# Nakula Natural Area Reserve
## Management Plan

2015

Department of Land and Natural Resources
Division of Forestry and Wildlife

NAKULA NATURAL AREA RESERVE
MANAGEMENT PLAN SIGNATURE PAGE

Maui District certification: This plan was prepared by a team of Division of Forestry and Wildlife (DOFAW) staff to provide a management framework for Nakula Natural Area Reserve.

Scott Fretz - DOFAW Maui Branch Manager — Date: 10/29/15

DOFAW Administrator's approval: I have reviewed the Nakula Natural Area Reserve Management Plan and concur with the recommendations herein. I agree this Management Plan will serve as a guiding document for the management of Nakula Natural Area Reserve.

Sheri S. Mann - DOFAW Acting Administrator — Date: 10/30/15

Department of Land and Natural Resources Board approval: This plan conforms with the purpose of the Natural Area Reserve System as stated in Hawai'i Revised Statutes (HRS § 195-1) and associated Hawai'i Administrative Rules (HAR§ 13-209), to preserve in perpetuity specific land and water areas which support communities, as relatively unmodified as possible, of the natural flora and fauna, as well as geological sites, of Hawai'i.

Suzanne D. Case - BLNR Chairperson — Date: 11/2/15

Approved by the Board of Land and Natural Resources at its meeting held November 13, 2015

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# Summary of Acronyms

| | |
|---|---|
| **BLNR** | Board of Land and Natural Resources |
| **CIP** | Capital Improvement Project |
| **DHHL** | Department of Hawaiian Homelands |
| **DLNR** | Department of Land and Natural Resources |
| **DOFAW** | Division of Forestry and Wildlife |
| **FR** | Forest Reserve |
| **FY** | Fiscal Year |
| **GIS** | Geographic Information System |
| **HISC** | Hawai‘i Invasive Species Committee |
| **HRS** | Hawai‘i Revised Statutes |
| **LHWRP** | Leeward Haleakalā Watershed Restoration Partnership |
| **MISC** | Maui Invasive Species Committee |
| **MFBRP** | Maui Forest Bird Recovery Project |
| **MNSRP** | Maui Nui Seabird Recovery Project |
| **NARF** | Natural Area Reserve Fund |
| **NAR** | Natural Area Reserve |
| **NARS** | Natural Area Reserves System |
| **NEPM** | Native Ecosystems Protection and Management |
| **NIP** | Native Invertebrate Program |
| **NPS** | National Park Service |
| **PEPP** | Plant Extinction Prevention Program |
| **RCUH-PCSU** | Research Corporation of the University of Hawai‘i - Pacific Cooperative Studies Unit |
| **T&E** | Threatened and Endangered |
| **USFWS** | United States Fish and Wildlife Service |
| **USGS** | United States Geological Survey |
| **YCC** | Youth Conservation Corps |

# EXECUTIVE SUMMARY

*Figure 1. View of Nakula Natural Area Reserve from the highway.*

Nakula Natural Area Reserve (NAR or Reserve) is situated on lands within the upper portions of Kaupo and Kahikinui in the Hana District on the south slope of Haleakalā, Maui (Figure 1). The Reserve was formally established in 2011 by Governor's Executive Order 4365 from lands withdrawn from the Kahikinui Forest Reserve (FR). The 1,500 acre (ac) (607 hectare (ha)) Reserve was created to protect leeward Haleakalā koa (*Acacia koa*) forest and natural communities, including rare and endangered plants and animals.

This type of forest once covered an estimated 40,000 ac, extending from Makawao to Kaupo. It has been so badly impacted by human activities (primarily logging and cattle ranching) that it has been reduced to approximately 5% of its original range, and even this has been severely degraded. Active management is needed to protect this last remnant of forest from disappearing and to restore it to its former extent.

The overall management goal of the Nakula Management Plan is to protect, halt ecosystem degradation, maintain, and enhance the Reserve's unique natural and cultural resources. Management programs have been developed to support this overall goal and include the following:

1. Restoration
    - Forest Restoration
    - Forest Bird Restoration
    - Seabird Restoration
    - Bat Restoration
    - Invertebrate Restoration
2. Threat Abatement
    - Ungulate Control
    - Invasive Plant Control
    - Predator Control
    - Fire Prevention and Response
    - Non-native Insects and Disease
    - Climate Change Adaptation
3. Information and Education
4. Research and Survey
5. Infrastructure Management

This Management Plan outlines the types of management activities planned in Nakula NAR for the foreseeable future. Specific activities will be updated based on accomplishments and available funding over time. Adaptive management will allow the prioritization of different goals and approaches as restoration of the NAR progresses with feedback from ongoing field monitoring of management activities.

Section 1 of the Management Plan provides background information on the physical setting, land use and condition of resources in the NAR. Section 2 describes the planned management actions including overall goals and objectives and planned short term and long term management actions. Section 3 summarizes planned management actions and the associated budget proposed to complete those actions. Section 3 is intended to be regularly updated (approximately every two years) and will be used by NARS staff for operational and biennium budget planning.

# 1 Background and Current Condition

Long-term management of Nakula NAR provides multiple benefits to the state. The natural communities within the Reserve provide habitat for a diverse range of native plants and animals, from rare birds to endemic invertebrates, preserving the biodiversity of Hawai‘i. The habitats of the Reserve are an important component of the larger landscape of protected and managed public and private lands stretching across the leeward slope of Haleakalā.

The Natural Area Reserves System (NARS) was created in 1971 by the Hawai‘i State Legislature to "preserve in perpetuity specific land and water areas which support communities, as relatively unmodified as possible, of the natural flora and fauna, as well as geological sites, of Hawai‘i (HRS § 195-1)." The legislature further found that these unique natural assets should be protected and preserved, both for the enjoyment of future generations and to provide baselines against which changes to Hawaii's environment can be measured. The NARS is administered by the Hawai‘i Department of Land and Natural Resources (DLNR) Division of Forestry and Wildlife (DOFAW) Native Ecosystem Protection and Management (NEPM) Section. NARS Commission members act in an advisory capacity for the Board of Land and Natural Resources, which sets policies for the Department. Hawai‘i Administrative Rules 13-209 relate to the management of the NARS.

The NARS is based on the concept of protecting native Hawaiian ecosystems – not merely single species. Because the natural resources of Hawai‘i are under constant threat from invasive species, human encroachment, feral ungulates, climate change, and other threats, the NARS seeks to protect the best remaining examples of the State's unique ecosystems. In addition to setting aside these areas as reserves, the NARS strives to actively manage these reserves in order to preserve the unique characteristics that make these areas an integral part of the natural heritage of Hawai‘i. NARS provide some of the best opportunities to effectively restore impacted ecosystem functions, and actively address overall goals of recovery of flora and fauna, due primarily to the relative intactness of their lands. Reflecting this, the mission of the NARS is: "The NARS exists to ensure the highest level of stewardship for Hawaii's natural resources through acquisition, active management, and other strategies."

The NARS presently consists of 21 reserves on five islands, encompassing more than 123,000 ac (49,776 ha) of the State's most unique ecosystems. The diverse areas found in the NARS range from marine and coastal environments to alpine desert, and from fresh lava flows to wet forests. These areas often serve as habitat for rare native plants and animals, many of which are on the verge of extinction. The NARS also includes important watersheds and is an integral part of the scenic landscape and natural beauty of Hawai‘i.

The NARS website at http://dlnr.hawaii.gov/ecosystems/nars/ provides general information on NARS management across the state as well as other NEPM Section programs and policies.

## 1.1 Site Description (Physical and Biological Resources)

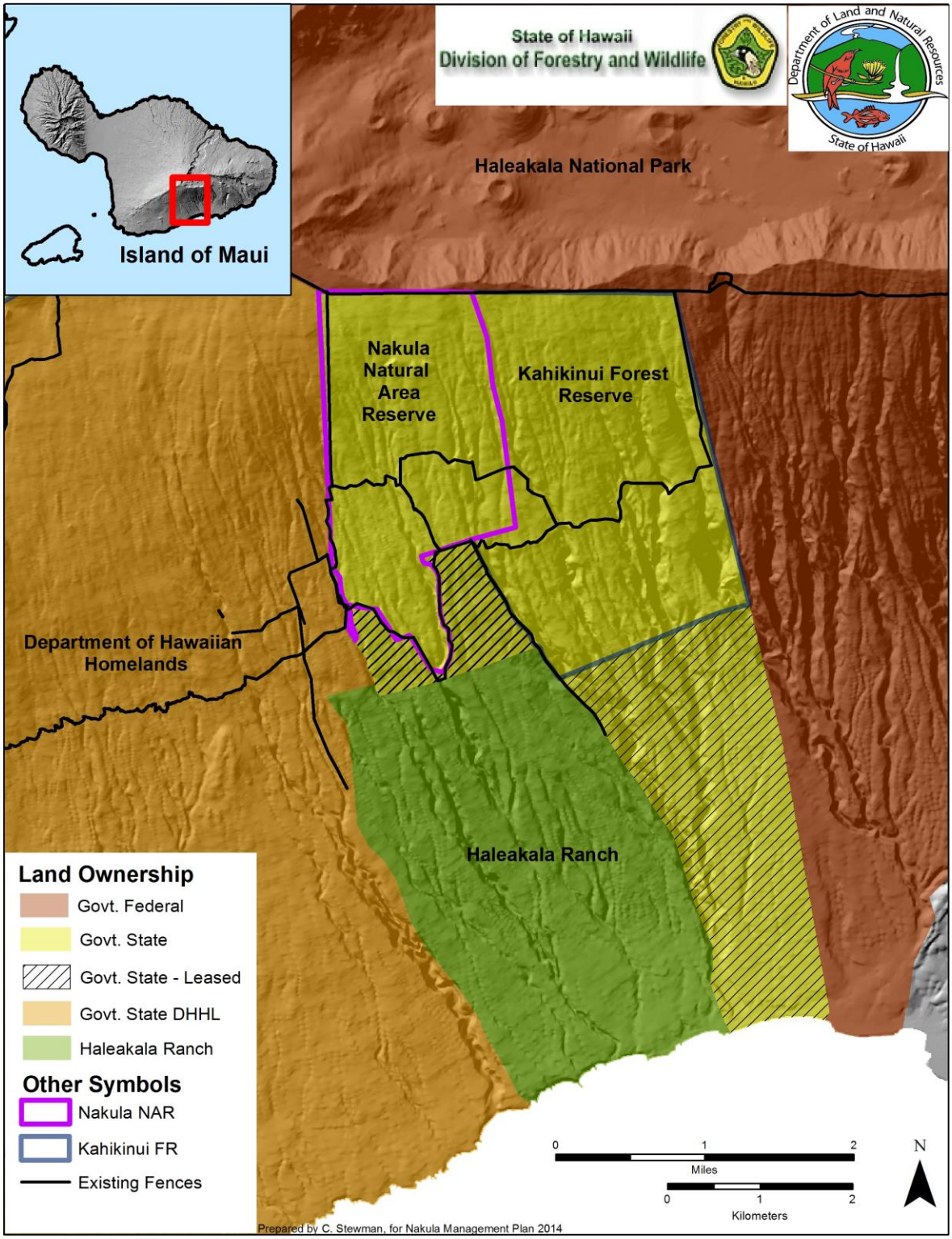
### 1.1.1 Location

Nakula NAR is located on the southern slope of Haleakalā on Maui in the Hana District, and includes approximately 1,500 ac (607 ha) (Figure 2 and Figure 3). The NAR boundaries encompass a wide elevational gradient from 3,600 ft (1,097 meters (m)) - 9,200 ft (2,804 m). The western boundary follows the canyon carved by Waiʻōpai stream; a ridge between the two forks of Pāhihi stream forms the eastern boundary. The upper elevation boundary is marked by Haleakalā National Park's boundary perimeter fence. The lower elevation boundary of the Reserve on the eastern side is at the 5,000 ft (1,525 m) elevational contour. The lower boundary dips downhill to include the area between major forks of Wailaulau gulch and then goes back up to about 5,000 ft (1,525 m) on the western side.

Neighboring lands include Kahikinui Forest Reserve to the east, lands administered by the Department of Hawaiian Homelands (DHHL) to the west, Haleakalā National Park to the north, and state-owned lands leased for pasture to the south.

*Figure 2. View from camp over lower Nakula NAR and surrounds.*

*Figure 3. Land ownership of Nakula NAR and surrounding lands.*



### 1.1.2 Climate

The Reserve is on the drier leeward side of Haleakalā. A primary consideration in the design of the Reserve boundaries was to capture the dramatic elevation change (5,600 vertical feet in 2½ miles), and the corresponding change in moisture regimes (from the moist forest of the afternoon fog belt at the Reserve's lower elevations up to the harsh dry desert conditions at the summit). These climatic differences result in a variety of native habitats across a relatively small area. A secondary consideration in the Reserve design was to capture as much lateral variation along the mountain contour as possible. Geologic and climatic factors also influence forest composition across the mountain slope. Koa dominated forest is prevalent on the western side of the Reserve, while a dry ʻōhiʻa (*Metrosideros polymorpha*) forest persists to the east.

Average annual rainfall in the mid-elevation sections of leeward Haleakalā is 35–50 inches (89–127 centimeters (cm)) (Giambelluca *et al*. 2013), with prevailing winds from the northeast. The temperature inversion, which fluctuates from 5,000–7,000 ft (1,500–2,134 m), results in cloud formation trapping warmer moist air with the area below the temperature inversion being substantially moister (UH-Hilo, Dept. of Geography 1998; Figure 4). Clouds at the inversion layer also result in increased moisture through fog drip, from moisture collecting on trees.

*Figure 4. Cloud formation along the inversion layer*.

### 1.1.3 Geology

The surface geology of the area consists of lava flows from Haleakalā Volcano, mostly Pleistocene in age (Kula Volcanic Series) with some Holocene (Hana Volcanic Series) in the southwest (MacDonald *et al.* 1986). A few cinder cones, including Puʻu Aliʻi, are also present. Lava tubes may be present in some areas.

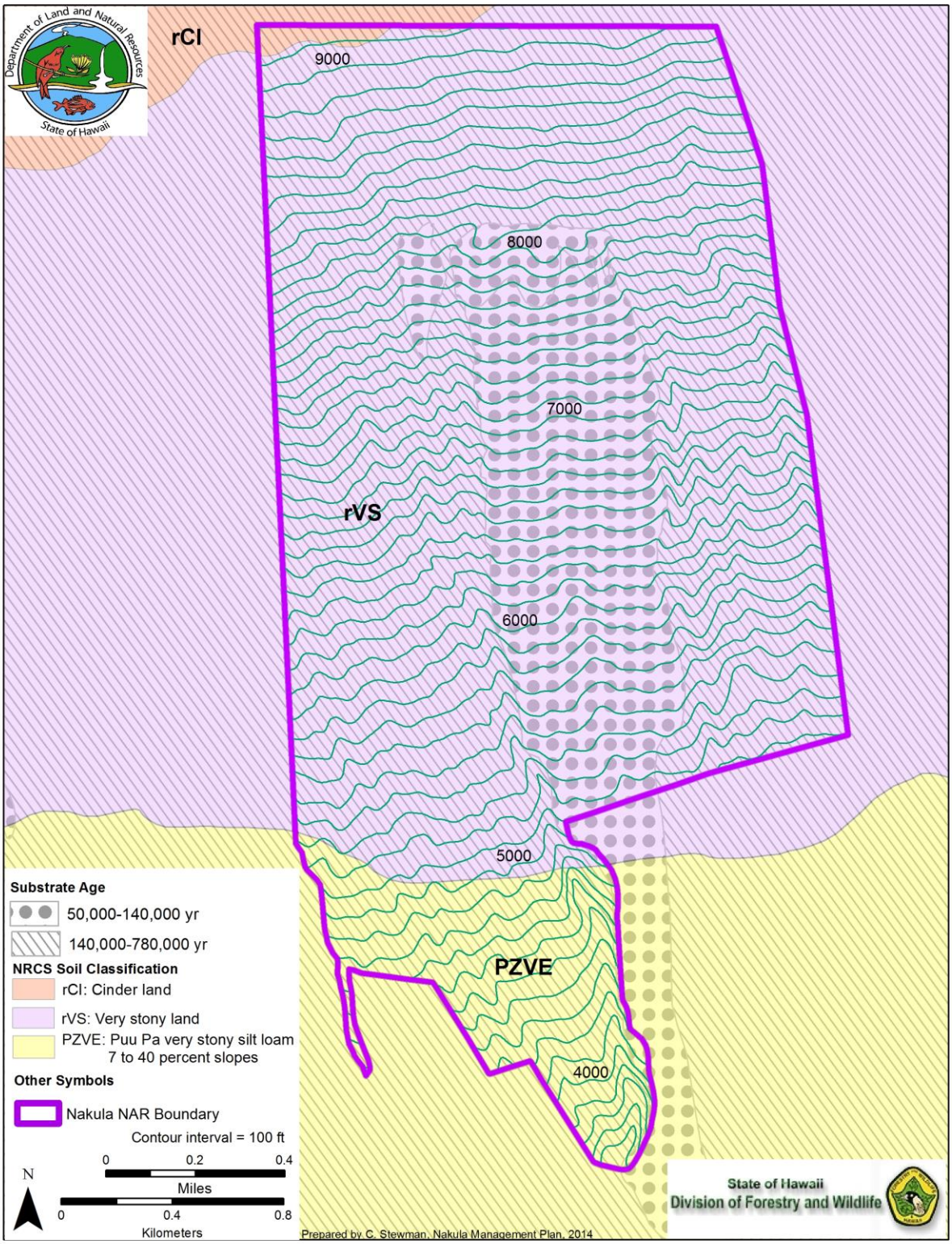
Noteworthy geologic features include highly dissected exposures of the Kula volcanic series, mantled with soils derived from ash and cinder deposits. The Puʻu Aliʻi cinder cone is a prominent feature located at 8,000 ft (2,438 m) elevation. The numerous gullies and gulches along the heavily dissected mountain slope provide sheltered micro-habitats that allow forest vegetation to extend upslope into the subalpine region. These drainages also hold numerous springs and seeps which may provide habitat for native invertebrates.

Surface flow of water on the leeward slopes is minimal and generally restricted to short-duration flash events. There are no perennial streams within the study area and the large gulches that develop further downslope are dry most of the year.

### 1.1.4 Soils

Natural Resource Conservation Service soil maps classify soils in the Reserve as: Very stony land; Puʻu Pa very stony silt loam, 7 to 40 percent slopes; and Cinder land (Figure 5). Soil erosion has been greatly accelerated by the presence of introduced ungulates, particularly cattle and goats and subsequent reduction of forest cover (Figure 6).

*Figure 5. Substrate age and soil classification of Nakula NAR.*



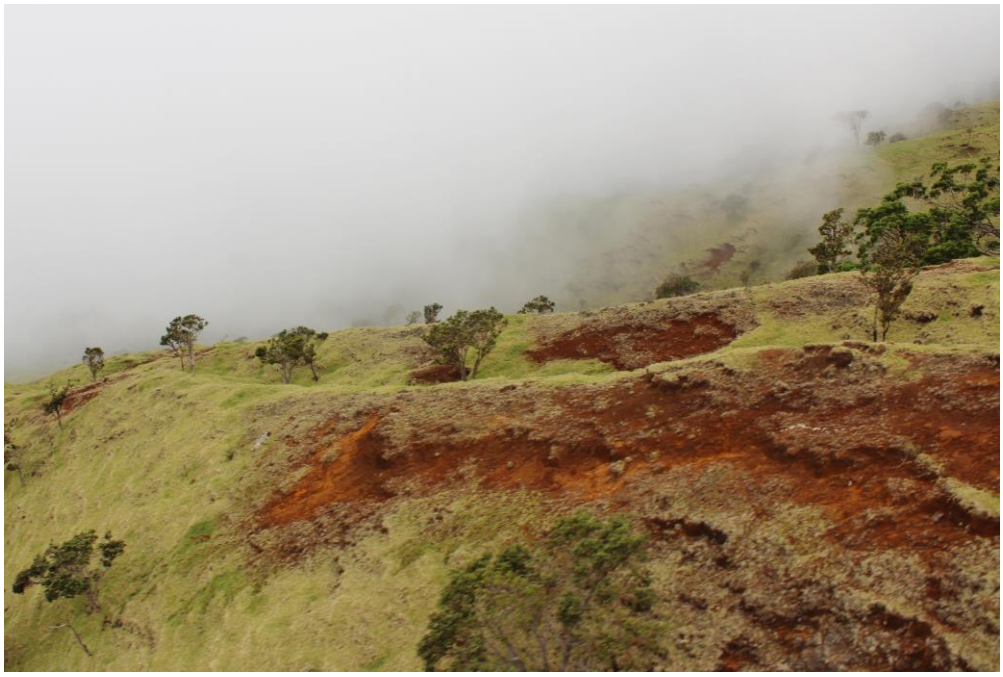


*Figure 6. Erosion scars from feral ungulate damage.*

### 1.1.5 Native vegetation

There are six native vegetation communities within Nakula NAR. Most of the native vegetation communities in the Reserve have been degraded to a large degree; primarily by grazing animals such as cattle and goats and the spread of introduced pasture grasses and other non-native plants. Native vegetation currently persists at higher elevations and on the walls of canyons too steep for ungulates to access. Generalized past native vegetation zones ("potential native vegetation"), which existed prior to disturbance has been mapped using elevational gradients described for these communities, rather than mapping the open parkland-like and degraded vegetation currently present in the Reserve (Figure 7). This plan contains two additional figures depicting current vegetation in different ways. Currently existing vegetation has been mapped by Jacobi (in prep.) as a revision of the Hawai'i GAP Analysis land cover map (Figure 8). Broad vegetation conditions currently present has also been generalized and mapped (Figure 9). Future native vegetation cover will certainly shift due to expected effects of climate change. This will alter the vegetation communities, their species composition, and the zones suitable for their perpetuation.

Plant community classifications follow Gagne and Cuddihy in Wagner *et al.* (1999). Vegetation communities include dry subalpine shrubland, two dry subalpine forest types, and three types of montane mesic forests. Areas above 5,247 ft (1,600 m) elevation are classified as subalpine, with the remainder of the Reserve in the montane mesic zone.

*Pūkiawe* (Styphelia tameiameiae)/*ʻŌhelo (Vaccinium spp.) Subalpine Dry Shrubland* : Between the top of the Reserve at 9,200 ft (2,804 m) and approximately 8,000 ft (2,438 m) a dense *pūkiawe* shrubland predominates, interspersed with native grass and fern patches.

*ʻŌhiʻa (Metrosideros polymorpha) Subalpine Dry Forest* /*Māmane* (Sophora chrysophylla) *Subalpine Dry Forest*: Between 8,000 ft (2,438 m) and 6,500 ft (1,981 m), the vegetation has been severely impacted by goats and the mountain has been mostly denuded of native vegetation. However, remnants of these two forest types can still be found in some of the steeper gulches, or in areas where the underlying substrate has resisted erosion.

*Koa/ʻŌhiʻa Montane Mesic Forest*: This forest type is found below the temperature inversion layer at about 6,500 ft (1,981 m) elevation. Leeward koa forests are unique in that the forest depends largely on precipitation and fog drip from afternoon clouds created by convection and diurnal heating. At the upper reaches, this forest is a dry subtype, with a koa canopy and an understory of tall ʻaʻaliʻi shrubs (*Dodonaea viscosa*). As moisture increases with decreasing elevation, species diversity and tree size increase, with this community being best expressed between 3,500 ft (1,069 m) and 4,500 ft (1,372 m) elevation. Due to ungulate grazing, the natural forest understory has been largely eliminated and replaced by non-native, perennial pasture grasses. However, gulches, cliff faces and other protected areas still contain a diverse assemblage of native ferns and other understory plants. These gulches provide a unique sheltered microhabitat, and also contain springs and seeps that feed intermittent streams.

*ʻŌhiʻa Montane Mesic Forest:* This forest type is dominated by ōhiʻa with native understory trees and shrubs. This forest type is found in the same elevational zone as the Koa/ʻŌhiʻa forest described above but is predominant in drier areas with shallower, less well-developed soils.

*Olopua (Nestegis sandwicensis) Montane Mesic Forest*: Below 3,500 ft (1,069 m) elevation, moisture decreases, and the vegetation grades into a much degraded remnant of what was once a diverse forest. This community is found in a very small area at the lower extent of the Reserve; within the canyon of Wailaulau gulch.

*Figure 7. Potential native vegetation of Nakula NAR.*

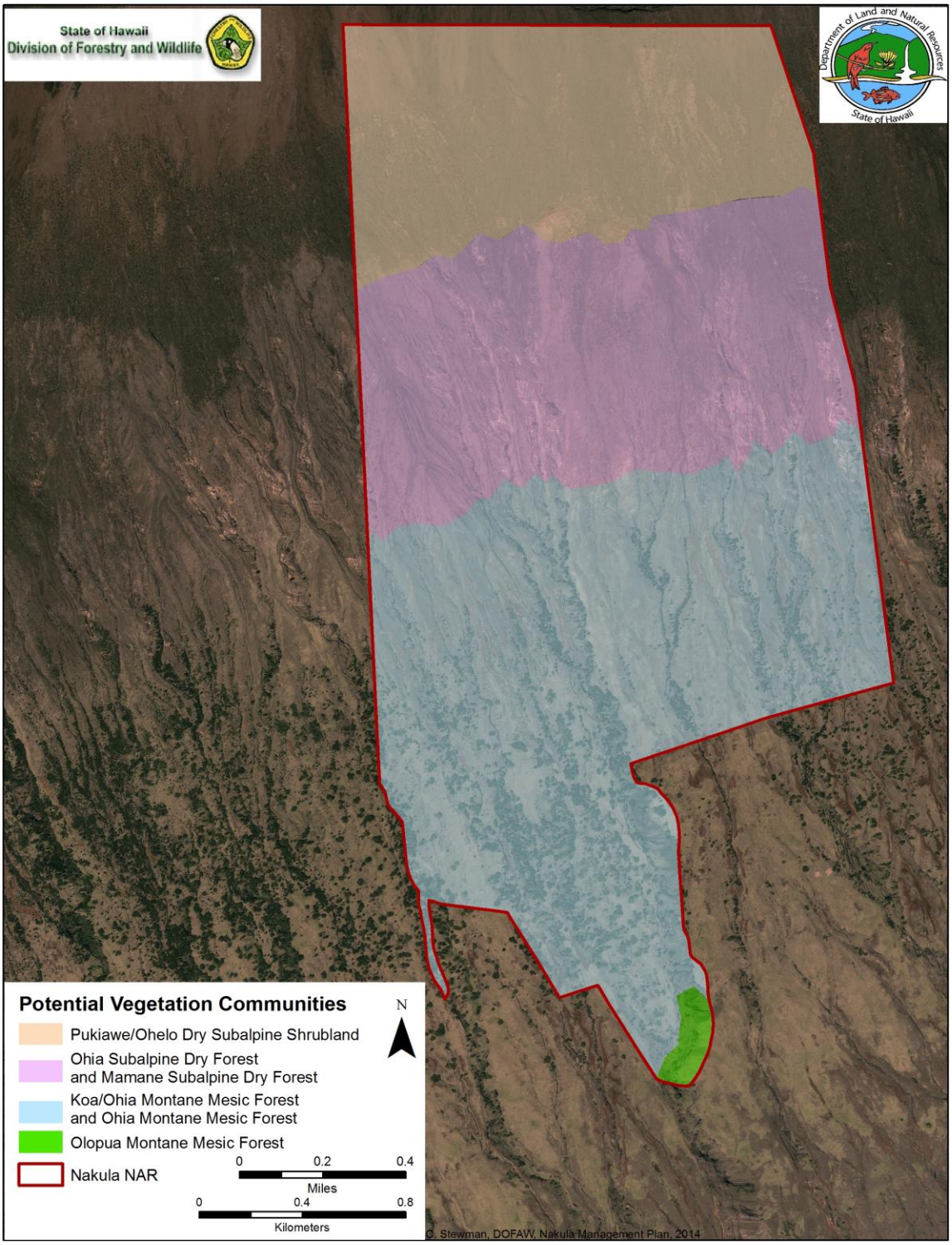


*Figure 8. Existing vegetation (land cover analysis) of Nakula NAR.*

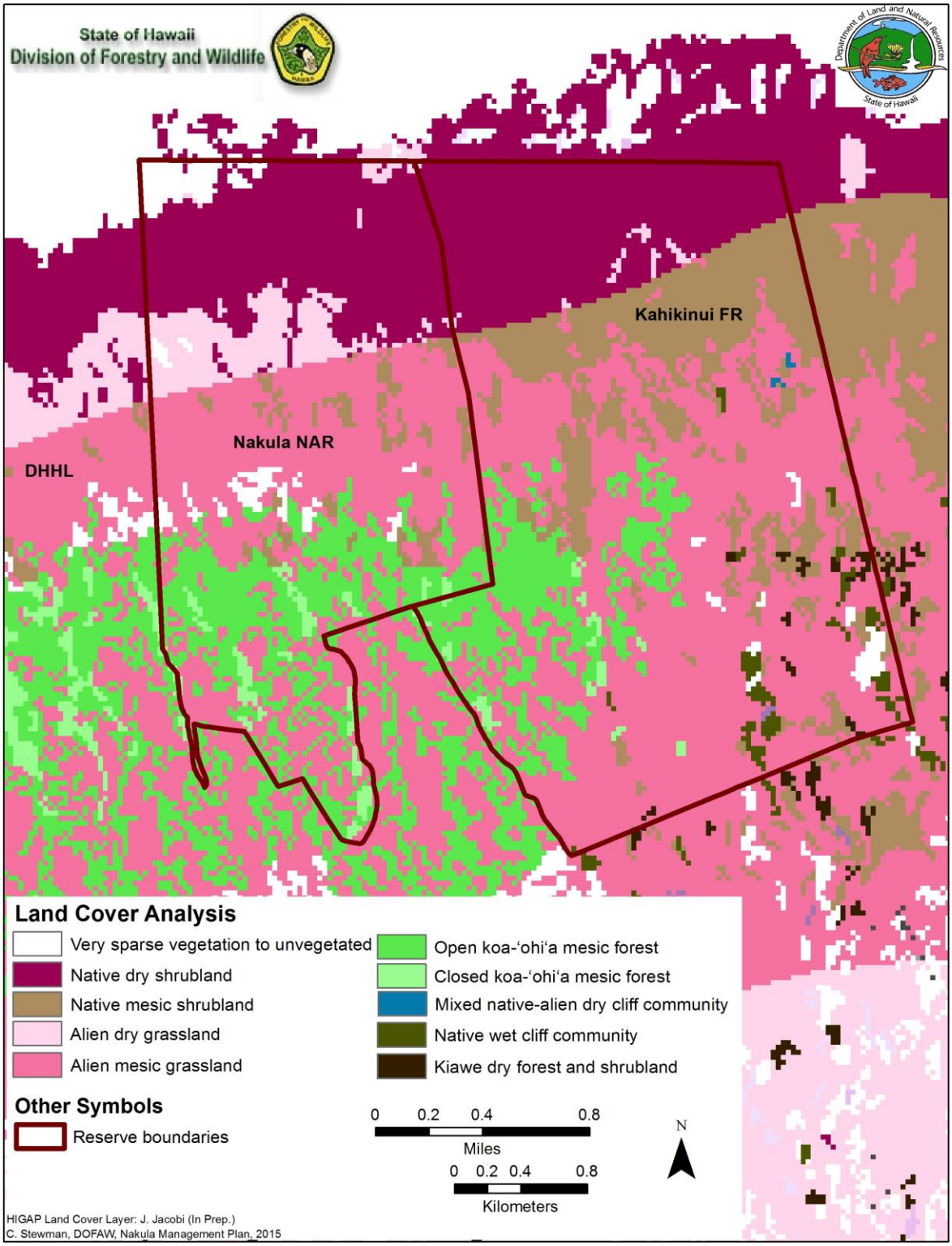


*Figure 9. Existing vegetation conditions of Nakula NAR.*

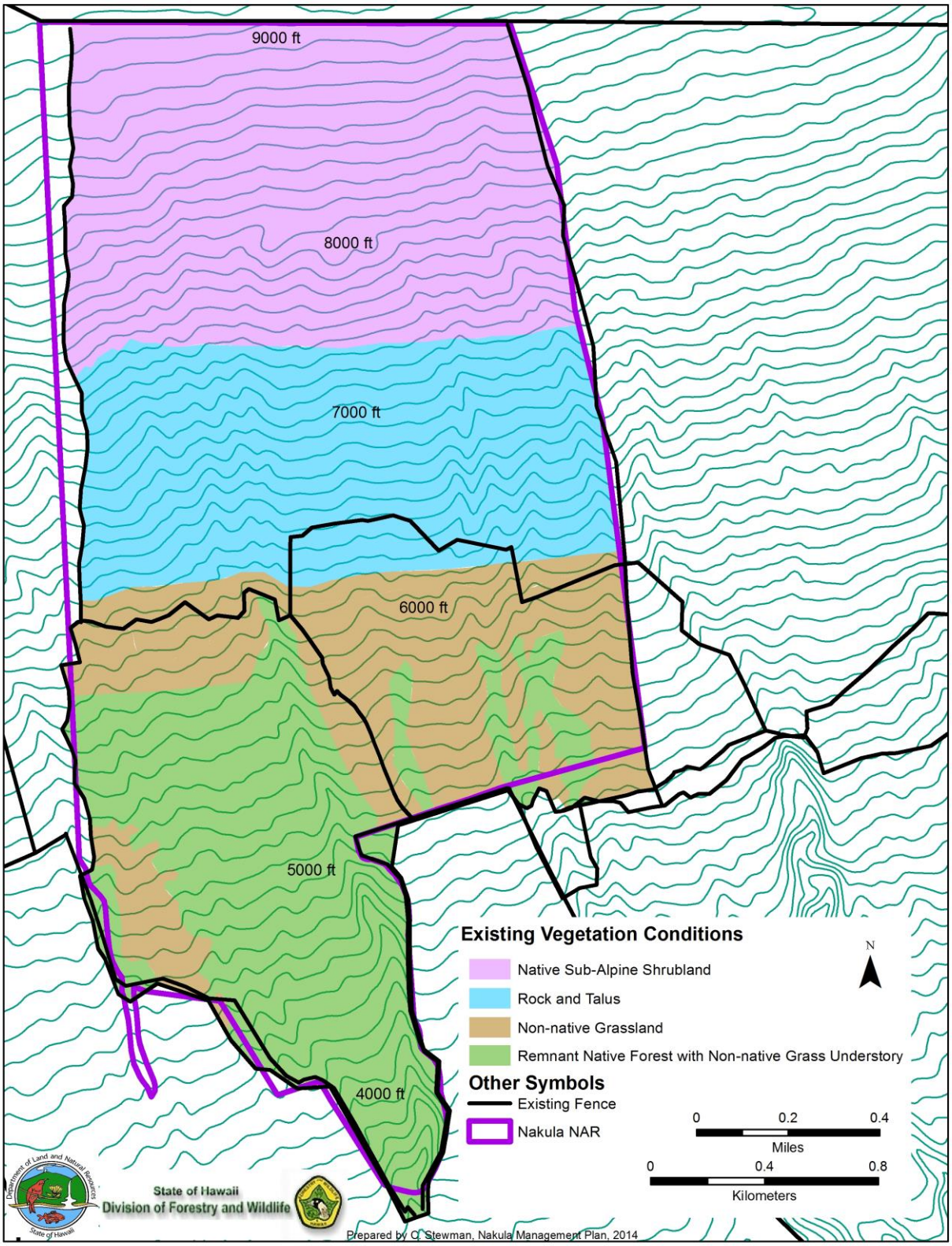


*Figure 10.* Diplazium molokaiense *(Endangered)*

There are numerous endangered and/or rare Hawaiian plant species in the NAR as well as a number of species recorded from similar habitat or with similar habitat requirements in both the immediate surrounding area, as well as other locations, that could potentially occur within the NAR. These species and other species are considered appropriate for reintroduction in the NAR (Table 1) due to it being suitable habitat, or in their historic range. Reintroduction into the NAR would also help address overall recovery of these species on a landscape scale. Nakula NAR is expected to provide both protected and actively managed habitat for populations of numerous endangered and/or rare Hawaiian plant species as part of DOFAW's overall plant recovery strategy.

Areas with similar habitat adjacent to the Reserve are designated critical habitat for various plant species including *Argyroxiphium sandwicense* ssp. *macrocephalum, Bidens micrantha* ssp. *kalealaha*, *Neraudia sericea, Diellia erecta, Diplazium molokaiense* and *Huperzia mannii*.

*Table 1. Endangered and rare plant species historically and/or currently found in or near Nakula NAR (Hank Oppenheimer, personal communication).*

| Scientific Name | Common Name | Status* | Location** |
|---|---|---|---|
| *Argyroxiphium sandwicense ssp. macrocephalum* | ʻahinahina, Haleakalā silversword | E | 2 |
| *Asplenium peruvianum var. insularum* | | E | 1 |
| *Bidens micrantha ssp. kaleaha* | koʻokoʻolau | E | 1 |
| *Cyanea comata* | | SOC | ? |
| *Cyanea obtusa* | haha | C | 2 |
| *Cyrtandra bisserata* | haʻiwale | SOC | 1 |
| *Cytrandra oxybapha* | haʻiwale | C | 2 |
| *Cystopteris douglasii* | | SOC | 2 |
| *Diellia erecta* | | E | 1 |
| *Diplazium molokaiense* | | E | 1 |
| *Geranium arboreum* | | E | 2 |
| *Hillebrandia sandwicensis* | | SOC | 1 |
| *Huperzia mannii* | | E | 2 |
| *Neraudia sericea* | | E | 2 |
| *Kadua foliosa* | | SOC | ? |
| *Ochrosia haleakalae* | holei | C | 2 |
| *Phyllostegia ambigua* | | SOC | 2 |
| *Phyllostegia haliakalae* | | E | 1 |
| *Ranunculus hawaiensis* | makou | C | 2 |
| *Ranunculus mauiensis* | makou | C | 2 |
| *Sanicula sandwicensis* | | SOC | 2 |
| *Santalum halekalae* | ʻiliahi | SOC | 1 |
| *Schidea inflexa* | | SOC | ? |
| *Sisyrinchium acre* | | SOC | 2 |
| *Stenogyne haliakalae* | | SOC | ? |
| *Zanthoxylum hawaiiensis* | ʻaʻe | E | 2 |

* Status E = Federally listed as Endangered, C = Candidate for listing, SOC = Species of Concern

**Location 1 = recorded from NAR, 2 = recorded from lands adjacent to NAR with similar habitat; could occur within NAR or be restored in the NAR. ? = possibly extinct, recorded from NAR vicinity

### 1.1.6 Native wildlife

The Reserve currently supports two endemic native forest birds (Table 2). The area is identified as a future recovery site for three endemic forest bird species although these species are not currently present: the endangered kiwikiu or Maui parrotbill (*Pseudonestor xanthophrys;* Figure 11) and the endangered ʻakohekohe or crested honeycreeper (*Palmeria dolei*) (U.S. Fish and Wildlife Service (USFWS) 2006; State of Hawaiʻi 2015) as well as the rare Maui ʻalauahio or Maui creeper (*Paroreomyza montana*). Recovery areas are habitat that will allow for the long-term survival and recovery of rare or endangered Hawaiian forest birds.

The endangered nēnē or Hawaiian goose (*Branta sandvicensis;* Figure 12*)* and state listed as endangered Pueo or Hawaiian Owl (*Asio flammeus sandwichensis*) also occur in the area. The endangered ʻuaʻu or Hawaiian petrel (*Pterodroma sandwichensis*) is also known from the region, but is currently present only in very small numbers in subalpine areas within the Reserve due to impacts of feral ungulates and non-native predators such as cats (*Felis silvestris catus*) and rats (*Rattus species*). Baseline surveys in 2012 and 2013 discovered eight burrows in upper elevation portions of Nakula NAR and Kahikinui Forest Reserve (Maui Nui Seabird Recovery Project (MNSRP) internal report).

*Table 2. Native birds (endemic/indigenous to Hawaiʻi) historically and/or currently found in or near Nakula NAR.*

| Taxon | Common Name | Federal Status |
|---|---|---|
| *Asio flammeus sandwichensis* | Pueo or Hawaiian short-eared owl | Endemic |
| *Branta sandvicensis* | Nēnē or Hawaiian goose | Endemic - Endangered |
| *Hemignathus virens* | ʻAmakihi | Endemic |
| *Himatione sanguinea* | ʻApapane | Endemic |
| *Palmeria dolei* | ʻAkohekohe or crested honeycreeper | Endemic - Endangered |
| *Paroreomyza Montana* | Maui ʻalauahio or Maui creeper | Endemic |
| *Pluvialis fulva* | Kōlea or Pacific golden plover | Indigenous |
| *Pseudonestor xanthophrys* | Kiwikiu or Maui parrotbill | Endemic - Endangered |
| *Pterodroma sandwichensis* | ʻUaʻu or Hawaiian petrel | Endemic - Endangered |


*Figure 11. Kiwikiu (Endangered).*

*Figure 12. Nēnē (Endangered).*

Appendix B contains a summary of all bird species known from the Reserve, both native and non-native.

Hawai‘i’s only endemic land mammal, the ‘ōpe‘ape‘a, or endangered Hawaiian hoary bat (*Lasiurus cinereus semotus*; Figure 13), is found in the Reserve (Todd et al, in prep). The Hawaiian hoary bat is an endangered species found on all the Main Hawaiian Islands except Niʻihau. Current population estimates range from a few hundred to a few thousand, but the actual number remains essentially unknown. According to the state Comprehensive Wildlife Conservation Strategy (2005), primary threats include habitat loss (especially tree cover), pesticides, predation, and roost disturbance. Nakula NAR offers potential for overall bat recovery, as well as a mitigation site addressing bat losses from wind energy, and other infrastructure developments.

*Figure 13. Hawaiian hoary bat (Endangered).*

Invertebrates in the area are poorly studied, but the Reserve is likely to be important habitat for native insects and snails and further research and survey is needed. Arthropod abundances were assessed at the Reserve as part of a study to assess the arthropod prey base for potential bird reintroduction (Peck *et al.* 2015). *Manduca blackburni*, the endangered Blackburn’s sphinx moth, is present on the south slope of Haleakalā and has critical habitat near (although not within) the Reserve. However, suitable habitat for the moth’s native food plant tree, ‘aiea (*Nothocestrum latifolium*) usually occurs at lower elevation areas below 4,000 ft, and the Reserve contains only a small portion of habitat at that elevation.

## 1.2 Land Use

### 1.2.1 Land designation and history

The NAR was established in 2011 by Governor’s Executive Order 4365 from lands withdrawn from the Kahikinui Forest Reserve (FR). The NAR lies within the State Conservation District, Resource (R) Subzone.

The FR System was created by the Territorial Government of Hawai`i in 1903 to provide the necessary water requirements for lowland agriculture demands and surrounding communities by protecting and enhancing important forested *mauka* (mountain) lands for their abundance of public benefits and values. Nakula NAR was formerly part of a larger tract established as the Kahikinui FR on December 22, 1928. The original Kahikinui FR included mauka lands at Kahikinui, Nakula, Kaupo, Nu‘u, Wailaulau, and Papa‘anui. These lands totaled approximately 16,013 ac that are now owned by the State of Hawai‘i,

private entities and the DHHL. Management responsibility was originally given to the Territorial Department of Forestry.

Correspondence dating from that time repeatedly mentions that large herds of feral goats, as well as cattle trespassing from neighboring ranches, were considered a critical threat to the survival of this forest. Numerous attempts were made over the years to address threats posed by feral goats and cattle, including construction of cattle fences along forest boundaries, and establishing access for goat hunters. However success was very limited due to the remoteness of the location and limited resources available. Some level of goat control was achieved through public hunting; primarily in the western portion of the Forest Reserve via a road and trail that started near the lower Skyline Trail above Polipoli State Park and ended at Waiʻōpae Gulch 3.5 miles away. Access was managed and maintained by DOFAW through a cooperative agreement with the DHHL that established the Kahikinui Game Management Area. In 1984, 8,747 ac of DHHL land was withdrawn from the FR in accordance with Attorney General Opinion No. 75-3, dated March 21, 1975.

In 1994, the DHHL rescinded its access and management agreement with DOFAW. While the intent of this action was to allow DHHL to manage forest lands for the benefit of settlers, it restricted general public access to the Nakula region, including access for public hunting.

### 1.2.2 Public use

Although the public is allowed in the NAR for recreational and cultural uses, the Reserve is extremely remote and there are no currently available public access routes. With landowner permission, the Reserve is accessible through the DHHL lands to the east; or through lands owned/leased by Haleakalā Ranch to the south. These accesses are not available to the general public. The upper portion of Nakula cannot be reached from Haleakalā National Park as the park requires the public to stay on designated trails.

Some uses of the Reserve, including hiking or nature study with groups larger than ten, some types of research, scientific collecting, gathering (including Native Hawaiian religious and customary gathering rights) and commercial uses require a Special Use Permit (Hawaiʻi Administrative Rules 13-209).

The NAR was removed as a hunting unit in 2015 through Chapter 13-123, Hawaii Administrative Rules (Rules Regulating Game Mammal Hunting).

### 1.2.3 Infrastructure

Existing infrastructure primarily consists of fencing and temporary management infrastructure (e.g. management/research shelters, helicopter landing zones and management trails).

### 1.2.4 Related planning documents

*Table 3. Summary of related planning documents*

| Plan/Cooperative Effort | Comment |
|---|---|
| Hawai‘i Comprehensive Wildlife Conservation Strategy (2015) | Implements objectives 1, 2, 3, 4, and 5 |
| Kahuku Wind Power Hawaiian Hoary Bat Mitigation Plan (May 2014) | Nakula NAR project will mitigate for permitted take and provide a net benefit by increasing population numbers of the Hawaiian hoary bat via the creation/restoration of available foraging and roosting habitat. |
| Maui Forest Bird Recovery Project Workplan (2014-2015) | Summarizes restoration research planned for Nakula NAR as a preparation for kiwikiu reintroduction, bird management. |
| Maui Forest Bird Recovery Project Protocols for Restoration Trials in Nakula NAR (2012) | Description of restoration research protocols planned for Nakula NAR, as a preparation for Kiwikiu reintroduction, and bird management. |
| The Rain Follows the Forest - A Plan to Replenish Hawaii's Source of Water (DLNR, November 2011) | Portions of the Reserve are identified as a priority watershed area on the island of Maui. |
| DOFAW Statewide Assessment and Resource Strategy (SWARS) 2010 | Identifies areas of greatest need and opportunity for forests in Hawaii and develops a long-term strategy for management. Objectives include: 1.1. Identify and conserve high-priority forest ecosystems and landscapes; 2.2. Identify, manage and reduce threats to forest and ecosystem health; 3. 3. Enhance public benefits from trees and forests; 3.1. Protect and enhance water quality and quantity; 3.5. Protect, conserve and enhance wildlife and fish habitat; 3.7. Manage and restore trees/forests to mitigate and adapt to global climate change. |
| Leeward Haleakalā Watershed Restoration Partnership Management Plan (2006) | The plan describes threats and general management actions for DOFAW lands within the partnership. |
| U.S. Fish and Wildlife Revised Recovery Plan for Hawaiian Forest Birds (2006) | Supports recovery actions 1 and 2: protect and manage ecosystems for the benefit and recovery of forest birds. |
| Kahikinui Koa Forest Protection and Restoration Final Environmental Assessment (2004) | Environmental compliance for existing management actions at Kahikinui FR, including fencing of portions now designated Nakula NAR |
| U.S. Fish and Wildlife Service Recovery Plan for the Multi-Island Plant Cluster (1999) | Summarizes biological information and recovery actions needed for *Neraudia sericea* |
| U.S. Fish and Wildlife Service Recovery Plan for the Maui Plant Cluster (1997) | Summarizes biological information and recovery actions needed for *Argyroxiphium sandwicense* ssp. *Macrocephalum*, *Bidens micrantha* ssp. *kaleaha*, *Geranium arboretum*, and *Huperzia mannii* |
| U.S. Fish and Wildlife Recovery Plan for the Hawaiian Hoary Bat (1998c) | Supports objective 2: protect and manage current populations and identify and manage threats |

### 1.2.5 Partnerships

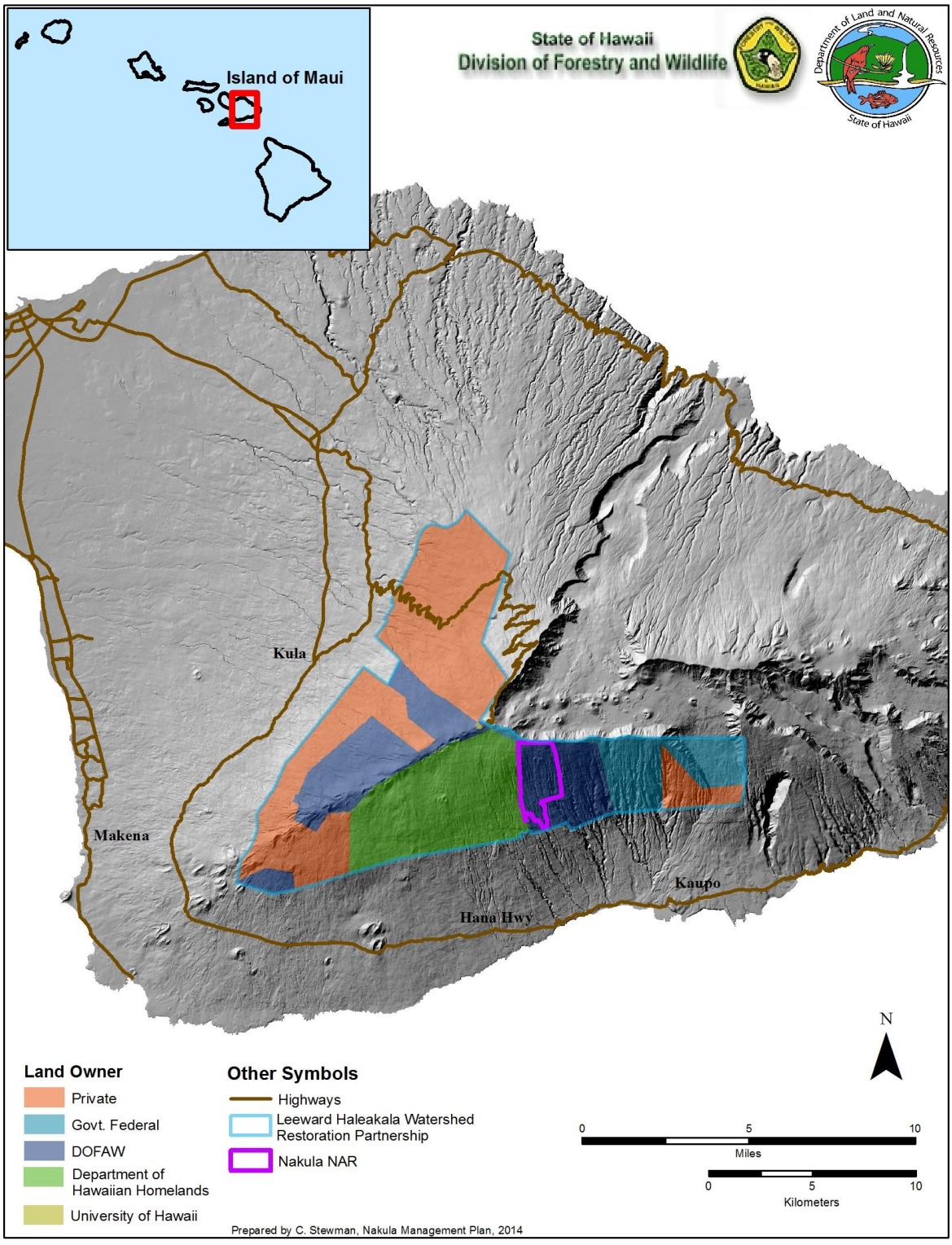
DOFAW works closely with numerous partners in order to increase the effectiveness and efficiency of management with limited resources. Many of the threats to the Reserve's resources, such as feral ungulates, invasive weeds, fire, invasive insects and introduced plant and animal diseases, occur across

land ownership boundaries. Landscape-scale forest recovery and recovery of endangered plants and animals also benefits from a partnership approach.

DOFAW is a member of the Leeward Haleakalā Watershed Restoration Partnership (LHWRP), and Nakula NAR is included within the partnership land area (Figure 14). The LHWRP includes 12 partners as well as 10 associate partners. Formed in 2003 and covering 43,000 ac (17,401 ha), the goal of LHWRP is to restore koa forests on Haleakalā from Makawao through ʻUlupalakua to Kaupō between 3,500 and 6,500 ft (1,067–1,981 m) elevation. Continued collaboration with the LHWRP, particularly adjacent landowners will enhance the effectiveness of forest recovery efforts as well as the response to regional threats like feral ungulates, weeds and fire.

NEPM staff will continue to work closely other partners including the Maui Invasive Species Committee (MISC) to jointly address incipient invasive species of plants and animals that threaten the Reserve; the Plant Extinction Prevention Program (PEPP) on rare plant recovery; the Maui Forest Bird Recovery Project (MFBRP) on forest bird recovery and forest bird habitat restoration; and the Maui Nui Seabird Recovery Project (MNSRP) on seabird restoration.

*Figure 14. Land ownership and management of the Leeward Haleakalā Watershed Restoration Partnership area.*



## 1.3 CULTURAL RESOURCES, ARCHAEOLOGICAL AND HISTORIC SITES

The Environmental Assessment for the Kahikinui Koa Forest Restoration Project (State of Hawai‘i 2004) provided background information on the cultural resources of the broader Kahikinui area. Although Nakula NAR encompasses a much smaller area, much of the information in that document is relevant, and portions of the document are summarized below.

> “Kahikinui is one of the traditional moku, or land divisions, of Maui. It is located on the southwest slope of Maui and sweeps from the dry, cliffed coastline through the better-watered uplands before terminating in the dry uplands on the southern rim of Haleakalā Crater. The origin of the name Kahikinui is not entirely certain, as it has been translated as “the great rising” (Handy 1972), as well as the “Great Tahiti” (Pukui and Elbert 1974), perhaps because of the similarities in shape and appearance between the islands of Tahiti and Maui. It may also refer to a navigational star (Pukui and Elbert 1986). Perhaps the name is meant to evoke a rich variety of meanings.
>
> Kahikinui, along with Kaupō and other moku on the west and south of Haleakalā, was extensively developed for dryland farming of ‘uala (sweet potato) and taro. Water was a limiting factor and ingenious agricultural methods were devised to conserve soil moisture. ‘Uala was often grown in makali‘i (Handy 1972), which were rocky areas specially prepared for planting. The arduous and risky nature of farming the ‘aina malo‘o – or dry lands – may account for the numerous temples to Lono, the deity responsible for rainfall and thunder (Kirch 1997). Abundant natural resources were present, including a wide variety of dryland forest trees. Perhaps even more important were marine resources such as fish, shellfish and crustaceans, and the fresh water springs that emerged near the coastline.
>
> Kahikinui and Kaupō, although not untouched during the 19th century, did not experience the intense changes in land use and population that occurred in many locations in Hawai`i. One of the few visitors was the French explorer Jean-François de Galoup de la Pérouse, who reported only a few small villages along the coast. Archaeological work reported in Kirch (1997) indicates that a much larger population was still living mauka, around 1,000 feet in elevation, which were hidden by distance and topography from la Pérouse.
>
> In the Mahele of 1848, which installed a Western system of land title that ultimately disenfranchised many commoners, Kahikinui wound up in the hands of the government and in the personal holdings of Princess Ruth Ke`elikolani. Very few kuleana were awarded in the Kahikinui area. Just as disease began to decimate the population and more and more rural Hawaiians were drawn to the attractions of the growing port cities, cattle ranching began to dominate Kahikinui, no doubt aided by the ability to secure title to land. By the 1880s, a Portuguese named M. Pico (also called “Paiko”) was ranching Kahikinui, and much of Kaupō was also being ranched. The Hawaiian Homes Commission Act of 1920 established lands held in trust for the benefit of Native Hawaiians, and the government lands in Kahikinui were part of this trust. Lands above 4,000 feet in elevation were placed in the forest reserve of the territorial

government, and lands below 4,000 feet were leased to cattle ranchers. The traces of a long Hawaiian occupation were gradually obscured but not erased by alien vegetation, cattle trampling and soil erosion. The forest resources that sustained the Hawaiian culture also gradually degraded, and as late as 1910 the forest was much denser (Rock 1913).

According to the planning practicum cited previously (UH-Manoa, DURP 2000), the preserved, hidden resources of Kahikinui (and, for that matter, parts of Kaupō) offer special, almost unique values for the perpetuation of Hawaiian culture:

"Aside from the abundance of natural resources, Kahikinui is endowed with a wealth of cultural assets, gifts left by the ancestors. Because Kahikinui has experienced relatively little physical impact from the post-contact period such as urban development and large-scale agricultural use, it contains an abundance of intact sites, which include villages, heiau, agricultural structures and shrines. Sites are scattered across the moku in relative abundance with particularly high concentrations along the coastline and in the upland areas. Kahikinui may well be the only area in the State where this kind of concentration and variety of sites exist and as such it is an excellent living laboratory to study past Hawaiian life and land usage" (UH-Manoa, DURP 2000).

According to an ethnobotanical study of a site in leeward Haleakalā (Medeiros at al 1994), forest restoration is of cultural importance because many plants with traditional uses are rapidly disappearing from the area. One example is the famed mature koa trees of Haleakalā, which are prized for canoes (Fielding 2003) but are failing to regenerate.

Preserving and enhancing the cultural resources of Kahikinui, Kaupō, and other regions of leeward Haleakalā – which are increasingly seen as including biological resources - is the goal of a number of governmental and non-profit organizations. DHHL, in response to request from beneficiaries, awarded a number of homesteads in Kahikinui. The Kahikinui homesteaders have a community organization, Ka ʻOhana O Kahikinui, and are active in programs that promote conservation and cultural preservation. There is growing recognition that cultural perpetuation is inextricably tied to the preservation and restoration of the unique biological resources that Hawaiians utilized and husbanded for a wide variety of purposes over the course of centuries" (State of Hawaiʻi 2004).

Although a number of archaeological investigations have been conducted in the general region over the years, very few have extended to the higher elevations of the Reserve. An archaeological reconnaissance study and cultural practices assessment of the area was conducted in 2004 as part of the Environmental Assessment for the Kahikinui Koa Forest Restoration Project (State of Hawaiʻi 2004). The archeological survey primarily covered the area around the parcel perimeter, and no historic sites were recorded there. The report states that due to the steep terrain and high elevation in the area, it would be "expected to contain few sites, especially given the rugged topography of the area. If present, sites would include rock shelters, cairns, quarry sites, petroglyphs, ridge trails or other temporary-use sites." No ongoing cultural practices were identified.

## 1.4 SUMMARY OF MAJOR THREATS AND MANAGEMENT ISSUES

### 1.4.1 Invasive Species - Ungulates

The primary ungulates of concern in Nakula are feral goats (*Capra hircus;* Figure 15); however, feral cattle (*Bos taurus*), feral pigs (*Sus scrofa*), and axis deer (*Axis axis*) also pose a threat.

Medeiros *et al.* (1986) reported that goats had the most destructive impact on native vegetation on the south slope of Haleakalā as a whole under present conditions and have the greatest impacts in the Koa and Koa/ʻŌhiʻa zone, limiting reproduction of most native species and resulting in loss of forest and watershed deterioration.

Feral pigs destroy native vegetation and prevent its regeneration by eating, trampling, and digging up plants, and may accelerate the invasion of weed species by dispersing seeds on their coats and in their droppings. Pig disturbance of native ground cover through rooting and wallowing facilitates the invasion and establishment of weeds. In addition, pig wallows provide mosquito breeding sites that can promote the spread of avian diseases such as avian malaria and pox – the two most deadly diseases for native forest birds. The continued presence of feral pigs contributes to loss of native plants, loss of ground-nesting Hawaiian birds (e.g. nēnē, pueo) and loss of ground cover that adversely affects groundwater retention.

Feral cattle are present on adjacent DHHL lands to the west and were present in Nakula NAR and Kahikinui FR previously, but were removed when the fences were completed (2005–2013).

Axis deer were introduced to east Maui in 1959 and populations have greatly increased and spread across the island, negatively impacting farmers, ranchers, native forests and watersheds through browse and bark stripping (USGS 2008). Deer have been observed in and near the Reserve. The Maui Axis Deer Working Group, comprised of local farmers, ranchers, state and local agency personnel, tourist industry representatives, and hunters, formed in 2010 to address the Axis deer problem on Maui. The Working Group is developing a plan and initiating Axis deer management to reduce negative impacts across the island.

*Figure 15. Feral goats in the canyon near the eastern boundary of Nakula NAR.*

### 1.4.2 Invasive Species - Plants

Invasive non-native plants, or weeds, constitute a severe threat to the native ecosystems in the NAR. Certain priority weeds are problematic because they can establish and survive in undisturbed native forest; disperse long distances via wind or birds; affect large portions of land; displace native vegetation; grow and reproduce rapidly; convert diverse assemblages of native plants to monocultures of alien species; and encourage fire by increasing fuels on formerly natural fire breaks (i.e. lava flows). These weeds can displace distinctive native flora, resulting in a loss of species diversity and eventually in more pronounced and permanent changes to ecosystem function such as alteration of primary productivity, nutrient cycling, and hydrology. Many invasive weed species completely replace native vegetation resulting in total loss of native habitats thereby negatively affecting native bird, arthropod and snail communities.

Invasive weeds with great potential for spreading and causing habitat modification are identified in this plan as high priority for control or eradication. Weed species were prioritized based on observed invasiveness and other criteria including growth form, dispersal mechanisms, ability to displace native vegetation and ability to alter ecosystem cycles (water, nutrients and succession). High priority invasive weeds present and currently targeted for control in Nakula include:

- Tree poppy (*Bocconia frutescens*)
- Australian tree fern (*Sphaeropteris cooperi*)
- Silk oak (*Grevillea robusta*)

There are numerous additional weeds currently present that may be targeted for control incidentally during other management activities and/or as resources allow. These include but are not limited to species such as prickly Florida blackberry (*Rubus argutus*), fire tree (*Morella faya*), guava (*Psidium guajava*), hill raspberry (*Rubus niveus*) and white passionflower (*Passiflora subpeltata*).

Additionally, the rhizomatous mat or thatch forming perennial grasses such as kikuyu grass (*Pennisetum clandestinum*), velvet grass (*Holcus lanatus*), and vernal grass (*Anthoxanthum odoratum*), while providing excellent forage for introduced ungulates, form largely polyotypic (multiple grass species) ground layers that prevent natural regeneration and establishment of native herbs, shrubs and trees. The combination of long-term ungulate grazing with the dominance of these grass species have contributed significantly to deforestation of the Reserve into open parkland (Figure 16). A focus of planned management actions will be to re-establish a native canopy to shade out these grass species and replace them with a more diverse native understory.

Multiple additional weed species that are a serious concern to land managers are present in adjoining areas and have not yet been detected in the Reserve (e.g. Christmas berry (*Schinus terebinthifolius)*). It is a high priority to prevent the establishment of these species in the NAR. Other weed species may be added to the Reserve priority weed list if monitoring shows their range and abundance increasing in native ecosystems targeted for management.

*Figure 16. Invasive grass in upper Nakula NAR.*

### 1.4.3 Invasive Species - Other Animals

A variety of non-native small animals have the potential to become serious pests to the biodiversity found in Nakula. Feral cats, rats, mice, mongooses, dogs and birds are known to consume or compete with native species and may contribute to the spread of invasive weeds. Feral cats kill birds, which nest, feed, and roost in trees, as well as native sea birds and other species that nest on the ground or in burrows. Rodents prey on native birds (particularly females on the nest), eggs, nestlings, native land snails and endemic invertebrates and are also known to eat the seeds, fruits and/or strip the bark of native plants. Non-native birds may consume (barn owl) and compete with native forest birds for food, nesting sites and other resources and act as reservoirs for avian diseases. Non-native birds also contribute to the spread of weeds by eating the fruits of weedy species and spreading seeds and foraging on native seedlings. Jackson's chameleon (*Chamelaeleo jacksonii*) is a potential threat as it is known from nearby areas and it preys upon native invertebrates, such as insects, spiders, and snails.

Non-native invertebrates are present, but largely undocumented, and can consume native plants, interfere with plant reproduction, predate or act as parasites on native species, transmit disease, affect food availability for native birds, and disrupt ecosystem processes. For example, the black twig borer (*Xylosandrus compactus*) is harmful to numerous native tree species. The invasion of the yellowjacket wasp (*Vespula pennsylvanica*), voracious predators of numerous species of native invertebrates, is of concern. Slugs (particularly *Derocerus laevis* and *Limax maximus*) consume fruit from native plants and prey on seedlings and mature plants. Mosquitoes (*Aedes albopictus* and *Culex quinquefasciatus*) transmit deadly diseases to native birds.

### 1.4.4 Fire

Wildfires leave the landscape bare and vulnerable to erosion and non-native weed invasions. Hawaii's flora evolved with infrequent, naturally-occurring episodes of fire, so most native species are not fire-adapted and are unable to recover well after wildfires. Recent fires at Kahikinui in 2009 burned up to approximately 4,000 ft (1,219 m) elevation. The abundance and biomass of non-native grasses in the NAR will increase over the short-term due to removal of feral ungulates. This will increase the Reserve's vulnerability to the threat of fire, particularly during periods of extended drought. Invasive, non-native plants, particularly grasses, are often more fire-adapted than native species and will quickly exploit suitable habitat after a fire. The principal human-caused ignition threats are catalytic converters and other hot surfaces of vehicles or heavy equipment. The principal natural ignition source in this area is lightning.

### 1.4.5 Disease

Introduced diseases and pathogens can threaten both native animals and plants. The introduction of new diseases and pathogens, in addition to those currently known, is possible. Avian pox and avian malaria are mosquito-transmitted diseases that currently affect native Hawaiian birds. In the extreme isolation of

the Hawaiian Islands, birds evolved in the absence of these diseases and lost their natural immunity. Avian pox is caused by a virus (*Avipoxvirus*) and avian malaria by a single-celled parasite (*Plasmodium relictum*). For some bird species infection with these diseases is almost always fatal.

Other diseases also pose threats to the watershed, humans and wildlife. Cats are host of a potentially fatal disease called toxoplasmosis. In Hawai‘i, toxoplasmosis has killed native Hawaiian birds and also poses a threat to marine mammals. In addition to threatening wildlife, toxoplasmosis poses a significant health risk to pregnant women. Feral pigs can serve as reservoirs and vectors of diseases such as brucellosis and pseudorabies which are transmissible to humans, wildlife, pets and livestock. Pigs also spread fatal diseases such as fecal bacteria (*Enterococcus*) and *Escherichia coli* (*E. coli*), while pigs and other small mammals, especially rodents, spread leptospirosis.

Introduced plant diseases such as ‘ōhi‘a rust (*Puccinia psidii*) and koa wilt (*Fusarium oxysporum* f. sp. *koae*) have the potential to impact the major components of the forest throughout the NAR. ‘Ōhi‘a rust affects other taxa of the Myrtaceae or myrtle family. In severe infections, growing tips wither and die back. Koa wilt is a serious, often fatal fungal disease of the native koa tree. Trees affected with the disease rapidly lose their canopies and may die within a few months.

### 1.4.6 Climate Change

Climate change may affect the NAR through altering rainfall patterns and amounts. Changing climate may affect the abundance and seasonality of precipitation, thereby altering forest composition, growth and structure. Long-term shifts in the inversion height may accompany global climate change (Giambelluca and Nullet 1991). Rare ecosystems and species may be affected by relatively rapid changes in precipitation, temperature, and humidity that result from a rapid and drastic change in regional or local climate patterns. Detrimental invasive species may change their distribution and abundance due to changes in the climate (e.g. mosquitoes may be more frequently found at higher elevations due to warming temperatures). Increases in mosquito populations in the upper elevations would increase the incidence of avian disease, negatively affecting remaining native forest bird populations.

## 1.5 Overview of Existing Management

In general, existing and ongoing management has consisted primarily of threat abatement (fencing and ungulate management, non-native invasive plant control), restoration (forest recovery and rare plant restoration), and research and monitoring. Major accomplishments are summarized below.

### 1.5.1 Fencing and Ungulate Management

DOFAW has installed several 7.5–8 ft hogwire fences in Nakula NAR (Figure 17 and Figure 29). The fences exclude ungulates, allowing regrowth of koa forest and other native habitat, and will allow for

subsequent reintroduction of endangered forest birds to an improved habitat on leeward Haleakalā. The following fences and ungulate management projects have been completed:

- In 2005, DOFAW completed a fence for a portion of the Nakula tract. The project was undertaken in cooperation with neighboring landowner DHHL, as the fence protected forest on their lands as well.
- In July 2012, a fence was completed to enclose a management unit of 420 ac (170 ha), and all ungulates were removed from within the unit by November 2012. This unit (Wailaulau Unit) enclosed the best remaining forest in the NAR.
- In 2013, additional portions of the lower NAR were fenced in a management unit which also includes adjacent DOFAW lands of upper Kahikinui FR (Mauka Unit), which is 2,350 ac. Ungulate control in this unit started in 2014 and is ongoing.
- In 2014, staff completed construction of a 254 ac (103 ha) unit. This unit (West Pāhihi Unit) enclosed mesic Koa/ʻŌhiʻa forest habitat in both the Reserve and Kahikinui FR.
- Fence inspections and maintenance of all existing NAR fences occurs 2–4 times/year as well as after major storms.

*Figure 17. Installation of fence unit in upper Nakula NAR.*

### 1.5.2 Forest Recovery

Reforesting Nakula NAR to ultimately return the degraded/lost past vegetation communities (Gagne and Cuddihy in Wagner *et al.*, 1999) is a primary goal of ongoing NAR management. The focus of initial efforts has been in the Wailaulau Unit.

In October 2013, NAR staff started forest recovery in portions of the Wailaulau Unit with no existing tree canopy. At upper elevations within the Wailaulau Unit plantings occurred in areas with a higher native component of native grasses including hairgrass (*Deschampsia nubigena*) and native shrubs and also in a large cinder erosion scar. These areas had more interstitial spaces in the ground layer to allow for the establishment of plantings without spraying non-native pasture grasses prior to planting. In a 15 ac portion of the Wailaulau Unit on a ridgeline near the eastern fence of the unit, restoration included removal of the thick layers of non-native pasture grasses to reduce competition between non-native grasses and newly planted seedlings and enhance the success of restoration planting efforts. The invasive grassland was sprayed with an herbicide using a boom sprayer mounted on a helicopter (at an approximate cost of $300/ac) to enhance the success of forest recovery efforts.

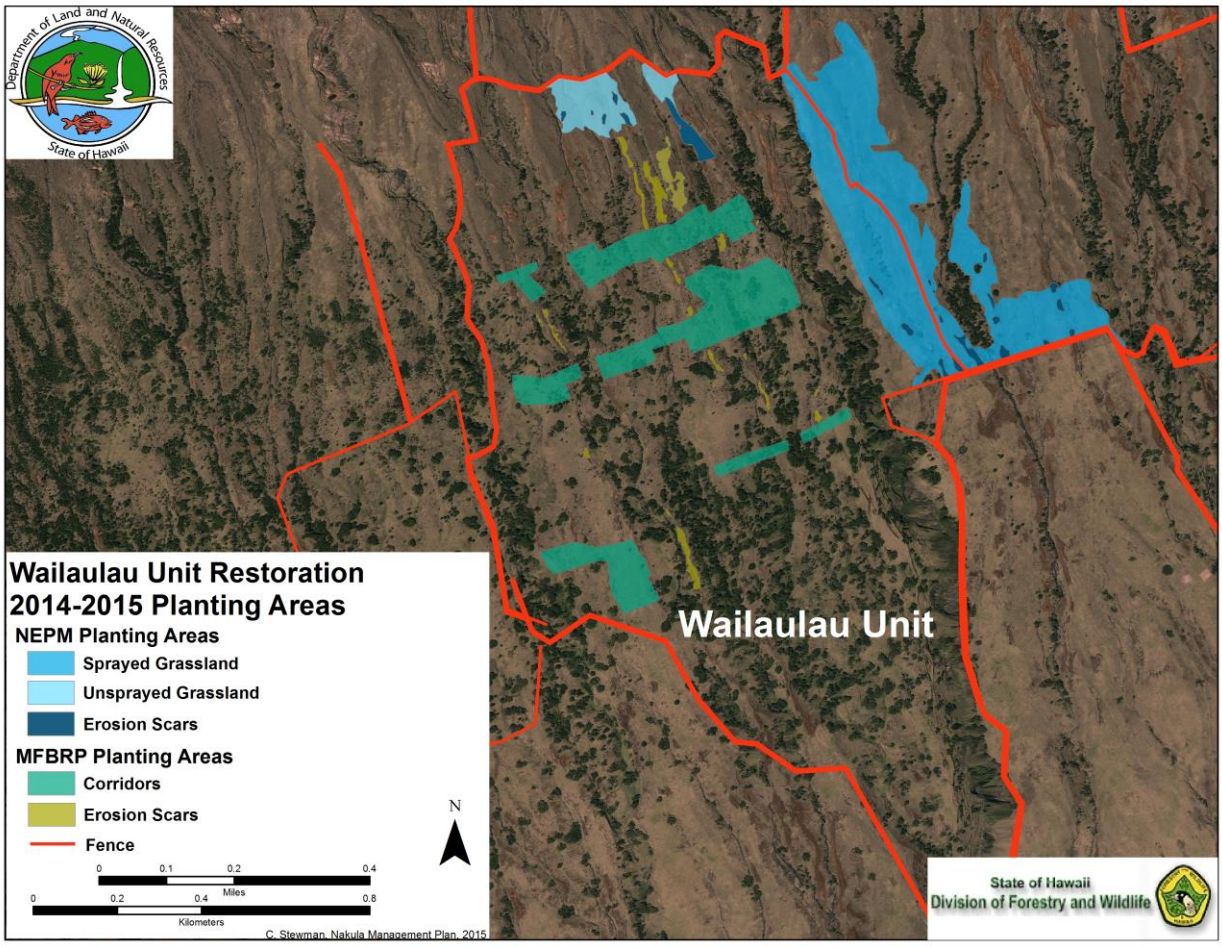
From February 2014 to August 2015, staff planted 40,550 native trees and shrubs into 57.2 ac in the Wailaulau and West Pāhihi Management Units including sprayed grassland (48 ac), upper elevation erosion scars (2.8 ac) and unsprayed grassland (6.2 ac) (Figure 20). Species planted included koa, ʻōhiʻa (Figure 18), aʻaliʻi, māmane, naio and ʻiliahi, which were grown by a contract nursery from seed collected from the area. Planting techniques involved removing dead grass biomass from the immediate planting site and then drilling a hole for planting with an auger drill (Figure 19). Different species of trees were interspersed, with a tree spacing of 20–30 ft for koa, 15–20 ft for ʻōhiʻa, 10 ft for māmane, 20–30 ft for naio, and 5–10 ft for ʻaʻaliʻi. Initial six month and annual survivorship monitoring of a representative sample of plantings has shown high survivorship for all species planted. One-year survival was 81% for sprayed grassland, 82% for erosion scars and 58% for unsprayed grassland. Regular monitoring will continue to inform management efforts.

In 2014–2015, Maui Forest Bird Recovery Project (MFBRP) staff, interns and volunteers also planted in erosion scars and open corridors within portions of the Wailaulau Unit to help connect existing vegetation and facilitate future seed dispersal (Figure 20). Approximately 16,700 plants of ten different common native tree and shrub species were planted across more than 30 ac. Planting sites were prepared with minimal herbicide application (~6.5 ft circle) for each tree and sites were spaced approximately 10 ft apart. The survival rate of these outplantings is 82% (10 species).

*Figure 18. ʻŌhiʻa* (*Metrosideros polymorpha*) *seedling.*

*Figure 19. Volunteer outplanting seedlings.*

*Figure 20. Wailaulau Unit forest restoration planting areas*



### 1.5.3 Rare Plant Restoration

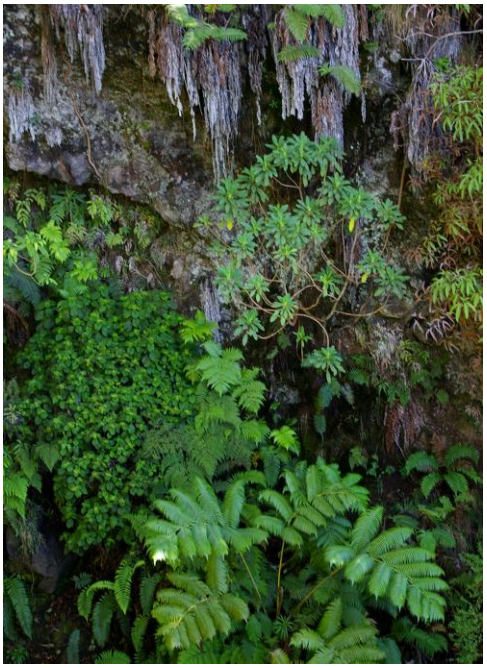


*Figure 21. Gulch habitat with more intact native vegetation.*

Nakula NAR is expected to provide both protected and actively managed habitat for populations of numerous endangered and/or rare Hawaiian plant species as part of the DOFAW's overall rare and endangered native plant recovery strategy. An exhaustive list of the plant species requiring such recovery actions, and which comprise appropriate taxa for what the Nakula NAR provides in its plant communities, substrate and habitat types, is under development. Hawai'i Plant Extinction Prevention Program (PEPP) has already been actively working in the Reserve conducting management actions specific to rare plant recovery. PEPP is focused on preventing the extinction of taxa with fewer than 50 individuals in the wild. Activities include rare plant surveys to locate wild individuals, collection of propagation and genetic storage materials, reintroduction through outplanting and monitoring the growth and survival of outplanted individuals. Reintroduction is occurring within the fenced Wailaulau Unit in the gulch bottoms, as these areas provide more intact native habitat. Outplanting is dependent on the availability of nursery stock, and PEPP has outplanted the following rare species in the Reserve: *Geranium arboreum, Phyllostegia ambigua, Phyllostegia haliakalae* and *Ranunculus mauiensis*.

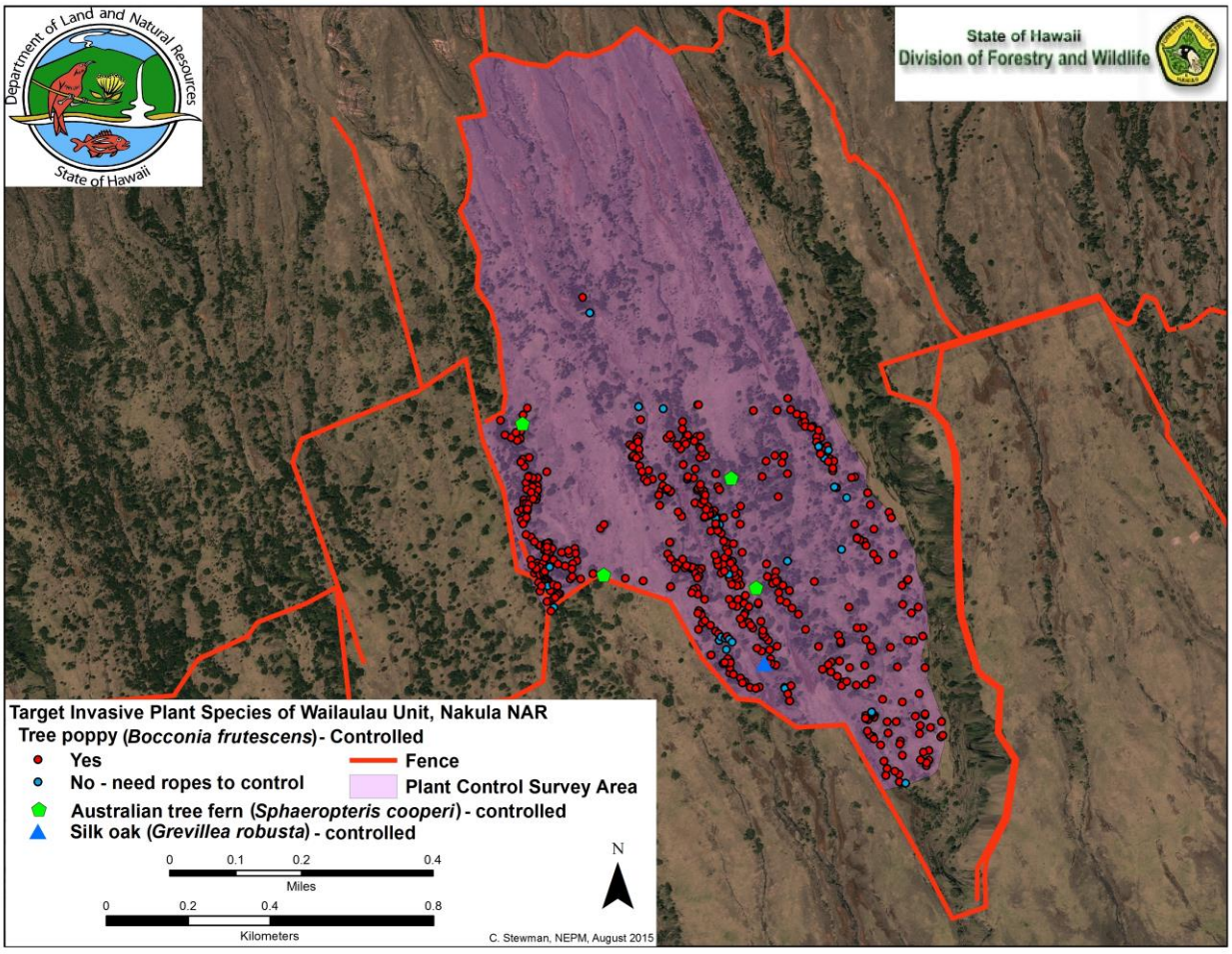
*Table 4 Summary of PEPP Outlanting in Nakula NAR (data provided by Hank Oppenheimer)*

| Taxon | # of Populations | # of Individuals Planted |
|---|---|---|
| *Geranium arboreum* | 2 | 48 |
| *Phyllostegia ambigua* | 1 | 12 |
| *Phyllostegia haliakalae* | 4 | 89 |
| *Ranunculus mauiensis* | 5 | 139 |

### 1.5.4 Non-Native Invasive Plant Control

Invasive plant mapping and control efforts using a combination of mechanical and focused chemical control methods were initiated in the spring of 2014 and have primarily targeted tree poppy (*Bocconia*) and limited occurrences of Australian tree fern in the Wailaulau Unit. 295 ac of the Unit were surveyed on foot or by helicopter for the presence of *Bocconia* and other invasive plants by LHWRP and NEPM staff (Figure 22). All populations were mapped and as much as possible, controlled immediately. Tree poppy stems are cut and then herbicide is applied to the freshly cut stem to prevent resprouting. PEPP staff has also done opportunistic control of tree poppy and Australian tree fern encountered while searching for, reintroducing and monitoring rare plants.

*Figure 22. Invasive plant control.*




## 1.5.5 Research and Survey

Maui Forest Bird Recovery Project (MFBRP) has been researching forest restoration in the Reserve within the Wailaulau Unit. The main goal of the MFBRP work in the Reserve is to determine the most efficient and cost effective methods to enhance and restore forest for release of endangered forest birds, particularly the kiwikiu or Maui parrotbill. The project has accomplished the following activities between 2012 and 2014:

- Finalized a plan for restoration trials with the American Bird Conservancy.
- Set up a field camp and weather station.
- Established restoration trial plots and collected seeds for propagation and outplanting.
- Applied experimental treatments to the plots. Trials included outplanting, seed scatter, natural regeneration and tree canopy plots with four treatments for non-native grass (control (no

treatment), scarification or biomass disruption (manually clearing grass with weed-eater or mattock), herbicide, and herbicide with scarification.

- Monitored trial plots and treatment results (refer to Appendix C for preliminary results). Collected information included slope, aspect, planting (dibble tube size), presence of tree protection shelter, rainfall, temperature, and treatment, and examined treatments for correlation with survival. This information will allow subsequent protocols and locations to be refined to increase seedling production and survival.
- Installed predator abundance grid.
- Conducted infill planting within existing canopy gaps in remnant forest corridors and erosion scars (see description under 1.5.2).

Maui Nui Seabird Recovery Project (MNSRP) conducted baseline surveys in 2012 and 2013 to assess the distribution and abundance of ʻuaʻu or Hawaiian petrel. These surveys also confirmed the presence of non-native predator species such as barn owls, cats and rats that are the key limiting factors in the survival of this species.

ʻŌpeʻapeʻa or Hawaiian hoary bat presence and activity was monitored in the Reserve in 2012–2014 by USGS Biological Resources Division and a report is under preparation (Todd *et al.*, in prep). The objective of the research was to determine species distribution, areas of habitat occupancy (high, low or zero), seasonal habitat through an annual cycle, identification of bat foraging areas and recommendations for bat management. Portions of Nakula NAR and the adjacent FR are included in the Kahuku Wind Power Hawaiian Hoary Bat Mitigation plan, finalized in 2014. The objective of the mitigation effort is to implement measures that will not only mitigate for the permitted take, but provide a net benefit to the species by increasing population numbers of the Hawaiian hoary bat via the creation/restoration of available foraging and roosting habitat. Management actions (fencing, ungulate control and forest recovery) in the West Pāhihi Unit (Figure 29) will increase bat habitat and are included in the bat mitigation plan. USGS monitoring data provides a baseline of hoary bat echolocation activity in the NAR and adjacent Kahikinui Forest Reserve that can be used to assess the success of Hawaiian hoary bat habitat restoration (Todd *et al.*, in prep).

Arthropod prey resources at Nakula NAR were studied by Peck *et al.* (2015) to assess the suitability of the Reserve for potential bird endangered bird reintroductions of kiwikiu and Maui ʻalauahio. This study compared arthropod prey abundances at Nakula to those at Hanawi NAR and Waikamoi Preserve, where those birds are currently found. To aid in the assessment of the arthropod prey base, the study also determined the diets of kiwikiu and Maui ʻalauahio by identifying arthropods in fecal samples.

### 1.5.6 Infrastructure Management

NEPM staff and partners have established and manage infrastructure critical for NAR management and research. There is currently a cabin in the Wailaulau Unit primarily used by the MFBRP. The NAR also contains a dozen strategically placed and regularly maintained helicopter landing zones (Figure 23) used for resource management, staff safety and transport of staff and volunteers.

*Figure 23. Helicopter landing zone to the south of the Reserve, used for transporting supplies to support management activities,*

# 2 PLANNED MANAGEMENT ACTIONS

This section describes the planned management actions. Each section includes background, objectives, a summary of planned short term and long term management actions, and a more detailed narrative description for each of the planned actions.

## 2.1 RESTORATION

### 2.1.1 Forest Restoration

**Background:** The forests of the NAR have been negatively impacted by years of feral ungulate activity. Although natural forest regeneration through the existing seed bank and koa root suckering is occurring rapidly in many areas following feral ungulate removal, more degraded areas will require active management through reforestation of common native species as well as rare species. Forest recovery is needed to restore Reserve ecosystems to a level than can support healthy and sustainable populations of native species, including rare and endangered plants and animals.

**Objectives:** Restore native forest ecosystems through reforestation.

**Actions:**

1. Seed collection and propagation.

2. Implement reforestation of common native species in targeted priority sites to reestablish native forest and shrubland (see Table 5 and Figure 24)

    - Re-establish forest canopy
    - Increase canopy cover and native species diversity in remnant native forest with non-native grass understory
    - Establish vegetation in barren areas
    - Increase native species diversity in native sub-alpine shrubland.

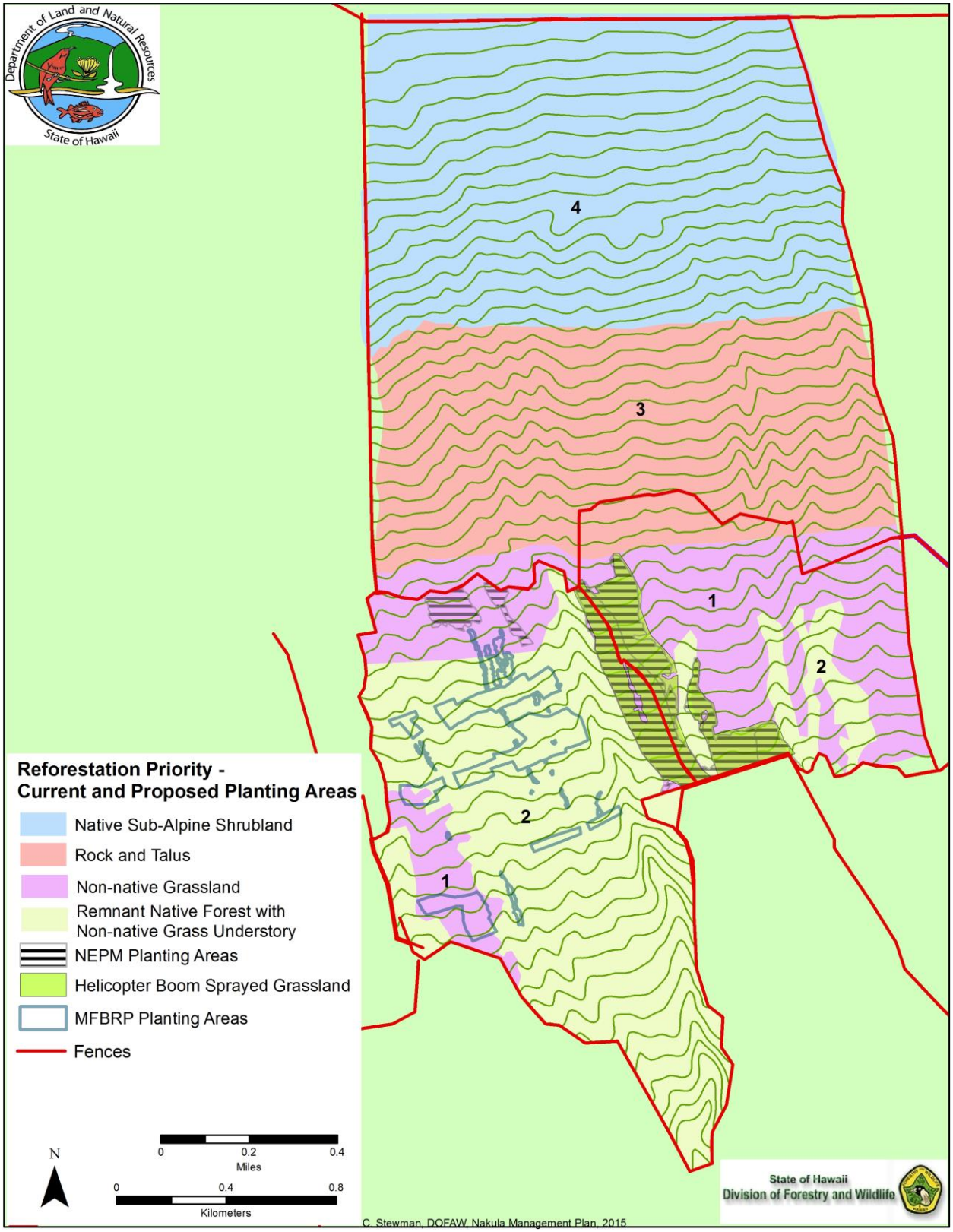
3. Rare plant restoration – Map, monitor and protect existing wild populations of rare and endangered plant species to contribute to their population stabilization and recovery and restore certain species of rare and endangered plants in appropriate protected habitat.

4. Monitor success of forest recovery actions and improve restoration strategies and techniques.

*Table 5. Forest Recovery summary (see Figure 24 for associated map).*

| | Habitat type | | | |
|---|---|---|---|---|
| | **Non-native grassland** | **Remnant native forest with non-native grass understory** | **Rock and talus** | **Native sub-alpine shrubland** |
| **Priority Level (1 = Highest, 4 = Lowest)** | 1 | 2 | 3 | 4 |
| **Acreage** | 287.8 | 368 | 370 | 477.4 |
| **Objective** | Reestablish canopy | Increase canopy cover and diversity to improve habitat for native wildlife | Establish vegetation in barren areas<br><br>Improve connectivity between smaller areas of existing forest and/or reforestation areas | Increase diversity |
| **Forest Recovery approaches for existing vegetation conditions** | Grass control and dense planting of 'pioneer' canopy species in large areas | Natural Regeneration<br><br>Infill 'pioneer' planting to close gaps in canopy<br><br>Planting of subcanopy species, especially bird & bat forage<br><br>Conversion of grass to native understory<br><br>Planting rare plants into appropriate habitat | Small scale plantings of common species in soil pockets and experimental techniques | Small scale plantings of rare/uncommon species and experimental techniques |

*Figure 24. Current and proposed planting areas within Nakula NAR.*



**Narrative Description of Actions:**

*1. Seed Collection and Propagation*

Partner cooperation and collaboration will be critical to the collection of adequate numbers and varieties of seeds to accomplish forest recovery objectives. By combining efforts with LHWRP and other partners we will be able to pool resources to do the work more efficiently and effectively. Seed collection requires a lot of time in the field monitoring seed development and then a large staff commitment to cover as much ground as possible when the seeds are ripe. In addition, seeds of appropriate species may not all be available from within the Reserve. Seed collection with partners across a larger landscape will enable collection from a greater variety of individual plants as well as species, increasing genetic variability as well as species diversity. In general, seed from local sources within or close to the NAR or from leeward Districts of Haleakalā are prioritized as seed sources. Species used in reforestation will generally be common, widespread species native to the Reserve. Seeds will be taken from as many founders as practicable. Propagation will be done using a contract nursery.

*2. Implement Forest Recovery*

Results from numerous other forest recovery research studies in Hawai‘i, including LHWRP and MFBRP, will inform the planned approach for forest recovery of Nakula. Additional research and future monitoring by NEPM staff and partners will also continue be used to refine and adapt forest recovery methods to increase success in achieving management objectives. Forest recovery will provide habitat for the critically endangered kiwikiu (Maui parrotbill), and enable the reintroductions of this species as well as restore habitat for many other endangered plant and animal species.

- Re-establish forest canopy – Priority sites include Wailaulau Unit and West Pāhihi Unit. Although the seed bank and koa root suckering may provide rapid regeneration in some areas once grazing animals are removed, more degraded areas will require more intensive management to facilitate forest recovery. Large-scale non-native grass control followed by planting of common native species may be an important step to develop a forest canopy. Planting will help jump-start natural regeneration of a native ecosystem by providing nurse trees and habitat for native insects and birds that will pollinate and disperse native seeds. Establishment of a forest canopy will allow for the reintroduction or enhancement of native plants and birds to assist in species recovery goals. Dense planting of native species may also help reduce widespread establishment of non-native invasive weed species and reduce non-native grass cover. Alternatively, other hands-on management techniques such as herbicide followed by grass removal will significantly increase the natural regeneration of early colonizing species and may be a key method to exponentially increase the native seedlings across the landscape very quickly.

- Increase canopy cover and native species diversity in remnant native forest with non-native grass understory – Priority sites include the Wailaulau Unit and gulches, which already have remnant canopy tree cover and are expected to have additional natural regeneration of canopy species through koa root suckering and the existing seed bank. Targeted planting of subcanopy, understory, rare and species important for forest bird foraging activities in appropriate habitat will

increase plant and animal species diversity, reduce cover of non-native grass understory and provide habitat and food plants for kiwikiu recovery.

- Establish vegetation in barren areas – Planting and other experimental techniques such as seed scattering will be used to re-establish vegetation (Figure 25). Certain areas will be targeted to increase connectivity between existing forest and forest recovery areas reducing overall fragmentation as well as erosion.

- Increase native species diversity in native subalpine shrubland – Subalpine shrubland contains more intact native habitat than lower elevation, formerly forested areas. These areas lack some of their original diversity due to impacts from feral ungulates. Certain rare and depleted plant species will be restored to these areas, primarily through planting.

*Figure 25. Forest recovery team at work.*

*3. Rare Plant Restoration*

The Nakula NAR needs to be a recovery site for all appropriate rare and listed endangered Hawaiian plant species. Those appropriate species once identified, will have recovery populations established through propagule acquisition, existing population enhancement, and outplanting actions.

NEPM staff will work cooperatively with other organizations and agencies on rare plant recovery including the Plant Extinction Prevention Program (PEPP), other DOFAW botanical staff and USFWS. NEPM staff will assist PEPP with reintroduction plantings and other threat management, as needed. PEPP is focused on preventing the extinction of taxa with fewer than 50 individuals in the wild but staff are also occasionally able to work on other rare species.

Numerous species of rare plants have been propagated and reintroduced into fenced, ungulate-free areas of the NAR to contribute to their overall recovery in the wild. In general, rare species reintroduction will occur in areas with more intact habitat, such as gulches. These species (Table 1) will continue to be a focus for the NAR rare species program. Management actions specific to rare plant recovery include surveys to locate wild individuals, collection of propagation and genetic storage materials and reintroduction through outplanting. All staff (both DOFAW and cooperating partners) working with rare plants will follow rare plant collection and reintroduction guidelines recommended by the Hawaii Rare Plant Restoration Group (interagency group of rare plant experts) http://www.hear.org/hrprg/. Outplanted plants will be mapped, tagged and monitored to assess their survival and growth. Staff and partners will implement additional management of threats to wild and/or reintroduced populations, as needed and as resources allow (e.g. fencing wild plants that are not within fenced management units, control of damaging weeds, insects, slugs, plant disease and/or mammalian predators).

PEPP priorities include continuing to survey the NAR as well as adjacent lands for additional rare species, obtaining material (seeds and cuttings) for propagation and genetic storage and reintroduction of rare species into protected habitat. PEPP staff will also continue to opportunistically control targeted priority weed species that threaten wild or reintroduced PEPP species. Species priorities include *Cyanea obtusa* and *Neraudia sericea* (both only known from a single individual), *Diellia erecta* and *Diplazium molokaiense*. PEPP will also opportunistically collect propagation materials from other species that are appropriate for reintroduction into protected habitat in the NAR including *Asplenium peruvianum* var. *insularum*, *Hillebrandia sandwicensis*, *Cytrandra oxybapha*, *Cyrtandra bisserata* and *Santalum halekalae*.

*4. Monitor success of forest recovery actions and improve restoration strategies and techniques, as needed*

Regular monitoring of a subset of plantings will help guide future plantings in terms of the success of specific pre-planting site treatments (e.g. non-native grass control), species specific establishment patterns and the types of habitats being reforested (e.g. erosion scars lacking topsoil and ground cover versus infill planting in remnant canopy corridors vs. sprayed grassland areas with thick topsoil and grass mats but no overstory species). Monitoring, including monitoring methods of the NAR at a large spatial scale, will also determine overall success in achieving restoration goals.

Gathering relevé plot data with ocular estimates of percent cover by species in restoration areas will enable the monitoring of trends in native and non-native plant cover and diversity over time. Large scale spatial monitoring will also track trends in total forest biomass over the long term, using suitable indices to allow for gauging reforestation success. This type of standardized vegetation monitoring will be continued, as resources permit, to assess the long-term results of management actions and to determine the effectiveness of forest recovery approaches at suppressing invasive grasses, establishing overstory and understory species and replacing multi-tiered functional forest communities in the Reserve.

NEPM staff will continue to work with partners such as MFBRP, MNSRP and LHWRP to encourage research, improve restoration strategies and develop techniques to address various potential restoration challenges (discussed in Medeiros *et al.* 1986) and summarized below:

- Changes in microclimate, due to loss of native overstory and/or understory, which lead to unsatisfactory conditions for germination and/or establishment of native species.
- Alteration of the soil environment (e.g. disruption of mycorrhizal relationships, introduction of exotic soil microorganisms).
- Absence of suitable sites for germination and establishment of native species due to the presence of introduced species.
- Loss of pollinators (native birds and insects) resulting in lack of reproduction, inbreeding depression and/or loss of genetic diversity.
- Lack of native plant seed dispersal due to extirpation of native birds.
- Loss of nutrients essential to vegetation recovery and health due to loss of seabird nutrient importation.
- Introduced insects or pathogens which may impact native plant species health.
- Predation of seeds by introduced rodents, birds, or insects.

### 2.1.2 Forest Bird Restoration

**Background:** The Reserve currently provides habitat for two endemic native forest birds and is identified as a future recovery site kiwikiu or Maui parrotbill as well as a possible recovery site for Maui ʻalauahio or Maui creeper, ʻakohekohe or crested honeycreeper and iʻiwi (*Vestiaria coccinea*). NEPM goals include protecting, maintaining, and enhancing the Reserve's unique natural and cultural resources, including native forest birds. While forest recovery actions described above are one of the most important management activities needed to enhance habitat for the protection and recovery of forest birds, other actions are needed to enhance the recovery of endangered bird species and/or to address specific threats to forest birds.

**Objectives:** Manage native forest birds, including rare and endangered species to ensure their long-term survival and recovery in secure and self-sustaining wild populations.

**Actions:**

1. Monitor forest birds.

2. Control small non-native mammalian predators - Remove predators such as rats, mongooses, cats and barn owls that pose a major threat to forest birds.

3. Assess other threats to forest birds and determine appropriate management actions.

4. Restore endangered birds to Reserve - Release endangered birds in appropriate habitat within the Reserve.

**Narrative Description of Actions:**

*1. Monitor forest birds*

Bird communities in the Reserve will continue to be regularly monitored by trained staff and collaboratively with agency partners, and the University to determine baseline population densities and trends. Monitoring will help determine how the Reserve's management actions such as reforestation and other management affect bird presence, abundance and recovery. Monitoring will be done with sufficient frequency to detect decline in populations that may be due to ongoing or new threats. Monitoring data will be provided to the Hawai'i Forest Bird Interagency Database Project.

- The Wailaulau Unit of the Reserve will be part of a larger long-term monitoring effort across forest bird habitat on Maui. Establishment of transects and monitoring of forest birds started in 2014 and is planned to be continued on an annual basis.

- Monitoring of experimental releases of endangered birds (see #4).

*2. Control non-native mammalian predators*

Small mammalian predator removal (e.g. removal of rats, mongooses and cats) may provide significant benefits to endangered birds, plants, and endemic invertebrates, but is extremely difficult and costly to implement on a large-scale using currently existing methods. Predator removal will be implemented in certain high priority areas (e.g. kiwikiu release sites etc.) using existing, approved methods. New methods for widespread control across large conservation areas are currently being developed and will be implemented if they are approved and offer a cost-effective way to remove predators.

*3. Assess other potential threats to forest birds and determine appropriate management actions*

Other threats include spread of mosquito-borne avian disease, non-native invertebrates which can transmit disease and affect food availability, competition from non-native birds for food, nesting sites and other resources, and non-native birds acting as reservoirs for avian diseases. Experimental management actions for these threats could be developed and the effectiveness of these analyzed. For example, MFBRP and other partners are conducting surveys throughout Nakula including adult and larvae mosquito surveys and blood sampling to assess the current disease prevalence. If disease poses a threat, mosquitoes could be controlled in wet areas or where water is pooling. Populations of non-native species could be reduced or eliminated if they pose a threat.

*4. Restore endangered birds to Reserve*

The MFBRP will be developing a reintroduction plan for kiwikiu or Maui parrotbill at Nakula NAR, and MFBRP staff and partners will be taking the lead on release efforts, which are planned within the next five years (by 2020). NEPM staff will be supporting this collaborative effort through the implementation of ongoing and planned management actions to maintain and improve native forest ecosystem habitat (e.g. fence maintenance, reforestation). This work is part of DOFAW's overall strategy to integrate habitat protection and restoration with species research, management, and reintroduction programs.

The short-term goal of these experimental releases is to create a separate disjunct population of kiwikiu which survives through multiple years. The long-term objective of the overall reintroduction effort is for

the newly established population of kiwikiu to be self-sustaining, successfully breeding, and achieve sufficient size to provide significant protection from extinction in case the source population is threatened or extirpated.

The kiwikiu is currently restricted to a population found at high elevations on the windward side of Haleakalā Volcano in Hanawi NAR, Waikamoi Preserve and Haleakalā National Park. Fossil evidence shows this species once occurred in low elevation, mesic and dry leeward forests on Maui (James and Olson 1992). Leeward East Maui is drier, and has fewer storm events. Kiwikiu were once found in this area prior to forest destruction by feral ungulates. The forest was predominately koa (*Acacia koa*), a tree that kiwikiu was historically noted to prefer (Perkins 1903).

In order to increase the range and population size, the MFBRP is hoping to establish an experimental population on the leeward slopes of Haleakalā. In 2009, the USFWS provided funds to collect data necessary to initiate the establishment of population on leeward east Maui, which was recommended by the Forest Bird Recovery Plan (USFWS 2006). Other state, private and federal funding supported fencing and restoration of the Kahikinui Forest Reserve and the Nakula NAR, the area selected to establish the population. A captive propagation program has reared kiwikiu, both from wild collected eggs and from captive pairs (Kueler *et al.* 2001).

While the exact makeup of a release cohort has not yet been determined, two options exist for the source of the birds to be released: individuals from the captive flock and translocation of wild individuals from elsewhere in the species' range. Currently, a base camp has been established from which to conduct the releases, but additional infrastructure, including a variety of field aviaries and hack towers will also need to be established. Additional facilities, infrastructure and trails may be needed at the current camp, in order to facilitate the introduction and monitoring of the released birds.

Once the release occurs, the MFBRP will intensively monitor released kiwikiu movements, breeding and habitat use to assess the success of release efforts and develop improved protocols for future releases. While kiwikiu will be the focus of experimental releases, other rare species such as ʻakohekohe (Figure 26) and Maui ʻalauahio will be a focus for similar efforts in the future.

*Figure 26. ʻAkohekohe*

### 2.1.3 Seabird Restoration

**Background:** The Hawaiian petrel or ʻuaʻu (*Pterodroma sandwichensis*; Figure 27) is a federally endangered seabird. A host of anthropogenic factors, including harvesting, habitat conversion, and introduction of non-native mammalian and avian predators has drastically reduced the population size and range of this species. Breeding colonies, previously distributed across all the main islands, are currently restricted to remote montane habitats on a few islands. The largest population of ʻuaʻu exists on Haleakalā, and consequently is critical for the conservation of this species. The Maui Nui Seabird Recovery Project conducted baseline surveys in Kahikinui FR and Nakula NAR and documented the presence of ʻuaʻu nesting burrows as well as non-native invasive predator species. Visibility enhancing tape is installed on all NAR and FR fences to provide visual cues to nocturnal seabirds help them avoid fences and reduce incidents of seabird injury or mortality.

**Objectives:** Survey, monitor and manage seabird populations at the Reserve to help contribute to their stabilization and overall recovery.

**Actions:**

1. Survey and monitor ʻuaʻu and other seabirds to determine relative abundance, activity, reproductive success and effectiveness of management.

2. Determine strategy and develop and implement control program for predators.

3. Recover and reintroduce seabirds to the Reserve.

**Narrative Description of Actions:**

*1. Survey and monitor ʻuaʻu to determine relative abundance, activity, reproductive success and effectiveness of management*

Seabird communities in the Reserve will be regularly monitored by trained staff and collaboratively with agency partners, and the University to determine baseline population densities and trends. Monitoring will help determine how the Reserve's management actions such as forest restoration or other manipulations affect bird presence, abundance and recovery. Monitoring will be done with sufficiently frequency in order to detect decline in populations that may be due to ongoing or new threats. Monitoring data will be provided to the Hawaiʻi Forest Bird Interagency Database Project for analysis. Initial surveys have detected eight known burrows in the upper elevations of both the Reserve and adjoining Kahikinui FR. Follow-up monitoring will be needed to detect any changes in population status as well as the effectiveness of management actions.

*2. Determine strategy and develop and implement control program for introduced predators*

One of the key limiting factors in the survival of ʻuaʻu is predation of chicks and adults at breeding burrows by mammalian predators and barn owls. To counter the severe and immediate threat of predation a predator control program in seabird habitat is needed. Information on relative abundance, activity and

seasonality of the predator population is not currently known and quantifying these factors will increase the effectiveness of a predator control program.

*3. Recover and reintroduce seabirds to the Reserve*

The MNSRP or other agency or University partners will be developing future seabird population enhancing and or reintroduction plans for seabirds (e.g. Hawaiian petrels as well as potentially Newell's shearwater and band-rumped storm petrel) at Nakula NAR. This work will potentially employ new techniques for seabird attraction and recovery (social attraction, and translocation). NEPM staff will be supporting this collaborative effort through the implementation of ongoing and planned management actions to maintain and improve native forest ecosystem habitat (e.g. fence maintenance, reforestation). This work is part of DOFAW's overall strategy to integrate habitat protection and restoration with species research, management, and reintroduction programs for recovery of endangered birds.

*Figure 27. Hawaiian petrel or ʻuaʻu (Endangered).*

### 2.1.4 Bat Restoration

**Background:** Bats are currently present at Nakula NAR and effective forest management and forest recovery proposed in this plan is expected to increase the amount of habitat available for bats thereby increasing bat populations and contributing to the overall recovery of the species.

**Objectives:** Provide a net benefit to the species by increasing population numbers of the Hawaiian hoary bat via the creation and restoration of available foraging and roosting habitat.

**Actions:**

1. Implement proposed general habitat management actions such as forest recovery and threat abatement to protect and restore native habitat to benefit bats at the Reserve

2. Perform surveys to monitor changes in bat activity levels over time

**Narrative Description of Actions:**

*1. Implement general habitat management actions such as forest recovery and threat abatement to protect and restore native habitat to benefit bats at the Reserve*

Forest recovery and threat abatement actions proposed in this plan will increase habitat available for bats. In particular, the 254 ac West Pāhihi Unit is planned to serve as a mitigation site for bats impacted by wind power projects elsewhere. The unit is located between the 4,800 to 6,200 ft elevation contours in the Kahikinui FR (Mauka Unit) and the Nakula NAR. Currently, vegetation in this area consists of about 80 percent non-native grassland, and 20 percent remnant mesic Koa/ʻŌhiʻa forest with grass understory. Over time, restoration efforts are intended to increase native vegetation cover and native insect prey base as well as provide a forest structure suitable for bat foraging, roosting, and breeding. Additionally, the restoration of native forest is expected to improve the functional connectivity of habitat within the greater Kahikinui area across the FR, NAR, and the adjacent DHHL lands.

*2. Perform surveys to monitor changes in bat activity levels over time*

Long-term monitoring of bats is needed to assess levels of bat activity in response to management, particularly forest recovery, and monitoring to measure net benefit to bats is required as part of the mitigation project. DOFAW will work in collaboration with USGS Biological Resources to develop a monitoring plan and implement bat monitoring. The mitigation plan recommends monitoring after the start of habitat restoration activities with subsequent monitoring occurring at five year intervals. Monitoring should consist of 3-month continual sampling efforts in the same three months of each sampling year. A 5-year cycle of feedback will be very important in planning new restoration parcels for other mitigation activities in Kahikinui as well as for adaptive management of the current project.

### 2.1.5 Invertebrate Restoration

**Background:** Very little is currently known about invertebrates at Nakula NAR, however, in general, Hawaiian ecosystems are dependent upon the ecological services completed by a diverse assemblage of native invertebrate species. Hawaiian tree and plant species could not exist without pollination and nutrient cycling which native invertebrate communities provide, and native invertebrates are essential food resources for native bird and bat populations. Consequently, conservation and management efforts which protect native invertebrate communities are needed to protect the native plants and animals which depend upon them. Threats to native invertebrates include, but are not limited to, habitat destruction and alteration, loss of native host plants and the invasion and establishment of non-native species.

**Objectives:** Ensure protection and management of native invertebrate species at Nakula NAR and facilitate additional survey and research on invertebrates to more effectively target management actions.

**Actions:**

1. Implement proposed general habitat management actions such as forest recovery and threat abatement to protect and restore native habitat for invertebrates at the Reserve.

2. Work with DOFAW's Native Invertebrate Conservation Program and others to facilitate additional survey, inventory and research on invertebrates to more effectively target management actions.

**Narrative Description of Actions:**

*1. Implement proposed general habitat management actions such as forest recovery and threat abatement to protect and restore native habitat for invertebrates at the Reserve*

In the absence of specific information targeted towards management of invertebrates, general management to protect and restore native forest habitat is assumed to benefit invertebrate species that use these native plants as food and as host plants. Threat abatement actions proposed will also likely be beneficial to native invertebrates as they will further restore native habitat and species.

*2. Work with DOFAW's Native Invertebrate Conservation Program and others to facilitate additional survey, inventory and research on invertebrates to more effectively target management actions*

DOFAW's Native Invertebrate Conservation Program partners with state and federal research and management agencies, non-profits and the public to facilitate research, management and protection of native threatened and endangered invertebrate species across the Hawaiian Islands. The objective of the Program is to expand the knowledge and resources available to effectively direct resource management, monitoring, research, conservation, and policy relating to Hawaiian invertebrate species. Nakula NAR could potentially be a future site for translocations of snails and other invertebrates as part of a species recovery strategy.

A comprehensive inventory in needed to establish baseline conditions for future comparisons. Additional monitoring will then be needed to monitor long-term trends in native invertebrates as a result of forest restoration actions. It would be beneficial to repeat the study by Peck et al. (2015) at 10 year intervals. The Nakula NAR needs to be a recovery site for all appropriate rare and listed endangered Hawaiian invertebrate species. Those appropriate species once identified, will have recovery populations established through existing population enhancement, and translocation actions.


*Figure 28. The Koa bug (Coleotichus blackburniae) is a native species whose host plants are koa and ʻaaliʻi*

## 2.2 THREAT ABATEMENT

### 2.2.1 Ungulate Management

**Background:** Eliminating threats from introduced ungulates, primarily feral goats and pigs, is a high priority management program and management units in the Reserve have been fenced and feral ungulates removed. Ungulate control will require ongoing effort, due to occasional ingress from adjacent properties. Continued ungulate management is needed to ensure the success of restoration efforts.

**Objective:** Preserve and protect native forest and watershed from feral ungulate damage by maintaining existing fenced units, completely removing ungulates from all fenced management areas and monitoring.

**Actions:**

1. Maintain integrity of existing fenced management units (Table 6 and Figure 29) through regular inspection, maintenance and replacement of fencing.

2. Remove all ungulates from fenced management units.

3. Monitor existing fenced ungulate-free units for ungulate ingress, and control ungulates.

**Narrative Description of Actions:**

*1. Maintain integrity of existing fenced management units through regular inspection, maintenance and replacement of fencing*

Maintenance of existing fences will limit reinvasion of ungulates into ungulate-free areas as well as areas with ongoing ungulate control. NEPM staff will inspect and maintain all fences in the Reserve west of Pāhihi gulch (7 miles of fencing). Portions of joint fenced units with Kahikinui FR will be inspected by DOFAW Forestry staff to the east of Pāhihi gulch.

*2. Remove all ungulates from fenced management units*

Various approved methods will be used to remove all the ungulates from the fenced management units including aerial shooting and staff control. Ungulate control thereafter will be done as necessary based on ingress of ungulates into ungulate-free areas.

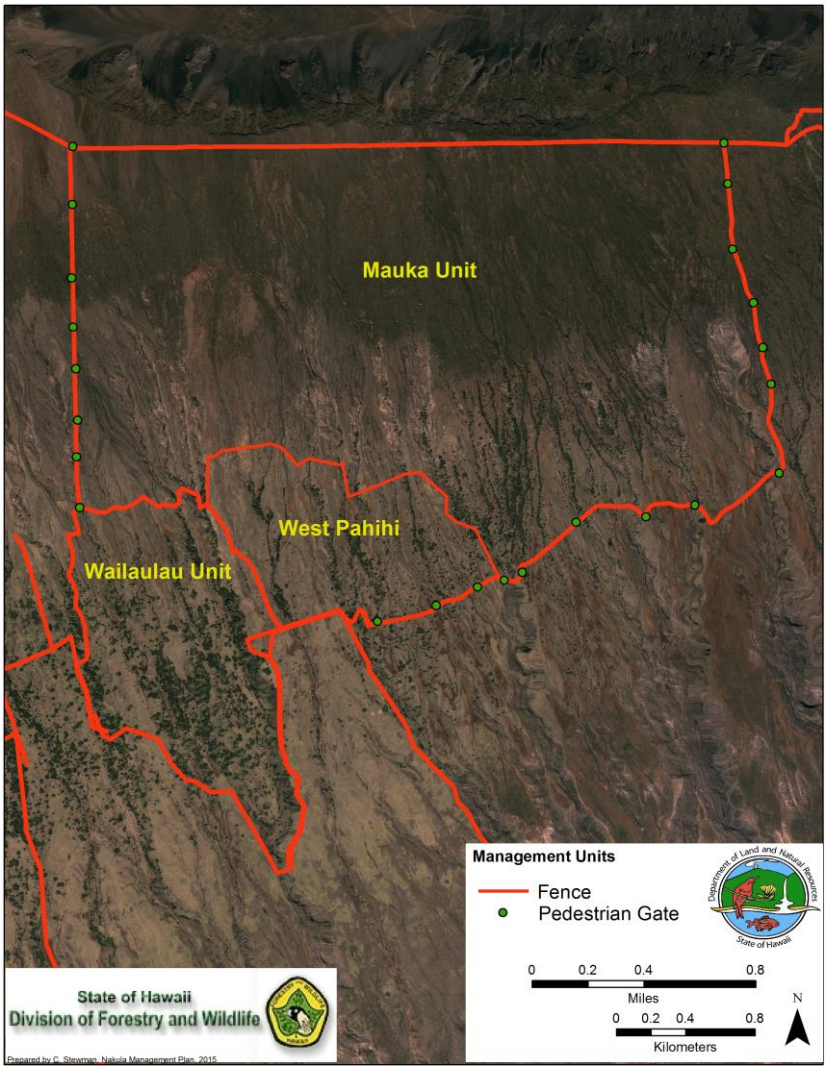
*3. Monitor existing fenced ungulate-free units for ungulate ingress, and control ungulates, if necessary*

Regular monitoring of units for ungulate presence/absence during fence inspections and incidental observations during other management activities will inform staff of ungulate ingress so ungulates can be removed promptly, preventing population growth and re-establishment in management units.

*Table 6. Management unit summary.*

| Management unit | Size (acres) | Year fencing completed |
|---|---|---|
| Wailaulau Unit | 420 | 2012 |
| Mauka Unit | 2,350 | 2014 |
| West Pāhihi Unit | 254 | 2014 |

*Figure 29. Fenced management units of Nakula NAR*



### 2.2.2 Invasive plant control

**Background:** Invasive plants, or weeds, constitute a severe threat to the native ecosystems in the NAR. Invasive weeds with great potential for spreading and causing habitat modification are identified in this plan as high priority for control or eradication.

**Objective:** Protect intact native areas within the NAR by eradicating incipient weeds, and if possible, eradicate or contain select high priority weeds in fenced units within the NAR.

**Actions:**

1. Monitor and map the distribution of high priority weeds and develop a control strategy.

2. Control weeds along invasion corridors (e.g. trails, fences) and within management units using approved methods (chemical, manual and/or biocontrol).

3. Prevent introduction of new weeds, invertebrates and pathogens.

4. Monitor weeds to detect changes in long term distribution and abundance and determine the effectiveness of management.

5. Support state-wide weed early detection and prevention programs and weed control research including new chemical, mechanical and biological control techniques, and participate, where appropriate, in experimental weed control management methods.

**Narrative Description of Actions:**

*1. Monitor and map the distribution of high priority weeds and develop a control strategy*

Weed monitoring and mapping provides a valuable baseline for weed distribution and abundance and is also essential to developing a comprehensive control strategy. Distribution mapping includes compiling transect monitoring data, incidental observations and reconnaissance surveys to map the distribution and abundance of weeds. Results from surveys will then be used to better delineate the weed populations core extent and outlying individuals, and permit the development of an effective monitoring and control strategy.

*2. Control weeds along invasion corridors (e.g. trails, fences) and within management units using approved methods (chemical, manual and/or biocontrol)*

NAR priority areas for weed management are generally fenced, ungulate-free management units. Removal of ungulates from fenced units is a critical first step in weed control because it allows for the recovery of native vegetation by minimizing ground disturbance and reducing the spread of weeds by ungulates.

Weed control goals for Nakula management units include early detection and preventing the establishment of incipient, habitat modifying weeds that are not currently present in the NAR or are still localized. Widespread weeds such as non-native pasture grasses are targeted for control to enhance the success of native forest restoration efforts. For priority weeds already present in the NAR, the goal is to eliminate all known occurrences within targeted control areas and/or to contain the spread of priority species. Due to limited resources for monitoring and control, NAR staff will focus control efforts in high priority forest recovery areas, disturbed areas such as trails, and fence lines as these often serve as corridors for weed establishment and spread.

A combination of control techniques including manual, mechanical and targeted herbicides are used to remove weeds. The technique used is based on the characteristics of the target species, the sensitivity of the area in which the species is found, and the effectiveness of the control technique.

Weed control projects

- Control non-native grass in Wailaulau Unit to enhance restoration efforts and reduce grass native forest areas ultimately replacing non-native grasses with native understory and ground-cover species.

- Control priority weeds such as Bocconia and identify new satellite populations by sweeping management units periodically as funding and resources allow. Invasive populations are prioritized for control based on safety, weed density, proximity to rare plant populations or managed sites, and logistical feasibility. Bocconia seed is dispersed by birds and by streamflow and the plants are almost exclusively present in forested stream corridors and gulches while being largely absent from open grasslands and exposed ridgelines. Surveys and control efforts have focused on forest corridor sweeps, covering each side of each gulch. NEPM staff will systematically survey, monitor and implement follow-up control every 3 to 5 years, although highly infested sites may be revisited annually. Management efforts will prioritize control of mature seeding plants with follow-up on previously treated areas at short enough intervals to control younger plants before they mature and reproduce.

*3. Prevent introduction of new weeds, invertebrates and pathogens*

Prevention is a critical component of the weed management program, and it is important to avoid and/or reduce the inadvertent introduction and spread of weeds, invertebrates and pathogens by researchers, managers and students working in and visiting the area. The NAR will establish biosecurity protocols and checklists, filed with the NAR Manager, for all management operations, researchers, and visitors. Standard procedures will include checking and decontaminating all boots, clothing or equipment prior to bringing crews and equipment into the Reserve using visual inspections, using scrub brushes or other cleaning techniques to remove any loose dirt or organic matter from boots and clothing or resource management equipment (e.g. helicopter slingload nets). Mandatory prevention protocols and checklists will be followed and implemented by all staff, partners, volunteers and researchers working within the NAR.

*4. Monitor weeds to detect changes in long term distribution and abundance and determine the effectiveness of management*

NAR staff monitor weed control areas to evaluate the effectiveness of control efforts and conduct follow-up control of new seedlings and/or resprouting individuals.

*5. Support state-wide weed early detection and prevention programs and weed control research including new chemical, mechanical and biological control techniques, and participate, where appropriate, in experimental weed control management methods*

DOFAW is collaborating with the LHWRP, Maui Invasive Species Committee (MISC), and researchers on weed control research into new monitoring, mapping (including remote sensing) and control methods. These methods will be tested and integrated into the weed management program, as appropriate. For example, DOFAW is working with partners to develop and refine Herbicide Ballistic Technology (HBT) for control of *Bocconia* on steep, inaccessible slopes. HBT is an emerging technology that involves firing of an encapsulated, herbicide-filled projectile from a modified paint ball gun. Due to widespread and heavy infestations of certain weeds (e.g. fireweed) and limited resources, NARS staff and partners intend to test the efficacy of approved biocontrol agents within the Reserve, when available.

### 2.2.3 Predator control

**Background:** Mammalian predators pose a threat to numerous species at Nakula NAR including forest birds, seabirds, native invertebrates and plants. Removal of predators, while difficult, will provide significant benefits to native species and ecosystems.

**Objectives:** Control predators to benefit native species and ecosystems

**Actions:**

1. Develop a predator control program and implement in high priority areas.

2. Expand predator control to implement on a larger-scale when more effective control methods are developed and approved.

**Narrative Description of Actions:**

*1. Develop a predator control program and implement in high priority areas*

NEPM staff will work with partners to implement predator control in high priority areas such as endangered forest bird reintroduction sites and seabird nesting areas. Staff will remove predators such as rats, mongoose, and cats that pose a major threat to birds. Predator control will be targeted to these high priority sites due to the limitations of current approved control methods.

*2. Expand predator control to implement on a larger-scale when more effective control methods are developed and approved*

New methods for widespread control across large conservation areas are currently being developed and will be implemented if they are approved and offer a cost-effective way to remove predators.

### 2.2.4 Fire prevention and response

**Background:** Fire management is incorporated as part of this management plan because of the threat it poses to the Reserve native forests and neighboring forests across leeward Haleakalā.

**Objective:** Employ appropriate fire management strategies including pre-suppression, suppression, and post-suppression rehabilitation to reduce wildfire occurrence and minimize wildfire impacts.

**Actions:**

1. Implement fire prevention measures, including fire breaks, educational outreach to neighbors and signage along roads.

2. Suppress fires safely and aggressively using appropriate means.

3. Continue NAR staff training and certifications for effective and safe fire response.

**Narrative Description of Actions:**

*1. Implement fire prevention measures, including fire breaks, educational outreach to neighbors and signage along roads*

Many fires are caused by humans, so fire prevention measures will include increased educational efforts for those accessing the property, road or area closures in the event of extreme fire danger and suppression of non-native grasses in fire prone areas. Weed control and planting of common native species will be used to restore certain disturbed areas to prevent fire and/or following damage from fire. DOFAW will work to create vegetated fuel breaks under regenerated and/or planted koa by shading-out and/or spraying non-native grasses so groundcover is primarily leaf litter. This type of fuel break would likely reduce fire intensity and the rate of fire spread compared to non-native grass.

*2. Suppress fires safely and aggressively using appropriate means*

In the event of fire, DOFAW will respond to fires in the Reserve. The most effective control of a fire will be through measures that result in the least amount of impact or disturbance to natural and archeological resources. The method of suppression will be determined by the on-site situation, with special regard to the potential expansion of fire damage to the resources within the Reserve. Minimum impact methods of suppression will be applied whenever such methods are sufficient.

*3. Continue NAR staff training and certifications for effective and safe fire response*

Training of existing and new staff is a critical component of effective response to fire. NEPM staff will maintain current fire response certifications by attending regular required staff trainings.

### 2.2.5 Non-native insects and disease

**Background:** While introduced diseases and pathogens threaten both native animals and plants, little is currently known about presence and/or specific impacts on species and ecosystems at Nakula. In addition, effective management for most of these threats is generally not available except under certain very limited circumstances.

**Objectives:** Prevent and reduce the negative impacts of non-native insects and disease on species and ecosystems at Nakula NAR.

**Actions:**

1. Prevent the introduction of new diseases and pathogens through effective biosecurity.

2. Monitor native species and ecosystems to detect presence of harmful invasive insects, diseases and pathogens.

3. Encourage additional research and survey at Nakula on impacts of introduced insects and disease and effective management of these threats.

**Narrative Description of Actions:**

*1. Prevent the introduction of new diseases and pathogens through effective biosecurity*

Biosecurity is a set of precautions that aim to prevent the introduction and spread of harmful organisms (pests, pathogens or invasive species). New plants and animals arrive in the islands on a continual basis from the mainland, other islands in the Hawaiian archipelago or even other areas from the same island. Preventing the introduction of new invasive species is a high priority as these introductions only serve to increase the funding needed to control these species and further put Hawaii's native forests at risk. Organism introduction can occur via transportation by animals or humans, the wind and/or through species nearby expanding their range. There is also the risk of introductions from management work such as outplanting native plants grown in a nursery. Staff will implement sanitation to prevent the introduction of harmful species such as invertebrates (ants, wasps, pathogens, etc.) by cleaning and inspecting boots, clothing, equipment and materials (including plants for outplanting and seeds) to ensure they are free of dirt or organisms to lessen the chance of introductions.

*2. Monitor native species and ecosystems to detect presence of harmful invasive insects, diseases and pathogens*

Ongoing monitoring by DOFAW and partners planned and discussed in other sections for forest recovery areas, rare plants, birds, etc. will assist in early detection of new potential threats.

*3. Encourage additional research and survey at Nakula on impacts of introduced insects and disease and effective management of these threats.*

See research and survey section below.

### 2.2.6 Climate Change Adaptation

**Background:** Climate change may affect the NAR through altering temperatures and rainfall patterns and amounts. Changing climate may affect the abundance and seasonality of precipitation, thereby altering forest composition, growth and structure. Long-term shifts in the inversion height may accompany global climate change (Giambelluca and Nullet 1991). Rare ecosystems and species may be affected by relatively rapid changes in precipitation, temperature, and humidity that result from a rapid and drastic change in regional or local climate patterns. Detrimental invasive species may change their distribution and abundance due to changes in the climate (e.g. mosquitoes may be more frequently found at higher elevations due to warming temperatures). Increases in mosquito populations in the upper elevations would increase the incidence of avian disease, negatively affecting remaining native forest bird populations.

The uncertainty of potential changes in future climate creates challenges for restoration and management because past conditions may not be accurate predictors of the conditions under which plant and animal communities will survive, evolve, and adapt at particular locations. Climate change may result in changes in community structure and shifts in biomes that alter suitable habitat for species. Effective management will depend on accurate predictions of potential changes, effective monitoring to document patterns of change, and adaptive management to respond to changing circumstances.

**Objectives:** To maintain the biological integrity of the NAR, and the native flora and fauna into the future, and to provide adaptive management for effects of shifting existing habitat zones, and species compositions.

**Actions:**

1. Obtain and stay abreast of the most suitable climate change models, and predictions, that relate to the region. Encourage site specific modeling that will predicate current and future management.

2. Conduct monitoring of the plant and animals of the Reserve to document climate change patterns, impacts to plant and animal communities, and inform planning.

3. Plan and execute adaptive management in the NAR to allow for flora and fauna preservation in concert with shifting habitat zones, changes in precipitation, and advance of detrimental and or novel species, due to climate change.

4. Prepare long-term management policy to address expected future conditions not currently provided for in NAR strategic plans or management guidelines.

**Narrative Description of Actions:**

1. *Obtain and stay abreast of the most suitable climate change models, and predictions, that relate to the region. Encourage site specific modeling that will predicate current and future management.*

Work with partners to develop site specific and species specific habitat suitability models for select species. Use models to identify changes in community structure and biome shifts. Apply models for the recovery of endangered species for which the NAR may provide future suitable habitat in the face of climate change.

2. *Conduct monitoring of the plant and animals of the Reserve to document climate change patterns, impacts to plant and animal communities, and inform planning.*

Monitor climate change in the reserve and use climate change models to inform vegetation monitoring. Detect changes in survival and reproductive success of species impacted by climate change.

3. *Plan and execute adaptive management in the NAR to allow for flora and fauna preservation in concert with shifting habitat zones, changes in precipitation, and advance of detrimental and or novel species, due to climate change.*

Adjust restoration and management plans as climate shifts to ensure that management actions are responsive to and appropriate for changed conditions.

4. *Prepare long-term management policy to address expected future conditions not currently provided for in NAR strategic plans or management guidelines.*

Many DOFAW plans and policies will require update to address impacts of and adaptation to a changing climate.

## 2.3 Information and Education

**Background:** DOFAW's mission includes facilitating partnerships, community involvement and education. DOFAW outreach staff uses a variety of methods to connect with communities across demographics and islands including: websites, social media, press releases, public outreach events, educator workshops, field trips, classroom visits, and the youth programs. Due to the remote and inaccessible location of Nakula NAR, limited educational activities are feasible on site. Educational goals will be integrated with other aspects of natural resource management and research and will be accomplished through a strong reliance on partnerships.

**Objectives:** Build public understanding and support for the NAR and the state's unique native resources.

**Actions:**

1. Maintain and expand opportunities for youth internships.

2. Provide the public with information about the Reserve and ongoing management.

3. Work with partners to support joint educational and volunteer efforts.

4. Install educational signage in the Reserve.

**Narrative Description of Actions:**

*1. Maintain and expand opportunities for youth internships*

The NEPM program is planning on continuing participation in the State of Hawaii Youth Conservation Corp (YCC) Program, which enables young adults to gain entry-level experience as they work with natural resource professionals to conduct natural resources management (Figure 30). Internships often lead to future jobs or advanced degrees in natural resource management.

*2. Provide the public with information about the Reserve and ongoing management*

As it is difficult for the public to actually visit the Reserve, Maui NEPM staff will work with DOFAW Outreach staff to share information on Reserve resources and management through the web, social networking, video, and traditional media. NEPM staff will also provide presentations and outreach to researchers and managers, schools and community groups to communicate research findings and management goals. Dissemination of information learned from forest recovery projects will help inform other forest recovery efforts on Maui and around the state.

*3. Work with partners to support joint educational and volunteer efforts*

Partners such as LHWRP and MFBRP have ongoing educational and volunteer programs and have a greater capacity to support such programs with on-site activities at Nakula and elsewhere on Maui. Maui NEPM staff will work with these partners to integrate information about ongoing Nakula NAR management into these existing programs.

*4. Install educational signage in the Reserve*

Educational signage will increase public knowledge about the NAR, and will be installed in areas along the boundary adjacent to proposed trails when developed.


*Figure 30. Hawai‘i Youth Conservation Corps (YCC) interns learning about helicopter safety prior to outplanting trip.*

## 2.4 RESEARCH AND SURVEY

**Background:** Nakula NAR offers unique opportunities for research and staff review all research permits before they are approved. NEPM staff will continue to collaborate with partners, interested researchers, and students so their research can better address critical management needs.

**Objective:** Encourage additional surveys and research to better address critical natural resource management needs in the Reserve.

**Actions:**

1. Refine and modify existing inventory and monitoring programs (monitoring protocols, data management and analysis).

2. Encourage research including applied research with direct relevance to land management issues such as forest restoration, effective management of invasive plants and animals, and recovery of native plants and animals.

3. Encourage basic research and survey to establish historical baselines of all natural resources and collect data on other topics relevant to land management.

**Narrative Description of Actions:**

*1. Refine and modify existing inventory and monitoring programs (monitoring protocols, data management and analysis)*

Existing monitoring for ungulates, birds, weeds, forest recovery and rare plants will be refined as needed to ensure monitoring is providing information relevant to informing management.

*2. Encourage research including applied research with direct relevance to land management issues such as forest restoration, effective management of invasive plants and animals, and recovery of endangered native plants and animals*

Research aimed at effective ecosystem restoration is of great relevance to other areas in Hawai‘i. The Reserve also provides an ideal site in which to test hypotheses about how invasive species impact ecosystems and determine the most effective methods of controlling or eliminating invasive species. Examples of priority research topics include:

- Methods to most effectively convert a koa forest with a grass understory into a native understory or native leaf litter that effectively out-competes grass.

- Research on potential issues with key matrix forest restoration species (e.g. lack of flowering and seed production).

- Effective control techniques and alternative methods for control of priority weed species.

- Assess overall arthropod resource base at the landscape level by performing vegetation surveys to estimating the amount of each foraging substrate available.

- Monitor for changes in arthropods as restoration proceeds to determine whether arthropods respond favorably to increased host plant density and diversity.

- Bird reintroduction research topics (as outlined in MFBRP 2014).

*3. Encourage basic research and survey to establish historical baselines of all natural resources and collect data on other topics relevant to land management*

Information on the basic natural history and abundance of the endemic and often endangered plants and animals in the Reserve is needed to understand how species may respond to a changing environment (e.g. as a result of climate change) and how management and conservation measures can be used to enhance recovery and adaptation. Baselines research/survey needs include:

- Identify critical gaps in natural resource inventories for the NAR and initiate additional surveys and monitoring (e.g. invertebrate surveys).

- Weather, climate and hydrologic research and monitoring, in cooperation with partners.

- Additional research and survey at Nakula on presence and impacts of introduced insects and disease and effective management of these threats.

## 2.5 INFRASTRUCTURE MANAGEMENT

**Background:** A limited amount of essential infrastructure is needed to protect and effectively manage the NAR and support staff research and management actions. Existing and planned infrastructure includes items such as water catchment, management and public access trails, helicopter landing zones, field camps and bird release aviaries. Infrastructure and facilities development will be limited, small-scale and in many cases temporary to ensure minimal impacts on the environment and natural and cultural resources.

**Objectives:** Develop and maintain needed infrastructure to protect and effectively manage the NAR.

**Actions:**

1. Develop and maintain needed infrastructure to support staff research and management actions.
2. Develop and maintain infrastructure for bird reintroduction actions.
3. Develop and maintain public trails.

**Narrative Description of Actions:**

*1. Develop and maintain needed infrastructure to support staff and partners research and management actions*

DOFAW and partners have existing temporary camps and helicopter landing zones in the Wailaulau Unit and other areas primarily used for fence construction and forest recovery projects. Other camps and landing zones will be developed on an as needed basis as restoration continues in other areas. Camps are generally mobile, temporary structures with light impacts and minimal development. One camp (a temporary shelter built on a wooden deck with water catchment) to support forest recovery projects is planned for the eastern portion of the NAR at approximately 5,200 ft. elevation. In 2015, NEPM staff will be installing a 1,000 gallon water tank with a roof catchment in the West Pāhihi Unit. This water will be used for emergency fire response as well as for watering of forest recovery plantings in times of drought.

*2. Develop and maintain infrastructure for bird reintroduction actions*

The MFBRP currently has existing infrastructure in the Wailaulau Unit of the Reserve including a weatherport, water catchment and management trails. Additional infrastructure such as tent platforms and bird release aviaries may be needed in the future to support bird reintroduction efforts. Holding or release aviaries will need to be erected at release sites. These will most likely be placed on scaffolding to minimize predator access and removed when do longer needed.

*3. Develop and maintain public trails*

DOFAW has previously proposed increased public access to the Kahikinui FR and Nakula NAR area through construction of a trail system and backcountry cabins located at Kahikinui FR (DOFAW 2012). Most of the proposed infrastructure is located in the FR; however a couple of trails are proposed to cross the NAR. Trail alignments are provisional, pending development of access agreements with neighboring landowners, field confirmation of the absence of threatened or endangered species and cultural resource sites and topographical considerations.

*Figure 31.Temporary Camp to support restoration activities*

# 3 Management Action Summary and Budget

This section of the plan summarizes planned short term management actions and the associated budget proposed to complete those actions (Table 7). This section is intended to be regularly updated (approximately every two years) and will be used by NARS staff for operational and biennium budget planning.

NEPM staff for the island of Maui work on all seven NAR on the island, including Nakula. In 2015, NEPM staff included four DOFAW staff, three University of Hawai‘i contractors (Pacific Cooperative Studies Unit) and two YCC interns. The budget below assumes current budget levels/existing staff will provide labor, materials and supplies for many of the ongoing and proposed management actions. New funding will be required to hire additional NAR staff and/or contractors to complete major new proposed projects including forest recovery and the expansion of weed management.

*Figure 32. Staff member leading volunteer outplanting activities.*

*Table 7. Budget required to implement management actions in the Nakula NAR (Fiscal Years 2016 and 2017). Shaded cells show where budget is included under general / other organizations' budgets or is to be addressed in the future.*

| Action | | Description | Budget | |
|---|---|---|---|---|
| | | | FY16 | FY17 |
| 3.1 RESTORATION | | | | |
| **3.1.1** | **Forest Restoration** | | | |
| 1. | Seed collection and propagation | | TBD | TBD |
| 2. | Implement reforestation of common native species in targeted priority sites to reestablish native forest and shrubland | Outplanting using NEPM funds (tree purchases) | $0 | $30,000 |
| | | Outplanting using US Forest Service State and Private Forestry FY15-16 grant funds (tree purchases) | $100,000 | $0 |
| | | Supplemental water (water catchments to supplement planting) | $2,500 | $2,500 |
| | | Helicopter transport for outplanting (1 trip every second month) | $21,000 | $21,000 |
| 3. | Rare plant restoration | | TBD | TBD |
| 4. | Monitor success of forest recovery actions and improve restoration strategies and techniques, as needed | | TBD | TBD |
| **3.1.2** | **Forest Bird Restoration** | | | |
| 1. | Monitor forest birds | Helicopter transport to support Maui Forest Bird Recovery Project work | $7,500 | $7,500 |
| 2. | Control small non-native mammalian predators | (Refer to action 2c) | $0 | $0 |
| 3. | Assess other threats to forest birds and determine appropriate management actions | (Part of NEPM and Maui Forest Bird Recovery Project regular operations budgets) | $0 | $0 |
| 4. | Restore endangered birds to the Reserve | | TBD | TBD |
| **3.1.3** | **Seabird Restoration** | | | |
| 1. | Survey and monitor 'ua'u and other seabirds to determine relative abundance, activity, reproductive success and effectiveness of management | (Part of Maui Nui Seabird Recovery Project regular operations budget) | $0 | $0 |

| | | | |
|---|---|---|---|
| 2. Determine strategy and develop and implement control program for introduced predators | (Refer to action 2c) | $0 | $0 |
| 3 Recover and reintroduce seabirds to the Reserve | | TBD | TBD |
| **3.1.4 Bat Restoration** | | | |
| 1. Implement proposed general habitat management actions | (Refer to actions 1a and 2a,b) | $0 | $0 |
| 2. Perform surveys to monitor changes in bat abundance and activity levels over time | | TBD | TBD |
| **3.1.5 Invertebrate Restoration** | | | |
| 1. Implement proposed general habitat management actions | (Refer to actions 1a and 2a,b) | $0 | $0 |
| 2. Work with DOFAW's Native Invertebrate Conservation Program to facilitate additional survey and research to more effectively target management actions | | TBD | TBD |
| **Restoration Subtotal** | | **$131,000** | **$61,000** |
| 3.2 THREAT ABATEMENT | | | |
| **3.2.1 Ungulate Control** | | | |
| 1. Maintain integrity of existing fenced management units through regular inspection, maintenance and replacement of fencing | Helicopter transport for fence maintenance (1 per quarter) | $10,000 | $10,000 |
| 2. Remove all ungulates from fenced management units | Aerial Capture, Eradication and Tagging of Animals (ACETA) follow up | $30,000 | $30,000 |
| | Animal control, to be determined by animal activity (survey, trapping, Judas goats etc.) | TBD | TBD |
| 3. Monitor existing ungulate-free units for ungulate ingress and control ungulates | (Part of NEPM regular operations budget) | $0 | $0 |
| **3.2.2 Invasive Plant Control** | | | |
| 1. Monitor and map the distribution of high priority weeds and develop a control strategy | (Part of NEPM and Leeward Haleakala Watershed Restoration Partnership regular operations budgets) | $0 | $0 |

| | | | | |
|---|---|---|---|---|
| 2. | Control weeds along invasion corridors and within management units using approved methods (chemical, manual and / or biocontrol) | Herbicide used for *Bocconia* control and to prepare outplanting sites | $10,000 | $10,000 |
| | | Helicopter transport for *Bocconia* control (1 trip every quarter) | $14,000 | $14,000 |
| | | Helicopter transport to support Leeward Haleakala Watershed Restoration Partnership work | $7,500 | $7,500 |
| 3. | Prevent introductions of new weeds and invertebrates | (Part of NEPM and Leeward Haleakala Watershed Restoration Partnership regular operations budgets) | $0 | $0 |
| 4. | Monitor weeds to detect changes in long term distribution and abundance and determine the effectiveness of management | (Part of NEPM and Leeward Haleakala Watershed Restoration Partnership regular operations budgets) | $0 | $0 |
| 5. | Support state-wide weed early detection and prevention programs and weed control research | | TBD | TBD |
| **3.2.3** | **Predator Control** | | | |
| 1. | Develop a predator control program and implement in high-priority areas | (Research and development being done by Maui Nui Seabird Recovery Project) | $0 | $0 |
| 2. | Expand predator control to implement on a larger-scale when more effective control methods are developed and approved. | (For future implementation) | $0 | $0 |
| **3.2.4** | **Fire Prevention and Response** | | | |
| 1. | Implement fire prevention measures, including fire break, educational outreach to neighbors and signage along roads | | TBD | TBD |
| 2. | Suppress fires safely and aggressively using appropriate means | (Part of DOFAW fire budget) | $0 | $0 |
| 3. | Continue NAR staff training and certifications for effective and safe fire response | (Part of DOFAW fire and NEPM regular operations budgets) | $0 | $0 |
| **3.2.5** | **Non-native Insects and Disease** | | | |
| 1. | Prevent the introduction of new diseases and pathogens through effective biosecurity | | TBD | TBD |

| | | | |
|---|---|---|---|
| 2. Monitor native species and ecosystems to detect presence of harmful invasive insects, diseases and pathogens | (Part of NEPM regular operations budget) | $0 | $0 |
| 3. Encourage additional research and survey at Nakula on impacts of introduced insects and disease and effective management of these threats | | TBD | TBD |
| **3.2.6 Climate Change Adaptation** | | | |
| 1. Obtain and stay abreast of the most suitable climate change models, and predictions, that relate to the region. | | TBD | TBD |
| 2. Conduct monitoring of the plant and animals of the Reserve to document climate change patterns, impacts to plant and animal communities, and inform planning. | | TBD | TBD |
| 3. Plan and execute adaptive management to allow for flora and fauna preservation in concert with shifting habitat zones, changes in precipitation, and advance of detrimental and or novel species, due to climate change. | | TBD | TBD |
| 4. Prepare long-term management policy to address expected future conditions not currently provided for in NAR strategic plans or management guidelines. | | TBD | TBD |
| **Threat Abatement Subtotal** | | **$71,500** | **$71,500** |
| 3.3 INFORMATION AND EDUCATION | | | |
| 1. Maintain and expand opportunities for youth internships | (Part of NEPM regular operations budget; $3,000 per year for supplies) | $0 | $0 |
| 2. Provide the public with information about the Reserve and ongoing management | | TBD | TBD |
| 3. Work with partners to support joint educational and volunteer efforts | (Part of NEPM regular operations budget) | $0 | $0 |
| 4. Install educational signage in the Reserve | | TBD | TBD |
| **Information and Education Subtotal** | | **$0** | **$0** |
| 3.4 RESEARCH AND SURVEY | | | |

| | | | |
|---|---|---|---|
| 1. Refine and modify existing inventory and monitoring programs | (Implement long term vegetation monitoring plots. Outplanting monitoring part of NEPM regular operations budget and trips) | $0 | $0 |
| 2. Encourage research with direct relevance to land management issues | | TBD | TBD |
| 3. Encourage basic research and survey to establish historical baselines | | TBD | TBD |
| **Research and Survey Subtotal** | | **$0** | **$0** |
| 3.5 INFRASTRUCTURE MANAGEMENT | | | |
| 1. Develop and maintain needed infrastructure to support staff research and management actions | Construction of management shelter (headquarters for reserve operations) | $0 | $15,000 |
| | Installation of rain shed / tank at 'Flat camp' | TBD | TBD |
| 2. Develop and maintain infrastructure for bird reintroduction actions | | TBD | TBD |
| 3. Develop and maintain public trails | | TBD | TBD |
| **Infrastructure Management Subtotal** | | **$0** | **$15,000** |
| 3.6 GENERAL OPERATIONAL COSTS | | | |
| 1. Subsistence for field crews | $100 per week per crew member (6) for 12 weeks | $7,200 | $7,200 |
| **General Operational Costs Subtotal** | | **$7,200** | **$7,200** |
| TOTAL | | **$209,700** | **$154,700** |

# REFERENCES


DHHL, Kahikinui Forest Reserve Community Management Conceptual Plan 7/1995

Gagne, W., and L. Cuddihy. 1990. "Vegetation," pp. 45-114 in W.L. Wagner, D.R. Herbst, and S.H. Sohmer, eds., Manual of the Flowering Plants of Hawai‘i. 2 vols. Honolulu: University of Hawai‘i Press.

Giambelluca, T.W and Nullet, D. 1991. Influence of the trade-wind inversion on the climate of a leeward mountain slope in Hawaii. Climate Research Vol. 1:207-216.

Giambelluca, T.W., Q. Chen, A.G. Frazier, J.P. Price, Y.-L. Chen, P.-S. Chu, J.K. Eischeid, and D.M. Delparte, 2013: Online Rainfall Atlas of Hawai‘i. Bull. Amer. Meteor. Soc. 94, 313-316, doi: 10.1175/BAMS-D-11-00228.1.

Gon, S. M., III, A. Allison, R. J. Cannarella, J. D. Jacobi, K. Y. Kaneshiro, M. H. Kido, M. Lane-Kamahele, and S. E. Miller. 2006. The Hawai‘i GAP Analysis Final Report. Report, U.S. Department of Interior, U.S. Geological Survey. 162 p plus tables, figures, maps, and appendices.

Handy, E.S.C. 1972. Native Planters in Old Hawai`i: Their Life, Lore and Environment. Honolulu: Bishop Museum Press.

Herbst, Wagner et al. Manual of The Flowering Plants of Hawai`i. 1999

Jacobi, J.D. 1989. Vegetation maps of the upland plant communities on the islands of Hawai‘i, Maui, Molokai, and Lanai. Cooperative National Park Resources Studies Unit Technical Report 68. University of Hawai‘i at Manoa and National Park Service.

Jacobi, J.D. In preparation. Revision of Gon et al (2006).

James, H. F., and S. L. Olson. 1991. Descriptions of thirty-two new species of birds from the Hawaiian Islands. Part II. Passeriformers. Ornithological Monographs 46:1-88.

Kirch, P.V., ed. 1997. Na Mea Kahiko o Kahikinui: Studies in the Archaeology of Kahikinui. Spec. Pub. No. 1, Oceanic Archaeology Lab., Univ. of California, Berkeley.

Kueler, C., A. Leiberman, P. Harrity, M. Kuhn, J. Kuhn, B. McIlraith, and J. Turner. 2001. Restoration techniques for Hawaiian forest birds: collection of eggs, artificial incubation and had rearing of chicks, and release to the wild. Studies in Avian Biology 22:354-358.

Leeward Haleakalā Watershed Restoration Partnership. 2006. Leeward Haleakalā Watershed Restoration Partnership Management Plan.

MacDonald, G.A., A.T. Abbott, and F.L. Peterson. 1986. Volcanoes in the Sea: The Geology of Hawai‘i. 2nd ed. Honolulu: University of Hawai`i Press.

McDaniel, S. and R. Ostertag. 2010. Strategic light manipulation as a restoration strategy to reduce alien grasses and encourage native regeneration in Hawaiian mesic forests. Applied Vegetation Science. DOI: 10.1111/j.1654-109X.2009.01074.x

McDaniel, S., R. Loh, S. Dale, and C. Yanger. 2011. Experimental restoration of mesic and wet forests in former pastureland, Kahuku Unit, Hawaii Volcanoes National Park. Technical Report No. 175. Pacific Cooperative Studies Unit, University of Hawai‘i, Honolulu, Hawai‘i. 26 pp

Maui Forest Bird Recovery Project (MFBRP). Protocols for Restoration Trials in Nakula NAR. 2012. Available at: http://www.mauiforestbirds.org/images/20130923_Nakula%20Trial%20Restoration_Final.pdf

MFBRP Workplan (2014-2015). 2014. Available at: http://www.mauiforestbirds.org/Publications/MFBRP_2014-2015.pdf

MFBRP Workplan (2015-2016). 2015 Available at: http://mauiforestbirds.org/Publications/MFBRP%202015-2016.pdf

Medeiros, A.C., C.F. Davenport and C.G. Chimera. 1994. Auwahi: Ethnobotany of a Hawaiian Dryland Forest. Technical Report 117. Cooperative National Park Resources Study Unit, Hawai'i. Department of Botany, University of Hawai`i at Manoa.

Medeiros, A.C, Loope, L. L., Holt, R. A. 1986 Status of the native flowering plant species on the south slope of Haleakala, east Maui Cooperative National Park Studies Unit, University of Hawai`i Technical Report 59.

Medeiros, A.C. and E. VonAllmen. 2005. Restoration of native Hawaiian Dryland Forest at Auwahi, Maui. U.S. Department of the Interior, U.S. Geological Survey. USGS FS 2006-3035

Palmer, D.D. 2003. Hawaii's Ferns and Fern Allies. Honolulu: University of Hawaii Press.

Peck, Robert W., P.C. Banko, J. Cappadonna, C. Steele, D.L. Leonard, H.L. Mounce, D. Becker, and K. Swinnerton. 2015. An assessment of arthropod prey resources at Nakula Natural Area Reserve, a potential site of reintroduction for Kiwikiu (*Pseudonestor xanthophrys*) and Maui `Alauahio (*Parareomyza montana*). Technical Report HCSU-059. Hawai'i Cooperative Studies Unit, University of Hawai'i at Hilo.

Perkins, R. C. L. 1903. Vertebrata. In D. Sharp, editor. Fauna Hawaiiensis. Vol. 1, Part IV. The University Press, Cambridge.

Price, J. S. M. Gon III, J. D. Jacobi, and D. Matsuwaki, 2007 Mapping Plant Species Ranges in the Hawaiian Islands: Developing a Methodology and Associated GIS layers. Hawai'i Cooperative Studies Unit Technical Report HCSU-008. University of Hawai`i at Hilo. 58 pp., incl. 16 Figures and 6 Tables.

Pukui, Mary K., and S. Elbert. 1974. *Place Names of Hawai`i*. Honolulu: University of Hawai`i Press.

Pukui, Mary K., and S. Elbert. 1986. Hawaiian Dictionary. Honolulu: University of Hawai`i Press.

Rock, J.F. 1913. The Indigenous Trees of the Hawaiian Islands. Honolulu: Territory of Hawai`i.

Scott, J. M., S. Mountainspring, F. L. Ramsey, and C. B. Kepler. 1986. Forest bird communities of the Hawaiian Islands: their dynamics, ecology, and conservation. Studies in Avian Biology 9:1-431.

Scowcroft, P.G. and Jeffrey, J. 1999. Potential significance of frost, topographic relief, and *Acacia koa* stands to the restoration of mesic Hawaiian forests on abandoned rangeland. Forest Ecology and Management 114: 147–158.

Sherrod, David R., J. Sinton, S.E. Watkins, and K.M. Brunt. 2007. Geologic map of the State of Hawai'i. Available at: http://pubs.usgs.gov/of/2007/1089/

State of Hawai'i Department of Land and Natural Resources Division of Forestry and Wildlife (DOFAW). 2004. Kahikinui Koa Forest Protection and Restoration Final Environmental Assessment. Available at: http://oeqc.doh.hawaii.gov/Shared%20Documents/EA_and_EIS_Online_Library/Maui/2000s/2004-12-23-MA-FEA-KAHIKINUI-KOA-FOREST-RESTORATION.pdf

State of Hawai‘i Department of Land and Natural Resources DOFAW. 2007. Technical Report No. 07-01. Review of methods and approach for control of non-native ungulates in Hawaii.

State of Hawai‘i Department of Land and Natural Resources DOFAW. 2011. The Rain Follows the Forest - A Plan to Replenish Hawaii’s Source of Water.

State of Hawai‘i Department of Land and Natural Resources DOFAW. 2012. Final Environmental Assessment Kahikinui Koa Forest Protection and Restoration Nakula Ahupua‘a, Island of Maui, Hawai‘i. Available at: http://oeqc.doh.hawaii.gov/Shared%20Documents/EA_and_EIS_Online_Library/Maui/2010s/2012-03-08-FEA-Kahikinui-Koa-Forest-Protection-and-Restoration.pdf

State of Hawai‘i Department of Land and Natural Resources DOFAW. 2014. Kahuku Wind Power Hawaiian Hoary Bat Mitigation Plan.

State of Hawai‘i Department of Land and Natural Resources DOFAW. 2015. Hawaii’s comprehensive wildlife conservation strategy. Available at: http://dlnr.hawaii.gov/wildlife/hswap/

Stein, V. 2007. Critical assessment of habitat for release of Maui Parrotbill. Pacific Cooperative Studies Unit. Technical Report 146.

Stone, C.P. 1985. Feral ungulates in Hawai‘i: Toward controlling the adverse effects of introduced vertebrates. In Stone, C.P. and J.M. Scott (eds.). *Hawaii’s Terrestrial Ecosystems: Preservation and Management*.

Stone, C.P., Cuddihy, L.W., and J.T. Tunison. 1992. Responses of Hawaiian ecosystems to the removal of feral pigs and goats. Pp. 666-704 in C.P. Stone, C.W. Smith, and J.T. Tunison (eds.). *Alien Plant Invasions in Native Ecosystems of Hawai`i: Management and Research*. University of Hawai‘i Cooperative National Park Resources Studies Unit, University of Hawai‘i Press, Honolulu.

Todd, C.M., Pinzari, C.A., and F.J. Bonaccorso. 2015. Acoustic surveys of Hawaiian hoary bats in Kahikinui Forest Reserve and Nakula Natural Area Reserve on the island of Maui. DRAFT University of Hawaii Technical Report (In Prep). Hawai‘i Cooperative Studies Unit, University of Hawai‘i at Hilo.

University of Hawai‘i at Hilo, Dept. of Geography. 1998. Atlas of Hawai‘i. 3rd ed. Honolulu: University of Hawai`i Press.

University of Hawai‘i at Manoa, Dept. of Urban and Regional Planning. 2000. Ka `Ohana O Kahikinui: Community Based Economic Development and Makai Management Plan, Moku of Kahikinui. Planning Practicum, 1999. Honolulu.

U. S. Fish and Wildlife Service (USFWS). 1992. Endangered and Threatened Wildlife and Plants; Determination of Endangered of Threatened Status for 15 Plants From the Island of Maui, HI. Federal Register, vol. 57, no. 95. 20772-20788.

USFWS. 1997. Recovery Plan for the Maui Plant Cluster. U.S. Fish and Wildlife Service, Portland, OR. 130 pp. + appendices. Available at: http://ecos.fws.gov/docs/recovery_plan/970729.pdf

USFWS. 1998. Recovery Plan for the Hawaiian Hoary Bat (*Lasiurus cinereus semotus*). U.S. Fish and Wildlife Service, Portland, OR. 59 pp. Available at: http://ecos.fws.gov/docs/recovery_plans/1998/980511b.pdf

USFWS. 1999. Recovery Plan for Multi –Island Plants. U.S. Fish and Wildlife Service, Portland, OR. 206 pages + appendices. Available at: http://ecos.fws.gov/docs/recovery_plan/990710.pdf

USFWS. 2003. Endangered and Threatened Wildlife and Plants; Designation of Critical Habitat for 60 Plant Species from the Islands of Maui and Kahoolawe, HI; Final Rule. Federal Register Vol. 68, No. 93. Available at: http://ecos.fws.gov/docs/federal_register/fr4140.pdf

USFWS. 2006. Revised Recovery Plan for Hawaiian Forest Birds. Region 1, Portland, OR. 622 pp. Available at: http://ecos.fws.gov/docs/recovery_plan/060922a.pdf

United States Geological Survey (USGS). 2005. Biocomplexity of introduced avian diseases in Hawai'i: Threats to biodiversity of native forest ecosystems. Prepared by B.L.. Woodworth, C. T. Atkinson, M. D. Samuel, D. A. LaPointe, P. C. Banko, and J. A. Ahumada. USGS Fact Sheet 2005-3139. Available at: http://www.usgs.gov/ecosystems/pierc/files/factsheets/bioc.pdf

USGS. 2006a. Feral cats: Too long a threat to Hawaiian wildlife. Prepared by S.C. Hess and P.C. Banko. USGS Fact Sheet 2006-3006. Available at: http://www.usgs.gov/ecosystems/pierc/files/factsheets/cats.pdf

USGS. 2006b. Hawai'i forest bird interagency database project: Collecting, understanding, and sharing population data on Hawaiian forest birds. Prepared by T.K. Pratt, B.L. Woodworth, R.J. Camp, P.M. Gorresen. USGS Fact Sheet 2006-3013. Available at: http://www.usgs.gov/ecosystems/pierc/files/factsheets/birds.pdf

USGS. 2006c. Feral pigs, introduced mosquitoes, and the decline of Hawai'i's native birds. Prepared by D.A. LaPointe. USGS Fact Sheet 2006-3029. Available at: http://www.usgs.gov/ecosystems/pierc/files/factsheets/pigs.pdf

USGS. 2008. Wild sheep and deer in Hawai'i - a threat to fragile Ecosystems. Prepared by Steve Hess. USGS Fact Sheet 2008-3102. Available at: http://pubs.usgs.gov/fs/2008/3102/fs2008-3102.pdf

U.S. Department of the Interior, National Park Service (USDOI-NPS). 1998. *East Maui Resource Inventory*. Prepared by the Trust for Public Land & Bay Consulting. Honolulu.

Simon, J.C., T. K. Pratt, K. E. Berlin, and J. R. Kowalsky. 1998. Age and Sex Identification of Akohekohe. Journal of Field Ornithology. 69:654-660.

Perkins, R. C. L. 1903. Vertebrata. Pp. 365-466 in D. Sharp (Editor). Fauna Hawai`iensis. Vol 1, part IV. Cambridge University Press, UK.

The Nature Conservancy Hawai'i. 2006. An Ecoregional Assessment of Biodiversity Conservation for the Hawaiian High Islands.

Cabin, R.J., Weller, S.G., Lorence, D.H., Cordell, S., Hadway, L.J., Montgomery, R., Goo, D. & Urakami, A. 2002. Effects of light, alien grass, and native species additions on Hawaiian dry forest restoration. Ecological Applications 12: 1595–1610.

Scowcroft, P.G. & Jeffrey, J. 1999. Potential significance of frost, topographic relief, and Acacia koa stands to the restoration of mesic Hawaiian forests on abandoned rangeland. Forest Ecology and Management 114: 147–158.

Wagner, W. L., Herbst, D. R., and Sohmer, S.H. 1999. Manual of the flowering plants of Hawai'i. University of Hawai'i Press, Bishop Museum, Honolulu.

# APPENDICES

# APPENDIX A DRAFT NAKULA NAR PLANT SPECIES LIST (DEVELOPED BY HANK OPPENHEIMER, MAUI PEPP)

| Family | Genus | Species | Subtaxon | Common name | Distribution | Abundance |
|---|---|---|---|---|---|---|
| ***Pteridophytes*** | | | | | | |
| Adiantaceae | *Adiantum* | *hispidulum* | | | naturalized | common |
| Adiantaceae | *Adiantum* | *raddianum* | | | naturalized | common |
| Aspleniaceae | *Asplenium* | *acuminatum* | | | endemic | occasional |
| Aspleniaceae | *Asplenium* | *adiantum-nigrum* | | | | occasional |
| Aspleniaceae | *Asplenium* | *contiguum* | | | | occasional |
| Aspleniaceae | *Asplenium* | *diellerectum* | alexandri | | endemic | rare |
| Aspleniaceae | *Asplenium* | *macraei* | | | | common |
| Aspleniaceae | *Asplenium* | *peruvianum* | insulare | | endemic | rare |
| Aspleniaceae | *Asplenium* | *polyodon* | | | | occasional |
| Aspleniaceae | *Asplenium* | *trichomanes* | subsp. densum | | endemic | occasional |
| Aspleniaceae | *Asplenium* | *unilaterale* | | | | occasional |
| Athyriaceae | *Deparia* | *petersenii* | | | naturalized | occasional |
| Athyriaceae | *Athyrium* | *microphyllum* | | akolea | endemic | common |
| Athyriaceae | *Diplazium* | *molokaiense* | | | endemic | rare |
| Athyriaceae | *Diplazium* | *sandwicianum* | | pohole | endemic | common |
| Blechnaceae | *Blechnum* | *appendiculatum* | | | naturalized | occasional |
| Blechnaceae | *Sadleria* | *cyatheoides* | | | endemic | |
| Blechnaceae | *Sadleria* | *souleyetiana* | | | endemic | occasional |
| Cibotiaceae | *Cibotium* | *glaucum* | | hapuu | endemic | occasional |
| Dennstaedtiaceae | *Hypolepis* | *hawaiiensis* | var. hawaiiensis | | endemic | occasional |
| Dennstaedtiaceae | *Pteridim* | *aquilinum* | var. decompositum | kilau | endemic | common |
| Dryopteridaceae | *Cyrtomium* | *caryotidium* | | ka apeape | endemic | occasional |
| Dryopteridaceae | *Dryopteris* | *glabra* | var. glabra | | endemic | common |
| Dryopteridaceae | *Dryopteris* | *fusco-atra* | var. fusco-atra | | endemic | occasional |
| Dryopteridaceae | *Dryopteris* | *wallichiana* | | | endemic | common |
| Dryopteridaceae | *Polystichum* | *bonseyi* | | | endemic | occasional |
| Dryopteridaceae | *Polystichum* | *haleakalense* | | | endemic | occasional |
| Dryopteridaceae | *Polystichum* | *hillebrandii* | | | endemic | occasional |
| Gleicheniaceae | *Dicranopteris* | *linearis* | | uluhe | indigenous | rare |
| Grammitidaceae | *Oreogrammitis* | *hookeri* | | | endemic | rare |
| Hymenophyllaceae | *Vandenboschia* | *davallioides* | | | endemic | oc |
| Lomariopsidaceae | *Elaphoglossum* | *paleaceum* | | | indigenous | occasional |

| Family | Genus | Species | Subtaxon | Common name | Distribution | Abundance |
|---|---|---|---|---|---|---|
| Marattiaceae | *Marattia* | *douglasii* | | pala | endemic | occasional |
| Polypodiaceae | *Lepisorus* | *thunbergianus* | | pakahakaha | indigenous | occasional |
| Polypodiaceae | *Polypodium* | *pellucidum* | | ae | endemic | occasional |
| Psilotaceae | *Psilotum* | *nudum* | | moa | indigenous | occasional |
| Pteridaceae | *Coniogramme* | *pilosa* | | loulu | endemic | common |
| Pteridaceae | *Pellaea* | *ternifolia* | | kalamoho laulii | endemic | occasional |
| Pteridaceae | *Pityrogramma* | *austroamericana* | | gold fern | naturalized | occasional |
| Pteridaceae | *Pteris* | *cretica* | | oali | indigenous | common |
| Pteridaceae | *Pteris* | *excelsa* | | waimakanui | indigenous | common |
| Pteridaceae | *Pteris* | *irregularis* | | iwa puakea | endemic | occasional |
| Thelypteridaceae | *Amauropelta* | *glomuliferum* | | palapalai o Kamapuaa | endemic | occasional |
| Thelypteridaceae | *Christella* | *parasitica* | | | naturalized | occasional |
| Thelypteridaceae | *Pneumatopteris* | *sandwicensis* | | hoio kuka | endemic | occasional |
| Thelypteridaceae | *Pseudophegopteris* | *keraudreniana* | | waimakanui | endemic | occasional |
| ***Dicotyledons*** | | | | | | |
| Apocynaceae | *Alyxia* | *oliviformis* | | maile | indigenous | common |
| Aquifoliaceae | *Ilex* | *anomala* | | kawau | indigenous | occasional |
| Araliaceae | *Cheirodendron* | *trigynum* | | olapa | endemic | occasional |
| Asteraceae | *Ageratina* | *adenophora* | | mexican devil | naturalized | occasional |
| Asteraceae | *Ageratina* | *riparia* | | | naturalized | occasional |
| Asteraceae | *Artemisia* | *australis* | | | endemic | occasional |
| Asteraceae | *Artemisia* | *mauiensis* | | | endemic | rare |
| Asteraceae | *Bidens* | *pilosa* | | beggars tick | naturalized | occasional |
| Asteraceae | *Dubautia* | *plantaginea* | | | endemic | rare |
| Asteraceae | *Dubautia* | *platyphylla* | | | endemic | occasional |
| Asteraceae | *Dubautia* | *reticulata* | | | endemic | rare |
| Asteraceae | *Hypochaeris* | *radicata* | | hairy cats ear | naturalized | common |
| Asteraceae | *Lapsana* | *communis* | | nipplewort | naturalized | occasional |
| Asteraceae | *Prunus* | *vulgaris* | | bull thistle | naturalized | occasional |
| Asteraceae | *Senecio* | *madagascariensis* | | fireweed | naturalized | rare |
| Asteraceae | *Youngia* | *japonica* | | | naturalized | common |
| Begoniaceae | *Hillebrandia* | *sandwicensis* | | | endemic | rare |
| Campanulaceae | *Clermontia* | *kakeana* | | oha wai | endemic | occasional |
| Campanulaceae | *Lobelia* | *hypoleuca* | | opelu, kuhi'aikamo'owahie | endemic | occasional |
| Caryophyllaceae | *Cerastium* | *fontanum* | subsp. triviale | common mouse-eared | naturalized | occasional |

| Family | Genus | Species | Subtaxon | Common name | Distribution | Abundance |
|---|---|---|---|---|---|---|
| | | | | chickweed | | |
| Celastraceae | *Perrottetia* | *sandwicensis* | | olomea | endemic | common |
| Epicridaceae | *Leptecophylla* | *tameiameiae* | | pukiawe | indigenous | common |
| Ericaceae | *Vaccinium* | *calycinum* | | ohelo ka laau | endemic | occasional |
| Ericaceae | *Vaccinium* | *dentatum* | | ohelo | endemic | occasional |
| Euphorbiaceae | *Euphorbia* | *peplus* | | petty spurge | naturalized | occasional |
| Fabaceae | *Acacia* | *koa* | | koa | endemic | common |
| Fabaceae | *Sophora* | *chrysophylla* | | mamane | endemic | rare |
| Fabaceae | *Trifolium* | *repens* | | white clover | naturalized | occasional |
| Gentianaceae | *Centaurium* | *erythraea* | | | naturalized | occasional |
| Geraniaceae | *Geranium* | *homeanum* | | | naturalized | common |
| Gesneriaceae | *Cyrtandra* | *biserrata* | | haiwale | endemic | rare |
| Gesneriaceae | *Cyrtandra* | *grayi* | | haiwale | endemic | common |
| Lamiaceae | *Prunella* | *vulgaris* | | self-heal | naturalized | rare |
| Lythraceae | *Lythrum* | *maritimum* | | pukamole | naturalized | common |
| Myrsinaceae | *Myrsine* | *lessertiana* | | kolea lau nui | endemic | occasional |
| Myrtaceae | *Metrosideros* | *polymorpha* | var. incana | ohia lehua | endemic | common |
| Myrtaceae | *Metrosideros* | *polymorpha* | var. glaberrima | ohia lehua | endemic | common |
| Onagraceae | *Epilobium* | *billardierianum* | | willow herb | naturalized | occasional |
| Oxalidaceae | *Oxalis* | *corniculata* | | yellow wood sorrel | Polynesian introduction? | common |
| Papaveraceae | *Bocconia* | *frutescens* | | tree poppy | naturalized | common |
| Piperaceae | *Peperomia* | *cookiana* | | ala ala wainui | endemic | occasional |
| Plantaginaceae | *Plantago* | *lanceolata* | | narrow-leaved plantain | naturalized | common |
| Primulaceae | *Anagalis* | *arvensis* | | scarlet pimpernel | naturalized | occasional |
| Ranunculaceae | *Ranunculus* | *mauiensis* | | makou | endemic | rare |
| Rosaceae | *Osteomeles* | *anthyllidifolia* | | ulei | indigenous | occasional |
| Rosaceae | *Rubus* | *hawaiiensis* | | akala | endemic | common |
| Rosaceae | *Rubus* | *rosifolius* | | thimbleberry | naturalized | common |
| Rubiaceae | *Coprosma* | *ernodioides* | | kukaenene | | occasional |
| Rubiaceae | *Coprosma* | *foliosa* | | pilo | | occasional |
| Rubiaceae | *Coprosma* | *montana* | | pilo | | rare |
| Rubiaceae | *Coprosma* | *ochracea* | | pilo | | occasional |
| Rubiaceae | *Kadua* | *affinis* | | manono | endemic | occasional |
| Rubiaceae | *Kadua* | *centranthoides* | | | endemic | rare |
| Rubiaceae | *Psychotria* | *sp.* | | | endemic | rare |

| Family | Genus | Species | Subtaxon | Common name | Distribution | Abundance |
|---|---|---|---|---|---|---|
| Rutaceae | *Melicope* | *clusiifolia* | | | | rare |
| Rutaceae | *Melicope* | *volcanica* | | alani | | occasional |
| Santalaceae | *Santalum* | *haleakalae* | var. haleakalae | iliahi | endemic | rare |
| Sapindaceae | *Dodonaea* | *viscosa* | | aalii | | common |
| Solanaceae | *Physalis* | *peruvianum* | | poha | naturalized | occasional |
| Solanaceae | *Solanum* | *americanum* | | popolo | Polynesian introduction? | occasional |
| Urticaceae | *Pilea* | *peploides* | | | endemic | occasional |
| Urticaceae | *Pipturus* | *albidus* | | mamaki | endemic | common |
| Urticaceae | *Urera* | *glabra* | | opuhe | endemic | occasional |
| ***Monocotyledons*** | | | | | | |
| Asteliaceae | *Astelia* | *menziesiana* | | painiu | endemic | rare |
| Cyperaceae | *Carex* | *alligata* | | | endemic | occasional |
| Cyperaceae | *Carex* | *meyenii* | | | indigenous | occasional |
| Cyperaceae | *Carex* | *wahuensis* | subsp. wahuensis | | endemic | occasional |
| Juncaceae | *Juncus* | *effusus* | | Japanese mat rush | naturalized | rare |
| Juncaceae | *Luzula* | *hawaiiensis* | | | endemic | occasional |
| Poaceae | *Andropogon* | *virginicus* | | broomsedge | naturalized | occasional |
| Poaceae | *Anthoxanthum* | *odoratum* | | vernalgrass | naturalized | common |
| Poaceae | *Axonopus* | *fissifolius* | | narrow-leaved carpet grass | naturalized | common |
| Poaceae | *Cenchrus* | *clandestinum* | | kikuyu grass | naturalized | common |
| Poaceae | *Deschampsia* | *nubigena* | | | endemic | common |
| Poaceae | *Eragrostis* | *brownei* | | sheep grass | naturalized | common |
| Poaceae | *Festuca* | *rubra* | | | naturalized | occasional |
| Poaceae | *Holcus* | *lanatus* | | | naturalized | common |
| Poaceae | *Melinis* | *minutiflora* | | molasses grass | naturalized | common |
| Poaceae | *Paspalum* | *conjugatum* | | Hilo grass | naturalized | occasional |
| Poaceae | *Sporobolus* | *africanus* | | smutgrass | naturalized | occasional |
| Smilacaceae | *Smilax* | *melastomifolia* | | hoi kuahiwi | endemic | occasional |

# APPENDIX B NAKULA NAR BIRDS (BIRDS CURRENTLY FOUND IN THE NAR).

| Taxon | Common Name | Status |
|---|---|---|
| *Acridotheres tristis* | common myna | non-native |
| *Alauda arvensis* | skylark | non-native |
| *Alectoris chukar* | chukar | non-native |
| *Asio flammeus sandwichensis* | Pueo or Hawaiian short-eared owl | endemic |
| *Branta sandvicensis* | nēnē, Hawaiian goose | endemic - endangered |
| *Callipepa californica* | California quail | non-native |
| *Cardinalis cardinalis* | northern cardinal | non-native |
| *Carpodacus mexicanus* | house finch | non-native |
| *Cettia diphone* | Japanese bush warbler | non-native |
| *Columba livia* | rock pigeon | non-native |
| *Fregata minor palmerstoni* | ʻiwa or great frigatebird | indigenous |
| *Garrulax canows* | hwamei, melodious laughing thrush | non-native |
| *Hemignathus virens* | ʻamakihi | endemic |
| *Himatione sanguinea* | ʻapapane | endemic |
| *Leiothrix lutea* | red-billed leoithrix | non-native |
| *Lonchura cantans* | African silverbill | non-native |
| *Lonchura punctulata* | scaly-brested munia | non-native |
| *Mimus polyglottos* | northern mockingbird | non-native |
| *Oceanodroma castro* | ʻakēʻakē, band-rumped storm petrel | indigenous - candidate |
| *Phaethon lepturus dorotheae* | koaʻe kea or white-tailed tropicbird | indigenous |
| *Phasianus colchicus* | ring-necked pheasant | non-native |
| *Pluvialis fulva* | kōlea, Pacific golden plover | indigenous |
| *Pterodroma sandwichensis* | ʻuaʻu or Hawaiian petrel | endemic - endangered |
| *Tyto alba* | barn owl | non-native |
| *Zenaida macroura* | mourning dove | non-native |
| *Zosterops japonicus* | Japanese white-eye | non-native |

# APPENDIX C MAUI FOREST BIRD RECOVERY PROJECT

## C.1. Nakula Experimental Restoration Trials Summary (as of 1 September 2015)

Reintroduction to historical habitat on leeward Haleakalā, Maui, is crucial to the long-term recovery of kiwikiu (Maui parrotbill; *Pseudonestor xanthophrys*). Nakula Natural Area Reserve has been identified as the area for this reintroduction. However, native habitat within the reserve is degraded and is expected to require significant restoration before it will be suitable to support a viable kiwikiu population. Maui Forest Bird Recovery Project conducted an experimental restoration trial in the Wailaulau unit of Nakula from 2012–2016 (monitoring still ongoing). This experiment was designed to identify the most efficient and effective method(s) of restoring forest in Nakula. Vegetation plots were divided into four experimental factors relating to restoration techniques (seed scatter, outplanting, natural regeneration and tree canopy*), assigned treatments (herbicide, biomass removal** and biomass disruption***) and monitored at 6 month intervals out to 24 months.

Two species (‘a‘ali‘i and koa) have exhibited >99% of the natural regeneration within the plots after 24 months, and the combined treatments of herbicide and biomass removal significantly increased the abundance of seedlings. This highlights the suppressive effect non-native grasses have on recruitment of native species. In addition, herbicide application alone did not increase natural regeneration and an increase in native seedlings was only achieved by the complete removal of grass biomass.

Survival of native outplantings was high (87% across seven species****) after 18 months, regardless of treatment. Survivorship was not affected by treatment in most outplanted species. However, survivorship of mamaki (*Pipturus albidus*) was significantly higher in the herbicide treatment and lowest in the control plots. Mean plant height after 24 months of five of seven species was greatest in the herbicide treatment indicating at least a marginal qualitative benefit of this treatment on outplantings.

Survival was similarly high (88%) for outplantings under canopy trees after 12 months indicating that the relatively moist microclimate provided by this treatment did not enhance survivorship. Natural regeneration was also similar under canopy trees compared to open grassland plots. No species whose seeds were dispersed in the seed scatter treatment germinated after 18 months.

* Tree canopy plots conducted the experimental manipulations under existing canopy trees
** Biomass removal included herbicide, weedeating, and removing dead/cut grass with rakes
*** Biomass disruption included spot scarification across landscape using a Pulaski
**** Species in outplantings included: koa (Acacia), ohia (*Metrosideros*), pilo *(Coprosma),* aalii (*Dodonaea*), akala (*Rubus*), mamane (*Sophora*), and mamaki (*Pipturus*)

Although these results are preliminary this experimental trial indicates that:

- Outplanting is necessary for recruitment of many species in open grasslands and outplantings do best after herbicide application
- Site-specific seed collection for outplanting is as if not more time intensive than plantings

- Significant recruitment of some species, particularly a`ali`i, can be achieved through removal of non-native grasses at a more efficient rate than with outplantings
- Outplanting survival and natural regeneration are not higher under existing canopy cover; and
- Manual dispersal of seeds does not result in recruitment of native seedlings.

## C.2. Maui Parrotbill (kiwikiu) reintroduction plan

To be added at a later date, when completed.

# APPENDIX D NAKULA SEABIRD RESTORATION PLAN

To be added at a later date, when completed

# APPENDIX E RARE PLANT RESTORATION PLAN

To be added at a later date, when completed