed removals and native seeds were sowed directly onto favorable microsites.

- It is far easier and wiser to spray herbicides or conduct mechanical removal of weeds before plantings are done than afterwards. For example, 3 foot (1m) circles can be sprayed with Roundup® at least 1 month prior to planting to ensure that plantings do not have to compete with surrounding weeds. Additionally, it is much easier to use a gas powered auger in bare areas than through grass or vine choked areas which wrap around the auger bit.

- Both chemical and mechanical removal of understory weeds can have damaging effects on delicate groundcovers and soil microorganisms. Herbicides if used inappropriately will kill beneficial soil microorganisms such as springtails and bacteria. Similarly, ripping up understory weeds with large surface root systems can also destroy slow growing moss, fungi, and lichen growth.

- The type of weed removal must be appropriate to the site conditions and the overall restoration goals. For example, at Honouliuli Preserve, a fairly intact ohia/pukiawe shrubland area also contained an infestation of *Clidemia hirta*. Rather than ripping up the dense mat of lichen and moss in order to mechanically remove the *Clidemia*, the *Clidemia* was first cut at the base using loppers or a chainsaw. Upon re-sprouting, the flushing regrowth was carefully sprayed with Roundup®. This was far more cost-effective than tediously treating each stump with Garlon 4® and only minimal non-target overspray effects occurred. Importantly, the mat of moss was left in place for ohia and pukiawe seeds to fall on and germinate.

- Herbicide treatments of overstory weed trees should also be done well before plantings go in to ensure that subsequent leaf and limb drops do not smother or crush plantings below. For example, it may take 9-16 months for large 50 foot guava trees to completely die following 20% triclopyr ester product in crop oil basal bark frill treatments. Planting beneath that large guava tree only 3 months after treatment can simply overwhelm plantings with leaf litter and harmful tannins.

- Large dead limbs that will crush plantings or pose hazards to work crews will also need to be removed or simply avoided.

- To encourage native seedling recruitment and outplanting success in former guava or eucalyptus stands, removal of the leaf litter by raking or by using a gas powered blower can improve microsite conditions over small (1/8th acre) areas. This raking action can also stimulate koa and mamaki germination if mature trees grow nearby.

Former guava stand now being filled by endangered. *Solanum sandwicense* plantings and *Pipturus albidus* recruits. Note the koa litter suppressing weed growth.

- Controlled burns are a common practice in agricultural and military training areas to quickly remove undesirable brush. While technically difficult in densely forested conservation areas, low-intensity controlled burns are an attractive tool to cheaply remove groundcover weeds while leaving canopy trees intact or to prepare a site for less intensive chemical weed control and eventual reforestation with native species.

- If feasible, heavy mechanical equipment can also quickly clear understory growth, construct roads and trails, and dig planting holes. For example, at one riparian restoration site in Vermont, backhoes were fitted with a 10 ft. disc that digs 50 one foot deep planting holes for willow slips in one movement.

6.6 COMPANION PLANTING OR CO-PLANTING

Companion planting or co-planting involves planting two species together in the same hole at a restoration site. This technique proved to be very successful in promoting the survival of slow growing common and endangered woody species in dry and degraded reintroduction sites on Oahu. For example, planting the slow-growing ohia lehua in the microclimate created beneath bushy *Bidens sp*. allowed for the outplanting of younger nursery stock of ohia, while dramatically improving ohia survival and vigor during the first 2 years (Garnett pers. com. 2003).

6.7 PREPARING PLANTS FOR PLANTING

All plant material should ideally be hardened off at least three weeks prior to outplanting by acclimating it to similar light, nutrient and soil water levels as the outplanting site. Plants should not be pot bound (repot well beforehand) and the outplanting site should be carefully chosen based on appropriate soil, sunlight, and climate for the particular plants. Fertilizations which encourage leaf growth should generally be stopped two months prior to outplanting to encourage more woody tissue (lignification) and root growth. A large amount of leaf and reproductive tissue usually means higher transpiration rates and potential transplant shock after plants are placed into forests with less available water. Pruning plants of their larger leaves or spraying the leaves with a wax designed for large tree plantings will also lower transpiration rates and lessen transplant shock.

Choosing the most vigorous plants for outplanting is important for long-term success. For example, using well-grown plants in 1 and 2 gallon Stuewe® tree pots, The Nature Conservancy-Oahu Program had survival rates above 85% for all but one rare species. As with most large living organisms, the health of a tree later in life is tied to the growing conditions early in life. Tree seedlings that are nutrient, water, and heat or cold stressed early on will not be able to grow quickly and become large healthy trees.

Before putting plants into the wild, plants need to be pest free. Plants should be closely inspected for ants, mites, mealy bugs, nematodes, undesirable fungi and other pests. If plants are small enough, one can even pull the plants out of the pots to inspect for root coiling, diseases, root mealy bugs, snails, and slugs. Healthy roots should look white with numerous root hairs. Soil drenches with systemic insecticides and fungicides at least three weeks prior to planting are one method of ensuring that nursery grown stock are pest free before being brought to the field. Fungicides should be used with caution as they may also kill desirable fungi that assist with plant nutrient uptake (e.g. vesicular arbuscular mychorhizal fungi). Growing plants in field nurseries is another means of ensuring that contaminants are not brought into uninfested areas.

MATERIALS NEEDED FOR OUTPLANTING:

- Pick
- Shovels
- Gas powered auger
- Buckets/crates/jugs (for water and mulch)
- Mulch
- Stakes/flags/tags
- Fertilizer
- Knife/shears (to cut away pot if plant is stuck)
- Gloves and eye protection
- Plant record forms

6.8 TRANSPORTING PLANTS TO THE SITE

Transporting large quantities of plant material to remote locations is a laborious and costly enterprise. Field nurseries offer the benefit of having plant material located at or near where they will actually be planted. Various other means have been used for decades for forestry efforts. Two of the most common methods are described below.

Hand carrying: If roads are too far from planting site, material will need to be carried in on ATVs, horses, mules, or on worker's backs. Freighter packs available from Forestry Suppliers Inc. are well suited for carrying heavy material. Taller plants can be carried parallel to the ground in crates to avoid damage from overhanging brush. Shoulder sacks to carry dibble tubes are also handy when moving plants from staging areas to actual planting sites. These are also available from Forestry Suppliers Inc..

Helicopter sling loading: While expensive at around $800/hour, helicopters are very useful in bringing large amounts of plant material and gear into remote areas. Plants can be transported in containers placed into slingnets, strapped directly to open sided or closed paneled pallets, or placed into large synthetic bags designed for dock operations.

Helicopter slingloading and power augering holes, tools of the trade for more intensive restoration efforts, Honouliuli Preserve, Oahu.

6.9 DIGGING THE HOLE

Pick a spot in an area friendly to plants. This could be a natural drainage area, away from foot traffic, out of strong winds, and not immediately next to another tree or plant. Use a pick to break up earth or a D-handled shovel for hole digging. If using hand picks or digging in rocky areas, use eye protection. Dig a hole twice just as deep as original pot. If the sides of the hole become smooth, break it apart to avoid a flowerpot effect (i.e. roots cannot grow through smooth hard walls). Large holes are important to trap more water and keep roots aerated. Plants need oxygen for respiration too. Keep excavated material in a pile to make it easier to refill hole.

Because some natives (e.g. ohia) are better planted at a larger size, larger ½ gallon or even 1 gallon sized pots and planting holes are needed to accommodate them. For some tree species as indicated in the planting table, The Nature Conservancy-Oahu Program recommends planting at these larger sizes to ensure survival and quicker initial growth. Digging these larger holes without power tools is very time consuming and physically demanding. In these situations, the use of a power auger can be very effective. In Hakalau Forest National Wildlife Refuge, a gasoline-powered engine drill (Echo model EDR-2400, $435, www.echo-usa.com) with a specialized planter bit (Power Planter bit #528H, $82, www.bradleysales.com) is used to dig holes for larger `ohi`a, as well koa and other understory plants. Stihl also makes a much heavier, but more powerful gas powered auger. Using the power auger increased the productivity of Hakalau volunteer crews from planting 200-300 trees in an 8 hour day, to planting 500 plants in a 6 hour day. Echo also makes smaller 9 lb. gas powered auger drill which can be used for smaller

dibble tubes (2” diameter). The same Echo gas powered auger drill can also be used for tree injections for herbicide work using a different bit.
When using an auger or any other power machinery, appropriate safety measures should be taken to prevent injury. Particularly in root bound and rocky areas, only individuals with good upper body strength and healthy spines should operate an auger.

6.9.1 Fertilizing the Hole

Once the hole is dug, check the drainage by pouring some water inside. If the water doesn't drain out within 20 seconds the soil probably has a lot of clay. Rocks and gravel may be needed at the bottom to provide better drainage. Some advocate a tough love stance by recommending that no fertilizer or compost be added as this will create an artificially high nutrient rich zone that the roots will never grow away from, leaving them stunted in the long-term after the fertilizer is depleted. Weeds may also use the fertilizer faster than the target plant.

However, The Nature Conservancy-Oahu Program does amend their planting holes (particularly on nutrient depleted ridgeline areas) with a balanced slow release fertilizer with micronutrients (Apex 9-12-16). Among other benefits, fertilizer encourages root growth upon planting, assisting with plant survival and growth. Upstart or Vitamin B1 (a transplant hormone) can also be mixed into water jugs used for watering at the time of planting. Other agencies have found potassium (potash form), phosphorus and bone meal also produced favorable results. Roughly a handful of potash and phosphorus each mixed into the soil at the bottom of the hole is adequate. If available, thoroughly rotten tree log bits can be mixed in as well as compost. Excessive amounts of fertilizer may encourage too much foliar plant growth or even be toxic to the plant (e.g. ammonification). Therefore, fertilizers for native plants should generally be used at the lowest recommended amounts on the product labels with test trials to determine optimum rates. See also the propagation chapter for a discussion on the use of mychorhizal inoculated soil.

6.9.2 Getting the Plant Out

It is very easy to damage a plant when transporting it, handling it and extracting it from its pot. Transplant shock can occur when root hairs are damaged to the point where they are less able to efficiently absorb water and nutrients from the surrounding media. To make extraction easier, squeeze the sides of the pot to loosen the soil. If the plant can be easily lifted, turn the pot on its side or completely over to let gravity drop it out. You of course need to be ready to catch the root ball when it does slide out. If it is really stuck, try slapping the bottom to jar it out. Pulling on the stem is generally a bad idea as this may damage surface roots. If need be, cut the plant out of its pot with a sharp knife. Keep the root ball (soil around the roots) as intact as possible. If roots are severely coiled at the bottom its probably best not to cut them as this will only severely stress the plant. Gently tug and free the roots from the pot as best as possible. For larger 1 gallon pots, pulling the plant out onto a 'shooter' spade shovel will help support the root ball as it is lowered into the ground.

6.9.3 PLANTING

1) As mentioned at the beginning of the chapter, the distribution of plantings can be critical to their success. Many shrubs and groundcovers are better able to establish themselves if planted in clumps or clusters. Cluster planting allows plants to trap organic matter much better as well as form more substantial mychorrizal associations in the soil. The immediate microclimate is also often improved facilitating germination and native seedling establishment.
2) If the soil in the hole is excessively dry and water is available, water the hole first before planting. This ensures that the soil that contacts the roots is sufficiently wet and will help prevent transplant shock.
3) Place the plant in the soil so that the original soil surface level in the pot is now level with the ground. If it is planted too deep, the stem may rot as debris and other matter collect in the hole. If it is planted too shallow, surface roots will become exposed as water flows over the surface.
4) Lightly pack soil back in around plant roots and thoroughly water if the ground is not already saturated. See also the discussion on watering in the following chapter.
5) For plants exposed to high winds or cold temperatures, some type of wind shield may be needed.
6) For plants planted on steep slopes, erosion from excessive surface runoff (overland flow) is of concern. Rocks or other available dead branches can be placed as a mini-dam around the lower edge of the plant to help stabilize it until fully rooted as well as collect debris and surface runoff.
7) Plantings should also be mulched with available leaf litter, rotten logs, or rocks. The amount of mulch depends on the size of the plant. A general rule is that a one foot in diameter ring of mulch is needed for every foot in plant height. Kukui logs when fully rotted make great mulch. Ancient Hawaiians planting their food crops in dry, arid and at times rocky fields, also commonly used rocks as mulch.
8) If desired, mark all plants with stake flags or other means for ease of relocation.
9) Conduct follow-up maintenance as needed. Post planting site treatment is described in the following chapter.

It takes a community to raise a forest, sometimes one tree at a time.

6.9.4 REFERENCES

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Appendix 6A: PALIKEA FENCE RESTORATION SITE PLAN

Timeframe: FY2004-FY2006

Vegetation communities: Oahu Diverse Mesic Forest with a Sugi Pine/Ohia lehua canopy

Size of site: 2.5 acres

Overall management goal: In the next three year period, utilize staff and volunteer assistance to restore a moderately degraded 2.5 acre highly diverse mesic community to provide a high quality habitat for rare plant species stabilization and rare animal protection.

Overall management objectives:

1. In three years reduce all habitat modifying canopy species cover by 80% while maintaining adequate habitat requirements for Elepaio, Apapane, Amakihi and Achatinella snails in the area.
2. Habitat modifying understory weed species cover will be reduced by 100% in three years.
3. Continue monthly rat baiting and maintain a pig free fenced and surrounding area through various ungulate control methods.
4. Plant 1000 canopy reaching trees and 1700 understory shrubs on west slope. Plant rare species in accordance with stabilization plans.

Overall monitoring objectives:

1. Using the Restoration Site Assessment form, over three years monitor the reduction in non-native canopy and understory cover and increase in native understory cover in two 50 x 50 m plots on the east facing and west facing slopes of the fence area.
2. Also, over three years, monitor the survival, vigor and reproduction of various rare elements in the area including naturally occurring rare plant populations, reintroduced plant populations, and rare bird and snail species.

General description: At 2800' below Puu Palikea, the 2.5 acre Palikea fence is a microcosm of Honouliuli Preserve. Several microhabitats exist within this small area. The gulch bottom consists of a mamaki riparian shrubland. The eastern and western facing slopes consist of a lowland diverse mesic community with over 40 fern and flowering plant species beneath a predominately Sugi pine canopy. Access is a 30 minute hike along the Palikea Trail at the southern end of Honouliuli Preserve. A 125 gallon catchment tank and two 55 gallon storage tanks are also on site. The fence was completed in the fall of 2000 allowing substantial recovery of the native understory in the gulch bottom.

Baseline conditions

- **Native canopy species include:** *Metrosideros polymorpha, Acacia koa, Pouteria sandwicensis, Psychotria sp., Zanthoxylum sp., Charpentiera obovata,* and *Ilex anomala*.
- **Rare canopy species include:** *Exocarpus gaudichaudii, Zanthoxylum dipetalum var. dipetalum,* and *Nothocestrum longifolium*.
- **Non-native, habitat modifying canopy species include:** *Psidium cattlelianum, Psidium guajava, Schinus terebinthifolius,* and *Morella faya.* The *Sugus pinus* canopy is not actively recruiting and while the pine litter is thick in areas, numerous native understory fern and flowering plant species are persisting and recruiting. Thus, the Sugi pine canopy will be left intact long into the future.
- **Dominant native understory species include:** *Pipturus albidus, Dianella sandwicensis, Hedyotis terminalis, Carex wahuensis,* and *Diplazium sandwichianum*. Numerous other native understory species exist in low-medium densities. Hoio fern cover in the gulch bottom has recovered to nearly 100%. For comparison, the neighboring unfenced gulch bottom hoio fern cover is about 10% with numerous weeds species present.
- **Dominant non-native habitat modifying understory species include:** *Clidemia hirta, Passiflora suberosa, Rubus rosifolius, Sphaeropteris cooperi, Melinus minutifolia, Oplismenus hirtellus,* and *Paspalum conjugatum.*
- **Rare understory species include:** *Cyanea grimesiana var. obatae, Cyanea calycina, Clermontia persicifolia, Schiedea pentamera,* and *Neraudia melastomifolia.* Notably, the *Cyanea grimesiana var. obatae* population is the largest, healthiest naturally occurring population left.
- **Reintroduced common native understory species include:** *Dodonaea viscosa, Hedyotis terminalis,* and *Bidens torta.*
- **Reintroduced rare plant species include:** *Cyanea grimesiana var. obatae, Cyanea superba, Urera kaalae, Silene perlmanii, Urera kaalae, Lobelia yuccoides,*and *Schiedea pentamera*.
- Common and rare plant reintroductions have been ongoing since the fall of 2002.
- Weed control for non-native canopy and understory species has also progressed somewhat sporadically since 2001, but more intensively since the summer of 2003.
- Rare bird and inverterbrate species also inhabit the fence and surrounding area. Two elepaio males and possibly one female are present in the fence area. The same elepaio pair nested successfully in the fence area in the spring of 2002. Additionally, a small, but genetically significant populations of *Achatinella mustelina* and *A. concavospira* are extant just outside the fence line. *Philonesia* sp. (snails) are also fairly common in the area. Rat baiting to protect these animal and rare plant species is done throughout the year.

Summary of Management Objectives:

Year	Canopy weed control	Understory weed control	Reforestation objectives	Rare plant objectives	Monitoring objectives
1	50% removal of xmas berry and strawberry guava	100% removal of non-native grass species, 100% removal of Clidemia hirta species	Continue Kookoolau, Aalii, and Manono plantings in sun bowl on west slope with 200 plants in FY04.	1) Continue augmenting Cyagrioba population w/ mixed founders 2) Continue Silper, Urekaa, Solsan reintroduction at rate of 50 per year	1) Complete restoration site assessments for two 50 x 50 m plots (east and west slopes) 2) Quarterly fenceline inspections 3) Monthly rat baiting 4) Complete rare plant monitoring as planned
2	30% removal of xmas berry, strawberry guava, and faya tree	Follow up removals of grass and Clidemia, 100% removal of Passion vine and Thimble berry	1) Plant 200 canopy trees on west slope 2) Plant 500 understory shrubs on west slope	Continue augmentations and reintroductions in accordance with rare plant stabilization plans	1) Complete restoration site assessments 2) Quarterly fenceline inspections 3) Monthly rat baiting 4) Complete rare plant monitoring as planned
3	Followup control of above habitat modifying canopy species	Follow up control of above habitat modifying understory species	1) Plant 500 canopy trees on west slope 2) Plant 300 canopy trees in guava kill area on east slope 3) Plant 1000 understory shrubs on west slope	Continue augmentations and reintroductions in accordance with rare plant stabilization plans	1) Complete restoration site assessments 2) Quarterly fenceline inspections 3) Monthly rat baiting 4) Complete rare plant monitoring as planned

Strategies and Tactics:

1) Canopy weed species control:

Year 1:

- Begin guava, faya tree, and xmas berry removal on east facing slope in, and work toward back bowl upgulch.
- Leave 25% of largest guava trees and faya trees but conduct 100% removal of xmas berry. 100% removal of basal resprouts and saplings of target trees.
- No chainsawing, strictly Garlon 4 at 20% with or without girdling depending on girth of tree.

Year 2: Continue same strategy, but shift to west facing slope.
Year 3: Conduct followup herbicide treatments of target trees that remain alive.

2) Understory weed species control:

Year 1:

- Continue followup grass control on east and west facing slopes at 100% removal.
- Continue Clidemia, Passion vine, and Lantana control on east facing slope, focusing on area upgulch of Cyagrioba population first and moving toward back bowl and then west facing slope (Plot 1). Use clip and drip method for more native areas, cut and spray regrowth for less native areas.
- Continue Thimble berry removals at 100% in planting areas and focusing on area upgulch of Cyagrioba population first (Plot 1).
- Ensure all plantings are released from weed competition.

Year 2:

- Continue followup grass control on back bowl, east and west facing slopes at 100% removal.
- Remove remaining Clidemia, Passion vine, Lantana, and Thimbleberry at back bowl and on west facing slope (Plot 2).
- Ensure all plantings are released from weed competition.
- Begin wholescale Clidemia and Molasses grass removals from areas immediately outside of the fence. Use chainsaw and spray regrowth method for woody species, or foliar Roundup® without cutting as appropriate.

Year 3:

- Conduct followup removals of all understory weeds in fence area, focusing around outplantings first.
- Ensure all plantings are released from weed competition.
- Continue wholescale Clidemia, Lantana, and Molasses grass removals from areas immediately outside of the fence. Use chainsaw and spray regrowth method for woody species, or foliar Roundup® without cutting as appropriate.

4) Planting strategy

Year 1:

- Continue Cyagrioba augmentation on lower east slope
- Continue Silper reintroduction in sunnier, wet cliff area
- Begin Urekaa reintroduction on west face, sun bowl
- Begin Cyasub reintroduction on lower slope, west slope

Year 2 and 3: Plant in accordance with Rare Plant Stabilization Plans

Common Natives Outplanting Palette:

Canopy	Subcanopy	Understory/groundcover
*Acacia koa *Metrosideros polymorpha *Pouteria sandwicensis *Pisonia brunoniana	*Charpentiera obovata *Pipturus albidus *Urera glabra	*Hedyotis terminalis *Bidens torta *Dodonaea viscosa *Nephrolepis cordifolia *Rumex albescens *Dianella sandwicensis
Psychotria mariniana	Labordia kaalae	Carex wahuensis

* = Species planted in the highest numbers

Rare Natives Outplanting Palette:

Canopy	Subcanopy	Understory/groundcover
None	*Cyanea grimesiana var. obatae *Urera kaalae *Solanum sandwicense	*Silene perlmanii *Cenchrus agrimonioides var. agrimonioides *Schiedea hookeri
	Cyanea calycina Cyanea superba	Schiedea pentamera Neraudia melastomifolia Dissochondrus biflorus

Appendix 6B: Restoration Site Assessment

Site Name/Plot #:		**Date:**	
Location:		**Aspect: (N/S/E/W)**	
Observer:		**Elev.(in ft. at photopoint):**	
GPS of photopoint (or nearest control point):	**N:** **E:** **Accuracy:**	**Baseline Condition: (yes/no)**	
Directions/flagging:		**Plot size (sq. meters)**	

HABITAT CHARACTERISTICS (CIRCLE):

Overstory Closure >2m	**Overstory height (All that apply)**	**Understory Closure <2m**	**Topography**	**Moisture Class**	**Slope (degrees)**
Closed 75-100%	2-5m	Closed 75-100%	crest	**Dry** <25"/yr	Flat 0-10°
Intermediate 25-75%	5-10m	Intermediate 25-75%	upper slope	**Dry-Mesic** 25-50"/yr	Moderate 10-45°
Open 0-25%	>10m	Open 0-25%	mid slope	**Mesic** 50-75"/yr	Steep 45-70°
			lower slope	**Wet-Mesic** 75-100"/yr	Vertical 70-90°
			gulch bottom	**Wet** >100"/yr	
			plateau-flat		

PHOTOPOINT DATA:

Date:	**Toward (bearing):______________** **List file name below:**	**Description:**	**Yes**
		Before weed removal (baseline):	
		After weed removal:	
		After outplanting:	
		Yearly monitoring (year 1-10)	Year:

COMMUNITY COMPOSITION:

List native and non-native species by six letter code and in order of abundance for each class. See species checklist for reference.

Overstory (>2m):

Classes:	**1000-101**	**100-11**	**10-1**
Species:	1)	1)	1)
	2)	2)	2)
	3)	3)	3)

Understory/ground cover (<2m):

Classes:	**1000-101**	**100-11**	**10-1**
Species:	1)	1)	1)
	2)	2)	2)
	3)	3)	3)

OVERALL RANK OF NATIVE INTEGRITY (CIRCLE):

Percentages reflect species composition and not percent cover. Overstory (>2m). Understory/ground cover (<2m). Habitat modifying species are asterisked in the checklist.

Good	**Fair**	**Poor**
>75% native overstory	50-75% native overstory	0-50% native overstory
>75% native understory	50-75% native understory	0-50% native understory
<25% habitat modifying weeds species in understory	25-50% habitat modifying weeds in understory	>50% habitat modifying weeds in understory

List and estimate/count all naturally occurring rare elements at site (by species code) :

Plants:____

Animals:____

List/count all species of outplanted rare plants at site (see rare plant forms for totals):

____

List/count all species of common natives outplanted. **Date of outplanting:** ____________

____

____

Appendix 6C: OUTPLANTING CHECKLIST FOR COMMON NATIVES AND RARE PLANTS

Note: For general guidelines, see Hawaii Rare Plant Restoration Group Guidelines for Reintroduction. For very specific guidlelines, see Rare Plant Reintroduction Appendix in the Makua ImplementationPlan.

THREE WEEKS PRIOR TO OUTPLANTING

PLANT PREP:

- Re-inventory nursery as needed to plan outplanting list.
- Inspect plants for pests, disease and remove weak ones from outplanting inventory.
- Apply systemic insecticide drench (Merit).
- (optional) apply fungicide (Subdue/Banrot).
- Apply Amdro and/or spray down nursery shadehouses with general insecticide (Sevin) for ant control as needed.

SITE PREP:

- Designate outplanting areas (flag) and mark locations for outlplanting species at site with marker stakes (pin flags).
- Cut and flag service trails.
- Designate and flag staging areas.
- Re-cut drop zones and flag as needed for helicopter operations.
- Follow up weed control as needed.
- Install/prep irrigation lines and/or stage enough water on site.
- Drill holes as needed. Note for drier areas, double holes needed.
- Bring in water jugs as needed.

TAGGING PREP FOR RARE PLANTS:

- Purchase marker flags, pvc posts, metal tags.
- Engrave tags with 1) Species code, 2) Population code 3) Date of planting.
- Update database.
- Cut pvc down to 1 m lengths.
- Drill holes in pvc.
- Spray paint tips with flourescent orange or red.
- Cut enough tagging wire.
- Drill holes in plant pots.
- Attach tags to pots.

ONE WEEK PRIOR TO OUTPLANTING

- Schedule heliops with vendor if flying in.
- Prepare heliops plan using template.
- Finish site prep, plant tagging as needed.
- Prepare outplanting site plan and maps for outplanting crew.
- Bundle pvc posts and rig plant carriers if walking in.
- Re-inspect plants carefully, pulling sample plants out of pots to look for root mealy bugs etc.
- Confirm with any volunteers and/or other agency staff and give overview of plan for the day.
- Complete schematic drawing of planting plan (outplanting layout, distribution of plantings)

DAY OF OUTPLANTING

- Prep heliops equipment (plant boxes, sling nets, carabiners, PPE, radios, flight plan etc.).
- Final inspection of plants and crates. Especially check bottom of pots and crate bottoms for snails, slugs and other undesirables.
- Rig plants to carriers or arrange in plant boxes for fly in.
- Label/flag crates as needed in accordance with outplanting site plan.
- Prepare final outplanting species list and tally plant numbers (before plants leave nursery).
- Prep outplanting tools (hammer, shovels, digging cups/bowls, gloves, plant wire, flagging, extra write-on metal tags, water jugs. etc.).
- If loading plants in vehicles, secure well to prevent spillage and lay down crates or drive slow to prevent windburn/leaf stripping.
- Brief crews on heli-ops plan, outplanting plan, and timetable for the day.